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Plenary Lecture 1

Oil Spill Response in a Semi-Closed Sea Basin by means of a Contingency Plan based on Fuzzy Logic - The Case of South-East Mediterranean

Professor Fragiskos Batzias
Laboratory of Simulation of Industrial Processes
Department of Industrial Management and Technology
School of Maritime and Industry
University of Piraeus
Greece
E-mail: fbatzi@unipi.gr

Abstract: A contingency plan aiming at prevention of accidental marine pollution, mainly due to hydrocarbons release, consists of a set of general guidelines, expected to become more specific when a certain pollution episode takes place. These guidelines form a dynamic network, where the nodes are the alternative/possible preventive/corrective actions that might be done; the interconnection of nodes signifies which actions are (or might be) in series and which in parallel. Although the guidelines should be simple and explicitly expressed in order to be comprehensible by all people (usually belonging to different specialties at various cultural levels) involved in such an emergency situation, the background upon which they stand includes processing of complex information on a real time basis. Since the events (and the relevant variables/quantifiers) of the pollution episode are stochastic, probabilistic or possibilistic methods should apply, making use of probability density functions or fuzzy sets, respectively. In order to cope with real situation applications, we have developed an Expert System (ES), in a modified fuzzy version to count for uncertainty, which consists of (i) a Knowledge Base (KB) with relevant information (at proper granularity level) and knowledge acquired by experience or extracted from other KBs by means of an Intelligent Agent (IA), and (ii) an Inference Engine (IE) combining Model/Rule/Case Based Reasoning (MBR, RBR, CBR, respectively) within an original interactive mode. Implementation of this ES is also presented, concerning (i) the Aegean Sea and certain areas between Crete and Cyprus and (ii) the region between the West Greek Shoreline and the islands of the Ionian Sea.

Brief Biography of the Speaker: Prof. Fragiskos Batzias holds a 5years Diploma and a PhD degree in Chemical Engineering, and a BSc in Economics. He has also studied Mathematics and Philosophy. He designed/developed the Laboratory of Simulation of Industrial Processes and the Research Group on Systems Analysis at the Department of Industrial Management and Technology of the University of Piraeus, Greece. He is teaching at the postgraduate courses (i) Systems of Energy Management and Protection of the Environment, running by the University of Piraeus, and (ii) Techno-Economic Systems, running by the Electr. & Comp. Eng. Dept. of the Nat. Tech. Univ. of Athens in cooperation with the University of Athens and the University of

Piraeus. His research interests are in chemical engineering systems analysis and knowledge based decision making. He has >100 publications in highly ranked journals and conference proceedings, including 29 research monographs in collective volumes, with 652 citations and an h-index of 13 (Scopus). He has participated (and chaired after invitation from the organizers) in prestigious international conferences, such as those organized periodically by the IEEE, the European Federation of Chemical Engineering (EFCE), the DECHEMA, CHISA, WSEAS Organizations. He organizes the annual Symposium on Industrial and Environmental Case Studies running successfully since 2004 within the International Conference of Computational Methods in Sciences and Engineering (ICCMSE).

Control System Model of Stable Natural Management on Marine Coasts of the Far-Eastern Russia

Igor S. Maiorov, Sergey Y. Golikov, Evgeniya A. Tikhomirova

***Abstract*—**Calculations defining relative tax values that allow providing inexhaustible natural management in the coastal areas and stable social and economic development of the coastal territories are introduced in the study. The calculations were made by "CoMPAS" software that allowed computing of the number of indicators characterizing level and quality of life of the population in the coastal territories. This software allows simulating consequences of investments into the extracting and recycling branches of economy, recreational-tourist system, and nature protection measures as well.

***Keywords*—**Environmental quality index, index of human development, quantity of marine bioresources, territorial budget value.

I. Introduction

MAIN obstacles hindering stable nature management of the coastal territories are the anthropogenic pollution of environment and, hence, reduction of biological diversity and degradation of agricultural lands. However the extent of anthropogenic pressure on the environment may be managed.

In order to define possible sustainable development, it is necessary to accept a number of the allowances allowing regulating economic, ecological and social-and-economic development of the territories. The allowances in the study are as follows: a business factor of control of the extent of anthropogenic pressure on the environment; a measure of stable social-and-economic development, and an extent of the environment degradation.

II. Methods

The tax for the businessmen polluting the natural environment was offered by A. Pigu [1] and named in his honor. It is accepted in the study as a business factor of control of the extent of anthropogenic pressure on the environment. Calculations of its relative value allow supplying of inexhaustible natural management in the coastal areas and stable social and economic development of the coastal territories.

The index of human development [2] is accepted in the study as a measure of stable social-and-economic development of the territory. It is calculated from the base indicators characterizing one of directions of human development each.

At any stage of the human development three groups of possibilities should be fulfilled: to live a long and healthy life; to acquire knowledge; and to have access to the resources necessary for a healthy way of life.

Generalizing indicator of an assessment of human development is the index of human development. It is calculated on the basis of the basic indicators characterizing directions of human development: longevity is an indicator of an expected life at birth; an educational level is an indicator of the adult literacy and involvement of the population into educational process; a standard of living is gross national product indicator per capita.

The qualitative characteristic of human development level depending on value of the human development index is represented in Table I.

Table I. The qualitative characteristic of human development level [3]

Level of the human capital development in the region	Index of human development in the region
High	0.8 and more
Middle	0.5 - 0.8
Low	0.5 and less

Extent of the environment degradation is estimated by an index of environmental quality represented by the relation of not degrading territories and water areas to a total territory and water area [4]. It varies from 0 to 1. With the higher indicator the environmental quality is better and the area of the degrading resource is lower. It is necessary to specify that this indicator is integrated, and its favorable value does not guarantee that there is no essential degradation in any local district.

In order to solve the task of stable development on marine coasts of the Far East of the Russian Federation the following

I. S. Maiorov is with the Far Eastern Federal University, Vladivostok, Russia (phone: +7(908)443-37-50; e-mail: ecology1@inbox.ru).

S. Y. Golikov is with the Far Eastern Federal University, Vladivostok, Russia (e-mail: golikov.sy@dvfu.ru).

E. A. Tikhomirova is with the Far Eastern Federal University, Vladivostok, Russia, and the V.I.Il`ichev Pacific Oceanological Institute, Far Eastern Branch, Russian Academy of Sciences, Vladivostok, Russia (e-mail: tikhomirova@poi.dvo.ru).

was used:

- specific use of lands and water areas in the Far-Eastern region [5] as the basis for general schemes of natural management that serve to provide a maximum of planed territorial organization of an economic system with the important features of the natural environment;
- intrinsic zoning [6] of the coastal territories in the Far East of Russia in order to ensure stable social and economic regional development.

Specific use [5] of the area of natural-economic division into districts means determination of the general economic system which depends less on a combination of natural resources than on the factors of natural environment influencing the type of economic activities. Of course, natural conditions of all mentioned districts are different, but they are combined by the following: each of them has certain factors strictly complicating economic activities. Such factors include severe weather conditions, high (about 5 m) wind-wave water rise near coasts, areas with tsunami danger, and paths of strong typhoons. The area of complicated natural-economic conditions covers the most of the southern Far East of Russia, and only the southern part of Primorye Territory belongs to the area with favorable natural-economic conditions. Such area includes the warmest districts of the Far East of the Russian Federation with the monsoonal climate covering the forest-steppe territory and the southern spurs of Sikhote-Alin [5].

All calculations were made by "CoMPAS" (Coastal Management Practices to Achieve Sustainability) software created with the help of the European Union's TASIS "IBPP-support of civil company and aboriginal initiatives" software and Leonardo da Vinci (the Dutch Agency) software. It is a freely distributed software allowing calculating a number of indicators characterizing level and quality of life of the population in the coastal territories. A simulation model of natural management on marine coasts allows simulating consequences of investments into various branches of industry, such as

- extractive and recycling branches of economy (from fishing industry, timber industry, pulp-and-paper mills to chemical industry);
- recreational-tourist system (from from tourist routes, bases of rest to medical-balneal centers);
- environment protection measures (from limitation of kinds of activity, building of natural sanctuaries to national parks).

The software allows considering various natural-economic areas. The areas with extreme natural-economic conditions will correspond to "high-marine" computational model, the areas with special complicated natural-economic conditions will correspond to "middle-marine" and the areas with complicated natural-economic conditions will correspond to "low-marine".

The "CoMPAS" software uses a step by step principle of action that, on the whole, meets principles of budgetary process in the Russian Federation. Its creators included into the software the following indicators of social and economic development of the coastal territories: budget of a territory; marine bioresources; population in a territory; income per capita; an environmental quality index; an index of human development. Calculations specified the relative value of Pigu's tax (in relation to a profitable part of the territory budget) that may provide stable social and economic development of a territory and prevent an eco-catastrophe. Hence, stable development in certain territory or water area will be characterized by an index of human development and an environment index.

The decision of the given task was divided into two stages. At the first stage, basic strategy of the territory development providing stable social and economic development was chosen; the direction of investments (conditions of their increase or reduction) was determined; interference of the developed industries was estimated; value of Pigu's tax was set up under condition of stable high indices of human development and environmental quality.

At the second stage of the task decision, the chosen strategy for various natural-economic areas was modeled; the relative value of Pigu's tax for every area was calculated; and their values were compared.

Decisions of the given task allowed to specify the most typical features of strategy for stable social and economic development of the coastal territories; the relative value of Pigu's tax providing stability of social and economic development of the coastal territories at the present level of environmental capacity of industry; effect of ecological factor on value of the differential rent in various natural-economic areas.

III. Results And Discussion

Some strategies were considered in the process of calculations. At the first step of an algorithm selecting a strategy of stable development, an arbitrary strategy was calculated, and then the method of consecutive improvements allowed developing of such strategy of coastal territory development, which would make it stable. Separation of investments into various industries is reached experimentally.

The strategies were applied consecutively in that order, as shown in Table II.

Every next strategy is characterized by a positive fluctuation received by a method of minor improvements made in the previous strategy of development. The process continued until certain "Strategy 4" revealed. In our opinion, this certain strategy provided rather stable social-and-economic development of the territory. The received results are shown in a dimensionless (relative) form, in order to average the effect of ecological factor on economic indicators of computer model. Duration of a settlement period is 10 years. If a smaller period for calculations is accepted, the effects of economic wave dynamics may be "lost" caused by loss of main funds [7].

In case of "Strategy 0" (Fig. 1), no stable development may occur. Though the population increases in proportion to increase of marine bioresources, nevertheless, the index of human development steadily decreases. It is caused by almost monotone environmental impairment and more than prompt reduction of income per capita level which falls to zero from the seventh calendar year, i.e. the population comes to housekeeping predominantly.

Table II. Characteristics of strategies of stable social-and-economic development in the coastal territories ("CoMPAS" software)

Code name	Short characteristics
"Strategy 0"	Budgetary funds are not invested anywhere.
"Strategy 1"	All budgetary funds are invested in a recreational-tourist complex only.
"Strategy 2"	All budgetary funds are invested in a recreational-tourist complex (50 %) and in nature protection measures (50 %).
"Strategy 3"	All budgetary funds are invested as follows: a recreational-tourist complex (20 %), fishing (10 %), agriculture (10 %), fish-farming (5 %), timber industry (5 %) and environment protection measures (50 %).
"Strategy 4"	All budgetary funds are invested as follows: a recreational-tourist complex (10 %), fishing (10 %), agriculture (10 %), fish farming (10 %), timber the industry (10 %) and nature protection measures (50 %). In case of a sharply deteriorating environmental quality index or retarding increase of the indicators rates, the investments are withdrawn from the corresponding industry and directed to the environment protection measures.

Value of the territory budget is enlarged till the fifth calendar year. Then, it starts to monotonically decrease with the increasing loss of the capital not offset by incomes decreased with environmental impairment and lack of financing of industries. It is obvious that in order to maintain the budget value up to the mark and, hence, to provide a high index of human development, the investments into the industry are necessary.

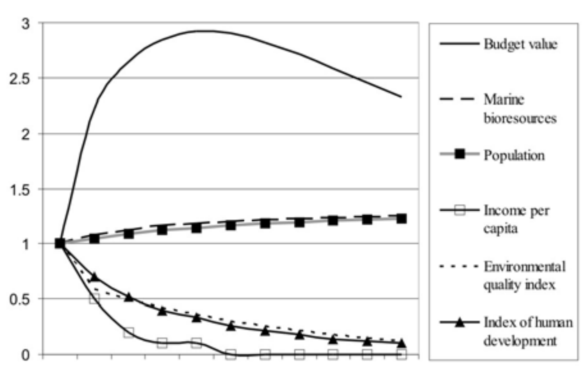

Fig. 1 relative indices of social-and-economic development for "Strategy 0"

In "Strategy 1" (Fig. 2), the recreational-tourist branch (the leading industry of coastal territories of the Far-Eastern seas) is chosen as the object for investments.

In "Strategy 1" fulfillment, the budget value is maximal in the second calendar year, however then it drops very sharply. Only quantity of the fish stores and quantity of the population are stable in development that is caused by lack of investments into the fishing industry. "Strategy 1" is also impossible to reach stable social and economic development of the territory.

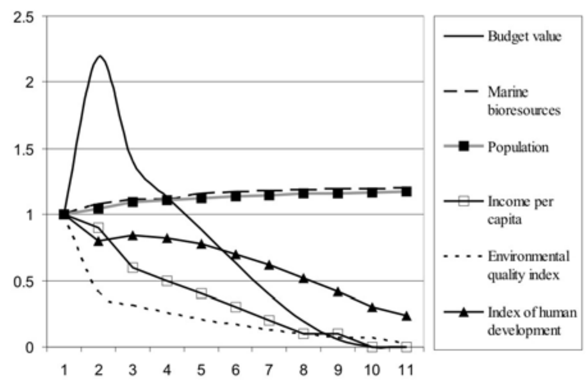

Fig. 2 relative indices of social-and-economic development for "Strategy 1"

"Strategy 2" (Fig. 3) includes the investments into environment protection activity that helps to assimilate consequences of pollution caused by anthropogenic pressure from recreational-tourist system of the territory. In this case, the budget maximum is reached in the second calendar year. Further, the slump of the budget occurs (rather than during "Strategy 1" fulfillment) because of insufficient investments into the recreational-tourist system development. Remaining indicators also rapidly fall, approximately in the third-fourth calendar years. Then they monotonically decrease and fall down to zero by the end of the calculation period. Only reserves of marine bioresources and quantity of the population develop stably that is also caused by lack of investments into fishery.

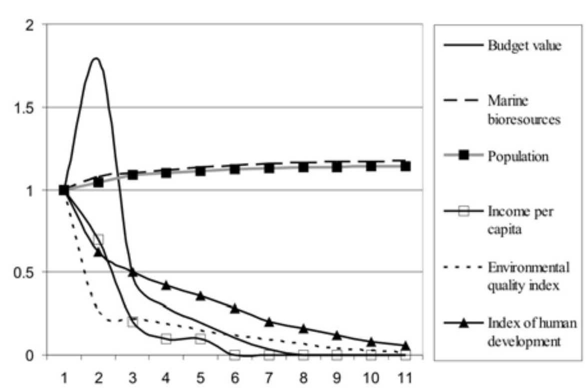

Fig. 3 relative indices of social-and-economic development for "Strategy 2"

We should note that allocation of a leading branch of economy and priority for its investments does not bring notable benefits. The situation similar to "Strategy 2" indicators is observed during priority development of fishing and timber industry. As we can see, the stable natural management in the coastal territory is not reached on fulfillment of the aforementioned strategies of social and economic development.

Though paradoxical, "Strategy 0" with zero budget of development is the best of the considered strategies. In the following strategies the sum of investments into environmental protection measures will not be less than the budget of territory development. Investments will be made into various industries, and not just in the leading industry, as in the two previous strategies.

Fulfillment of "Strategy 3" (Fig. 4), apparently, comes to stable natural management. Really, the budget increases, the income per capita achieves a local minimum in the third calendar year, however then it starts to increase and "pulls" the index of human development. The environmental quality index achieves a stable level by the tenth calendar year.

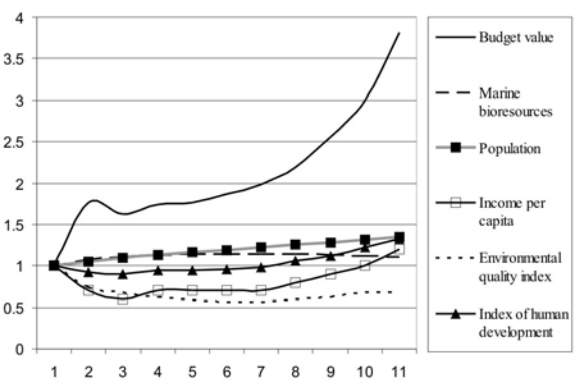

Fig. 4 relative indices of social-and-economic development for "Strategy 3"

But such situation cannot continue for a long time. The reserves of marine bioresources are maximal in the sixth calendar year and then start to monotonically decrease. The effect from it should follow after the tenth year that is beyond the calculation period. Consequently, the environmental quality index and the budget value should decrease. That will cause a "slump" of other indicators excluding population that only aggravates a situation. Thus, the stable natural management is unattainable in case of "rigidly" limited investments into the environment protection measures.

Rather stable social-and-economic development may be reached only in "Strategy 4" (Fig. 5). Its features are as follows:

- the budget in the first calendar year (designed to environment protection measures) is equal to the development budget;
- in case of sharp reduction of growth rates in any industry (or sharp increase of pollution from an industry), less investments are made into such industry;
- the funds withdrawn from the budget of development are invested into environment protection measures (directed to the advancing assimilation of environmental pollution).

As we can see from Figs. 1-5, the best strategy of social-and-economic development is "Strategy 4" characterized by leading growth of the budget of environment protection measures by means of the budget of development.

The worst is "Strategy 2" providing one-sided development of any industry, if the budget of development is equal to the budget of environment protection measures.

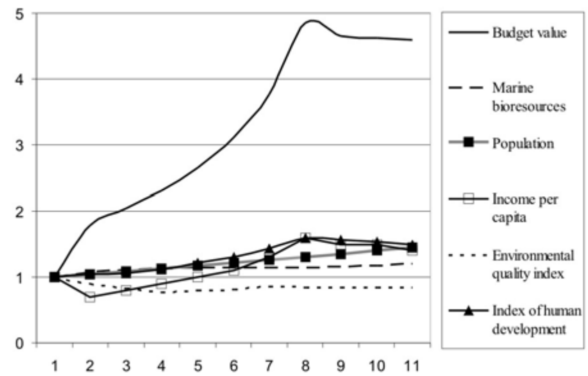

Fig. 5 relative indices of social-and-economic development for "Strategy 4"

Analysis of the abovementioned results shows that the similar simulation model may be used in design of ecological-economic policy of coastal development in the Far-Eastern Russia.

Among the described strategies, "Strategy 4" was chosen as the best strategy of coastal development (i.e. the strategy allowing achievement of a stable natural management within 10-year time diversity) with the following features. All budgetary funds are invested in the following proportion: a recreational-tourist system (10 %), fishing (10 %), agriculture (10 %), fish farming (10 %), timber industry (10 %), and environment protection measures (50 %). In case of deterioration of the environmental quality index or retardation of growth rates of the indicators, the investments are withdrawn from the conforming industry and forwarded to the environment protection measures. Here the stable development is understood as "soft" definition of stability. It means stabilization of the environmental quality index on any level high enough. A return to "wild nature" is not considered.

The next stage of the investigation is to define a tax levied from nature managers and directed to minimization of man's impact caused by land tenure. Such tax is directed to the following possible measures: land reclamation, chemical refining and bioscrubbling, breeding of certain kinds of animals, etc. Primary purpose of the calculations is to define a bite of the tax levied from land users in the territory budget, and to define the factors influencing the tax value. These calculations were carried out for the areas with extreme natural-economic conditions, special complicated natural-economic conditions, and the area with complicated natural-economic conditions as well. The calculations were carried out provided that the territory achieves stable development within 10 years of such strategy.

Analysis of the indicators of the strategy of stable social-and-economic development of the territory shows that the growth tendency, as a whole, is determined by the population development in the territory. Fluctuations in the share of investments into environment protection measures are caused by administrative influence applied depending on a status of the environmental quality index.

IV. Conclusion

1. Stable social-and-economic development and keeping of a high quality environment in the region in many respects depend on a direction of investments into developing industries and on values of the taxes collected from the nature managers.

2. The extent of anthropogenic pressure on the environment may be managed, if the consequences of stable social-and-economic development and the extent of environment degradation from development of priority industries are simulated.

3. Administrative decisions are accepted on the basis of the following: duration (minimum 10 years); priority in fund allocation to development of environment protection measures; strategy (definition of a development strategy for a region); an assessment of appropriateness of a development strategy for a region.

4. Acceptance of the appropriate administrative decision depends on a choice of development strategy for a region. Even with development of recreational-tourist industry as leading economy of coastal territories of the Far-Eastern seas (Strategy 1) it is impossible to reach stable social-and-economic development of the territory. Investments into environment protection activity, which helps to assimilate consequences of the contamination caused by anthropogenic pressure from a recreational-tourist system of territory (Strategy 2), will not provide stable social-and-economic development, as well, because it provides one-sided development of any industry under condition of equality of budgets of development and the budget of environment protection measures. “Strategy 3” fulfilled after the tenth year will lower an environmental quality index and the budget value that will cause “slump” of other indicators (except for the population) that only aggravate the situation. Rather stable social-and-economic development is reached only with “Strategy 4” fulfillment that is characterized by leading growth of the budget of environment protection measures by means of the budget of development.

5. Stable natural management is unattainable within any “rigidly” limited investments into the environment protection measures.

6. Analysis of the indicators of strategy of stable social-and-economic development of a territory shows that the growth tendency, as a whole, is determined by population development in the territory (fluctuations in the share of investments into environment protection measures are caused by administrative influence applied depending on a status of the environmental quality index.

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Shale gas revolution in Poland – challenges with replication of the US success

Jacek Hendel, Szymon Kuczyński, and Andrzej P. Sikora

***Abstract*—**In 2011, International Energy Agency announced that the world is entering a golden age of natural gas. Due to discovery of new hydrocarbons traps and large scale implementation of profitable unconventional gas extraction (tight, CBM, shale), global natural gas reserves to production ratio (R/P ratio) has been stagnated almost at this same level, for over 30 years, even though dramatic increases in gas production is evident. However, unconventional gas revolution started in US has not covered the rest of the world yet. In this review paper brief estimates of unconventional gas are discussed. Global shale gas potential as well as US basin production are pointed out. Shale gas revolution on North America and global energy markets are discussed. Main theme of this work is to compare US and Polish shale gas extraction experience. History data of drilling rigs working on American and Polish shale basins are presented. In addition, dropping of interest of shale gas extraction in Poland is illustrated and discussed.

***Keywords*—**shale gas resources, unconventional hydrocarbons, concessions, natural gas resources.

I. Introduction

In 2011, the International Energy Agency (IEA) in World Energy Outlook contemplated if the world is entering a golden age of natural gas [1]. Instructively, IEA pointed out that natural gas is the most environmentally friendly source of energy derived from fossil-fuels and should have a greater role in the global energy mix. The use of natural gas as an energy carrier generates the least air pollution, as well as greenhouse gas (GHG) emissions derived from fossil fuels [1]-[4]. It should be noted that unconventional gas resources such as tight gas, coalbed methane (CBM) and especially shale gas, are much more widely dispersed and far-reaching than oil resources [1] as presented in many reports and scientific papers [5]-[10], all studies, reports and others papers concerning shale gas resources and reserves are reviewed and summarized by McGlade and others [11]. Moreover, references indicate a recoverable resources pyramid including unconventional natural gas and oil reserves presents a greater yield than the conventional only resource pyramid. The International Energy Agency calculated that conventional recoverable resources would provide supply for 120 years of global consumption, but when unconventional would be added, reserves will be sustain for over 250 years [1]. In 1993 natural gas proved reserves were estimated at 118,4 Tcm (trillion cubic meters). At the end of 2003 it was 155,7 Tcm and at the end of 2013 proved reserves was calculated at 185,7 Tcm [12]. At this time, the global natural gas production was at levels: 2,05 Tcm, (1993), 2,62 Tcm (2003) and 3,37 Tcm in 2013 respectively [12]. According to British Petroleum [12] due to discovery of new hydrocarbons traps and large scale implementation of profitable unconventional gas extraction (tight, CBM, shale), global natural gas reserves to production ratio (R/P ratio) has been stagnated almost at this same level, for over 30 years, even though dramatic increases in gas production is evident [12]. Because of technical developments and "shale fever", the global R/P ratio has never has fallen below the level 50 although natural gas production increased by 140% between 1980 (1,43 Tcm) and 2013 (3,36 Tcm) [12]. This unconventional hydrocarbons revolution has a significant impact on regional and global gas and energy markets [11]. The increased potential of energy generation from natural gas and national capability and increased opportunities offered by shale gas extraction will be considered within this paper.

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J. Hendel is employee of the AGH University of Science and Technology, Krakow, POLAND, Faculty of Drilling, Oil and Gas, Department of Natural Gas Engineering (corresponding author: phone: +48 609 048 739; e-mail: hendel@agh.edu.pl).

S. Kuczyński, is employee of the AGH University of Science and Technology, Krakow, POLAND, Faculty of Drilling, Oil and Gas, Department of Natural Gas Engineering (e-mail: szymon.kuczynski@agh.edu.pl).

A. P. Sikora, is employee of the AGH University of Science and Technology, Krakow, POLAND, Faculty of Drilling, Oil and Gas, Department of Natural Gas Engineering (e-mail: andrzej.sikora@agh.edu.pl).

II. Terms and definitions concerning to natural gas resources

The best known mineral resource classification was created by Vincent Ellis McKeley and is called McKeley Box. There were several classifications systems used in the 20th century: the Former Soviet Union system in 1920s, Society of Petroleum (SPE) definition of proved reserves 1965; McKelvey Box 1972; SPE definitions for probable and possible reserves 1987; World Petroleum Congresses (WPC) resource systems and definitions 1987; SPE/WPC reserve definitions 1997, SPE/WPC/AAPG (American Association of Petroleum Geologists) resource definitions and classification systems from 2000 [13] and finally, the newest classification SPE/WPC/AAPG/SPEE/SEG (SPEE - Society of Petroleum

Evaluation Engineers; SEG - Society of Exploration Geophysicists). History of petroleum reserves and resources definitions are describe in SPE Guidelines [14]. Sometimes, other contradictions occur because of inappropriate terminology used by SPE and other institutions (e.g. term 'undiscovered' has divergent meaning in SPE and US Geological Survey terminology) [11], [14]. Based on McGlade et al. [11] work, several key definitions are explained in Table I.

Table I. Basic definitions for natural gas estimations [11]

Term	Abbreviation	Meaning
Original Gas In Place	OGIP	Total volume of natural gas that is trapped in gas reservoir (filed, play or region). The ratio of technically recoverable volume of gas to OGIP is known as *recovery factor*
Ultimate Recoverable Resources	URR	Volume of producible natural gas from well/play/region from beginning to the end of exploitation
Estimated Ultimate Recovery	EUR	Similar term to URR but commonly used to estimate single well gas potential, not region
Technically Recoverable Resources	TRR	Total volume of natural gas estimated to be producible with current technology, without consideration of exploitation profitability
Remaining Technically Recoverable Resources	RTRR	TRR with subtracted cumulative production from beginning to moment of RTRR estimation
Economically Recoverable Resources	ERR	ERR is a subset of TRR. It is total volume of gas that could be produced with current technology and makes project profitable. Other words, its estimated resource that are economically and technically producible.
Reserves		Part of discovered resources that have a particular chance to be produced.
Proved Reserves (1P)		Reserves that have 90% probability of being exceeded*
Proved plus **P**robable Reserves (2P)		Reserves that have 50% probability of being exceeded*
Proved plus **P**robable plus **P**ossible Reserves (3P)		Reserves that have 10% probability of being exceeded*

* there are also other definitions of 1P, 2P and 3P reserves. For more information see [14].

III. Short outlook of unconventional gas estimations

Between 1990 and 2012, more than 70 papers and official reports, estimating country, regional and global unconventional gas resources have been prepared [11]. Total number of reports (both official and unofficial) including academic articles and other analysis which concern US evolutions, evidences and challenges connected with shale revolution, has reached more than 167 papers till 16 August 2014 [15].The best known official reports are Annual Energy Outlooks drawn up by EIA and covered US hydrocarbons basins reserves. In 1997 and 1998 ERR were estimated. From 1999 till now TRR estimates are published [11]. Well recognized analysis and reports should be also pointed out. First European shale OGIP estimation was performed by Rogner [16] at 15,5 Tcm (549 Tcf). Wood Mackenzie and IHS Cambridge Energy Research Associates (IHS CERA) estimated TRR for Europe in January and February 2009 respectively. Wood Mackenzie reported shale gas TRR in Europe between 4,25 to 5,66 Tcm (150 Tcf and 200 Tcf) and IHS CERA between 3 to 12 Tcm [17]-[19]. World Energy Council assessed shale OGIP for nine continental regions in September 2010 [20], [11]. Other global estimates of shale gas potential were made by: Advanced Resources International (ARI) for EIA in April 2011 [9], by Medlock et al. in July 2011 [21], Bundesanstalt fϋr Geowissenschaften und Rohstoffe in February 2012 [6], and McGlade [11]. For US and/or Canada, or other single countries, there were more than 30 estimations published. Extensive database and knowledge about shale gas reserves and estimates are covered in McGlade et al. article [11], as well as in Melikoglu paper [22]. In this paper shale gas potential will be estimated from EIA Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States from June 2013, prepared by EIA and ARI [23].

IV. Global shale gas potential

According to EIA [23], global shale gas risked TRR are estimated for 206,7 Tcm (7299 Tcf) and according to ARI, in this same report, 220,7 Tcm (7795 Tcf) The total amount of risked Gas In-Place (GIP) was assessed at 1013,2 Tcm (35782 Tcf). Shale gas reserves are divided between continents quite evenly. Estimates are presented in table II.

North America covered nearly 30% of worldwide share gas TRR. Shale gas shares of South America, Europe, Africa and Asia are in range between 13% to 18,4% of global TRR potential. Australia has almost 6% of global TRR [23]. Global recovery factor is approximately 21% (with ARI U.S.' TRR estimations) [23].

Presented in Table II, global shale gas TRR is rather equally distributed around the world, however, ten countries with the greatest risked TRR, control over 80% of global TRR. China with TRR estimated at 31,6 Tcm, has over 14% of global TRR, as well as U.S. (32,9 Tcm). China, behind US, is the largest shale gas reserves owner with the most energy-intensive market, what, with strongly determined government, makes China perfect destination for oil & gas companies [22], [24].

However, administrative, industrial and monopoly-created barriers [25], as well as environmental issues [26] could slow down a Chinese energy revolution. Argentina has assessed TRR at 22,7 Tcm (more than 10% of global) and it is the world's second biggest shale gas formation owner - Vaca Muerta [22], [27], Algeria 20 Tcm (9%), Canada and Mexico 16,2 Tcm and 15,4 Tcm respectively (7% each one), Australia

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and Republic of South Africa 5,6% and 5,0% of global (12,4 Tcm and 11,0 Tcm, respectively) and finally, Russia with 8,1 Tcm (3,7%) and Brazil 6,9 Tcm (3,1% of global TRR) [23]. Similar values were used to prepare Fig.1 by Chen [28].

Table II. Worldwide shale gas potential by continents [23]

Continent	Risked GIP [Tcf]	Risked GIP [Tcm]	Risked GIP % of total	Risked TRR [Tcf]	Risked TRR [Tcm]	Risked TRR % of total
North America (ex.US)	4647	131,6	13,0%	1118	31,7	14,3%
U.S. (according to ARI)	4644	131,5	13,0%	1161	32,9	14,9%
Australia	2046	57,9	5,7%	437	12,4	5,6%
South America	6390	180,9	17,9%	1431	40,5	18,4%
Europe	4895	138,6	13,7%	883	25,0	11,3%
Africa	6664	188,7	18,6%	1361	38,5	17,5%
Asia	6495	183,9	18,2%	1403	39,7	18,0%
TOTAL	**35781**	**1013,2**	**100%**	**7794**	**220,7**	**100%**

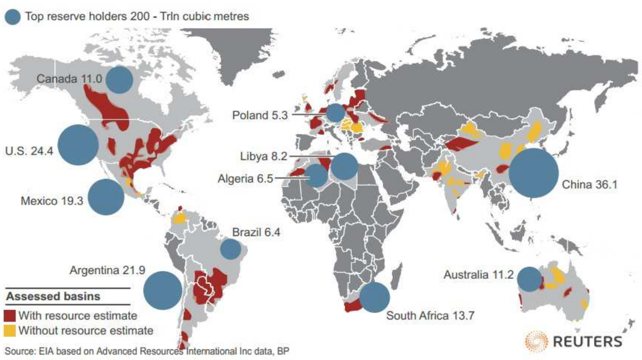

Fig. 1. Global top reserves holders after [28] (Thompson Reuters/ Catherine Trevethan), based on EIA and BP

There are little differences between Chen and EIA data presented because Chen utilized EIA estimates from 2011, as well as BP data from 2011. On Chen Fig.1 Poland and Libya are pointed out as key shale gas holders. In next paragraphs American and Polish unconventional natural gas basins will be taken into consideration. U.S. shale gas production and opportunities will be discussed more specifically as well.

V. United States Shale Gas Basins and Production

Due to implementation of profitable gas extraction and production from shale formations, United States has a supply of natural gas for over 100 years, assuming current gas consumption rate [15], [29]-[31]. There are several curial shale plays where the shale gas revolution was initiated. The potential of U S shale basins was assessed for EIA by ARI in 2011 and 2013 respectively. Table III and Table IV compares estimated made in 2011 [32] and 2013 [23]. The American shale basins are shown on Fig. 2.

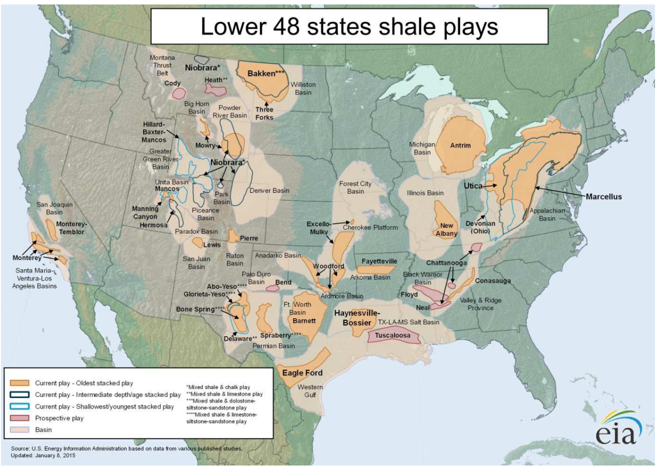

Fig. 2. 48 US Shale plays [23]

Table III. US Shale basins potential (TRR) [32]

Region	Basins	TRR [Tcf]	TRR [Tcm]	Share of total
Northeast	Marcellus	410	11,61	54,7%
	Antrim	20	0,57	2,7%
	Devonian Low Thermal Maturity	14	0,40	1,9%
	New Albany	11	0,31	1,5%
	Greater Siltstone	8	0,23	1,1%
	Big Sandy	7	0,20	0,9%
	Cincinnati Arch	1	0,03	0,1%
Gulf Coast	Haynesville	75	2,12	10,0%
	Eagle Ford	21	0,59	2,8%
	Floyd-Neal & Conasauga	4	0,11	0,5%
Southeast	Fayetteville	32	0,91	4,3%
	Woodford	22	0,62	2,9%
	Cana Woodford	6	0,17	0,8%
Mid-Continent	Barnett	43	1,22	5,7%
	Barnett Woodford	32	0,91	4,3%
Rocky Mountain	Mancos	21	0,59	2,8%
	Lewis	12	0,34	1,6%
	Williston-Shallow Niobrara (not assessed in INTEK report)	7	0,20	0,9%
	Hilliard-Baxter-Mancos	4	0,11	0,5%
U.S.	**TOTAL**	**750**	**21,24**	**100,0%**

Table IV. US Shale basins potential (TRR) [23]

Region	Basins	TRR [Tcf]	TRR [Tcm]	Share of total
Northeast	Marcellus	369	10,45	31,8%
	Utica	111	3,14	9,6%
	Other basins in Northeast	29	0,82	2,5%
Southeast	Haynesville	161	4,56	13,9%
	Bossier	57	1,61	4,9%
	Fayetteville	48	1,36	4,1%
Mid-Continent	Woodford (Ardmore+Arkoma+Anadarko)	77	2,18	6,6%
	Antrim	5	0,14	0,4%
	New Albany	2	0,06	0,2%
Texas	Eagle Ford	119	3,37	10,2%
	Barnett (+ the Barnett Combo)	72	2,04	6,2%
	Permian (includes Avalon, Cline, Wolfcamp in the Delaware and Midland)	34	0,96	2,9%
Rocky Mountain	Niobrara (includes Denver, Piceance and Powder River basins)	57	1,61	4,9%
	Lewis	1	0,03	0,1%
	Bakken/Three Forks	19	0,54	1,6%
U.S.	**TOTAL**	**1161**	**32,88**	**100%**

A. Marcellus basin

The biggest shale gas basin in US is definitely Marcellus (located in Northeast part of US, including parts of the states of New York, Pennsylvania, Ohio, Maryland, West Virginia and Virginia) and covers over 10 Tcm of TRR, more than 50% of total US shale TRR, in 2011 (according EIA in 2011) and more than 31% according estimation prepared by EIA/ARI in 2013. The daily gas rate from Marcellus measured through December 2014 (only from Pennsylvania and West Virginia) was 0,4 Bcm/day (14,2 Bcf/day) and It should be noted, that production from Marcellus has grown 14 times since May 2000 (nearly 1 Bcf/day) [33]. Increase in shale gas production from Marcellus is shown on Fig. 3. At February 6th, 2015, 71 gas rigs have been working on Marcellus shale formations. The peak in shale reservoir management was achieved in January 2011 when 143 rigs had been working [34].

B. Barnett basin

Barnett basin, located in Texas according to the newest estimates [23] has over 2,04 Tcm technically recoverable reserves. It represents more than 6% of total US shale gas TTR [23], previously TRR in Barnett was assessed at 1,22 Tcm [32]. More than 16 thousands wells have been drilled on Barnett Shale since early 1990s (vertical, horizontal as well as directional). By the end of 2012, 0,37 Tcm of gas have been produced from Barnett [35]. The daily gas production was 0,0057 Bcm/day (0,2 Bcf/day) in May 2000 and increased to 0,028 Bcm/day (1 Bcf/day) in February 2005. Production was doubled in next 2 years and was 0,057 Bcm/day (2 Bcf/day, February 2007), next, grew to 0,115 Bcm/day (4 Bcf/day) in October 2008 and finally reached the peak at 0,13 Bcm/day (5 Bcf/day) in November 2012. From that moment gas production rate is stable and amounts between 0,11-0,13 Bcm/day (3,9- 5,0Bcf/day) [33]. Barnett was the first extensively development play, thus in 2011 only 55-60 rigs were operated and by the end of 2012 this number has dropped to 29. By February 6th, 2015 only 9 rigs have been drilled [34].

C. Fayettteville basin

Located in Arkansas, stores 1,36 Tcm TRR [23] what is 4% of US TRR. Gas production form Fayetteville had increased from 0,0028 Bcm/day (0,1 Bcf/day) in January 2007 to more or less 0,07-0,08 Bcm/day (2,5-2,8 Bcf/day) and maintain that production level [33]. In 2011 about 30 rigs have been operated on Fayetteville. Since 2012, the number of active rigs has decrease from 30 to 13. In 2013 no more than 13 were active, and finally, the number of rigs does not exceeded 13 in 2014 [34].

D. Haynesville basin

Situated in Arkansas, Texas and Louisiana, stores near 4,56 Tcm of TRR (almost 15% of total US) [23], what makes it the second largest basin in US (after Marcellus). Total gas production form Haynesville was quite stabilized between 0,0037 Bcm/day (0,131 Bcf/day) in January 2000 and 0,0329 Bcm/day (1,16 Bcf/day) in July 2009 (with minimum at 0,002 Bcm/day; 0,07 Bcf/day). In middle 2008 production rate started growing and in November 2 Bcf/day was achieved. In April 2009 gas rate was equal to 3 Bcf/day, next in August production was at level 4 Bcf/day and at the end of 2010 it was 5 Bcf/day. In November 2011 production rate achieved maximum at 7,1 Bcf/day and from that moment constantly dropping to 4 Bcf/day by the end of 2014 (for details see fig. 3) [33]. In 2011 between 110 and 160 rotary rigs were constantly working. At the beginning of 2015, this number drop to 40 [34].

E. Other basins

Others major shale basins that should be considered within this article are: Utica, Woodford, Eagle Ford and Niobrara. Utica with 3,14 Tcm of TRR [23] is the fourth largest US basin. Production from Utica's fields has begun in middle of 2006. In June 2014, 1 Bcf/day was reached, and in February 2015, production increased to 0,05 Bcm/day (1,7 Bcf/day) [33]. Utica is still under development and number of working drilling rigs grows: from about 10 between 2011 and 2013 to more than 20 in 1Q of 2015 [34]. Woodford covers about 2,18 Tcm of TRR what contributes 6,6% of total US TRR [23]. The development of Woodford is going to the end. Only 9 rigs is currently working at fields [34]. The daily natural gas production rate from Woodford shale is shown on Fig.3. Eagle Ford located in Texas storages more than 10% of national shale gas TRR (3,37 Tcm) [23] and Niobrara 1,61 Tcm, which is nearly 5% [23]. Daily production of each basin and active drilling rigs are illustrated on Fig. 3 and Fig. 4 respectively.

VI. US Shale Gas Revolution Influence on North America and Global Natural Gas and Energy Market

As previously stated, the shale gas revolution in the US, preceded by the mastering of hydraulic fracturing has incontestable influence on global natural gas and energy markets. Daily production rate from the all shale gas plays increased from 0,1 Bcm/day in early 2000 to more than 1,2 Bcm/day (almost 40 Bcf/day) in December 2014 [33]. In that period of time, natural gas price, indexed on Henry Hub, was on similar price level $ 2,42 per MBtu in January 2000 and $ 2,99 per MBtu in February 2015 [33]. US consumption has grown from near 630 Bcm in 2001, through 659 Bcm in 2008 to almost 740 Bcm in 2013 [33].

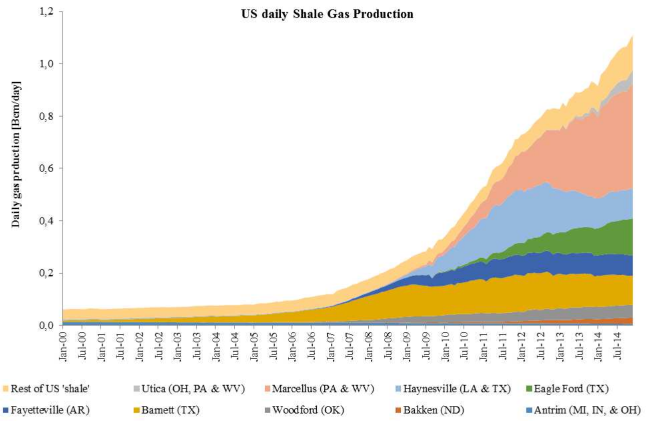

Fig. 3 Daily dry shale gas production [33]

The shale basins could be defined as "quite developed reservoir" because of dramatic drop of active drilling rigs on fields. (see fig. 4) [34].

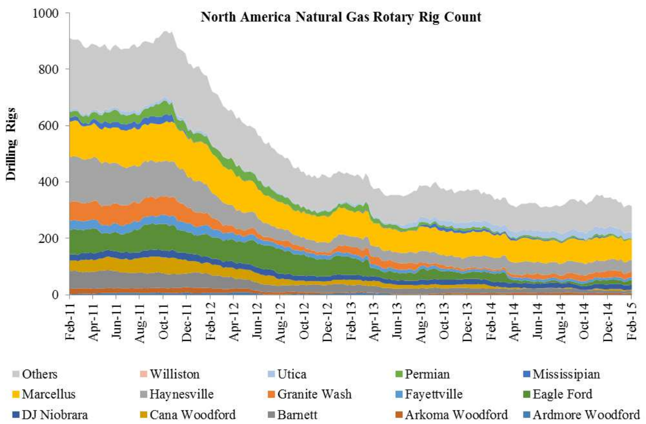

Fig. 4 North America Natural Gas Rotary Rig Count [34]

VII. Polish Shale Gas Basins Potential and Prospecting

Recently a few reports, which estimate Polish tight and shale gas resources, were announced. In 2014, estimations for tight gas reserves were prepared by Polish Geological Institute (PGI) (report published in March 2015) [36]. Shale gas resources, which are main aim of this paper, are discussed in details below.

Polish shale gas basins potential has been estimated in a few reports, resulting in a broad range of values. In 2009 Wood Mackenzie [18] and Advanced Resources International (Kuuskraa) [42] announced 1,40 Tcm and 3,00 Tcm, respectively. In 2010 Rystad Energy and state owned Polish Oil and Gas Company (PGNiG) announced 1,00 Tcm and 0,90 Tcm respectively [37]-[39]. In 2011, Advanced Resources International reported much higher assessment of Polish shale gas resources, equal to 5,30 Tcm [9]. Also in 2011 there were presented three other reports prepared by EUCERS - 1,87 Tcm [40], Medlock et al. [21] who reported 3,40 Tcm and Lane Energy Poland which reported 1,00 Tcm of recoverable gas for their 6 concession blocks in the Baltic Basin only. In 2012, the Polish Geological Institute estimated maximum recoverable resources of natural gas from shale deposits for Polish onshore and offshore basin to 1,92 Tcm [37] but the most probable range was estimated for 0,35-0,77 Tcm (onshore & offshore). Also in 2012 BGM and USGS reported 5,3 Tcm and 0,03528 Tcm respectively (about 10% what PGI estimated) [7], [41]. The latest ARI / EIA report from 2013 [23], estimates total recoverable reserves of natural gas from shale in Poland to 4,13 Tcm. All these reports present much higher estimates of shale gas resources than Polish conventional gas resources. It is planned that in 2015 new estimates for Polish shale gas recoverable resources will be generated [43]. Table V presents shale gas recoverable resource estimates for Poland.

Table V Shale gas recoverable resource estimates for Poland

Author / organization	Date of report	Resource estimate	Tcm	Tcf
ARI (for EIA)	Jun-13	TRR	4,13	146,00
			4,19	148,00
		OGIP	21,60	763,00
Mc Glade et al. / UKERC	Sep-12	"Resources"	4,30	151,85
USGS	Jul-12	TRR	0,03528	1,246
PGI	Mar-12	EUR - optimum - only onshore	0,23 - 0,62	8,14 - 21,87
		EUR - optimum (onshore & offshore)	0,35 - 0,77	12,22 - 27,11
		EUR - max (onshore & offshore)	1,92	67,79
BGR	Feb-12	"Resurces"	5,30	187,00
Medlock et. al.	Jul-11	TRR[a]	3,40[a]	120,00[a]
Khun and Umbach / EUCERS	May-11	TRR	1,87	66,10
		OGIP	23,90	844,00
ARI (for EIA)	Apr-11	TRR	5,30	187,00
		OGIP	22,41	792,00
Lane Energy (3Legs)	2011	"Resurces"	1,00	35,31
Rystad Energy	2010	"Resurces"	1,00	35,31
PGNiG	2010	"Resurces"	0,90	31,78
Kuuskraa / ARI	Dec-09	"Recoverable resources"	3,00	100,00
Wood MacKenzie	Jan-09	TRR	1,40	49,44

[a] - Medlock indicates that resources should be commercially viable so his definition, although described as technically recoverable resources, is in principle closer to ERR.

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Most prospective of shale gas accumulations were the Upper Ordovician and Silurian formations of the Baltic Syneclise, the Marginal and Lublin Troughs, and the Podlasie Depression as well as the Narol-Biłgoraj zone. Less prospective are the Upper Cambrian and the Tremadocian sediments of the Baltic Syneclise. The most perspective shale gas bearing formations in east Central East Europe, Silurian black shales, are the main object of research currently performed by industrial and scientific institutions.

A. Baltic Basin

In the EIA report from 2011, the Baltic Basin total area was estimated at 263 172 km^2 and holds the Lower Silurian shale formation at Llandovery. The prospective area was estimated on 22 911 km^2 with an average depth of 3750 m. TOC [wt.%] was calculated at 4,0% and thermal maturity at 1,75% Ro. Clay content was assessed as medium. Risked recoverable GIP is 3,6 Tcm [44], [32].

B. Lublin Basin

Second described, Lublin Basin has a total area equal to 30 774 km^2 and prospective area of 30 199 km^2. Formation is dated as Lower Silurian, from Wenlock. Interval occurs between 3000-4100m of depth (average 3050m). An average TOC and thermal maturity was estimated at the level of 1,5% and 1,35% respectively. Clay content is medium rank and risked recoverable GIP was estimated at 1,2 Tcm [44], [32].

C. Podlasie Basin

The total area of Podlasie Basin was estimated at 11 153 km^2 with risked recoverable GIP at 0,4 Tcm. The prospective area was assessed at 3432 km^2. Lower Silurian formation is also from Llandovery age. Formation interval is between 1750-3460 m with average depth 2605 m. TOC was obtained at 6,0%, thermal maturity 1,25% and clay content as medium [44], [32].

The details of geology, tectonic setting, stratigraphy, as well as relationships between gas occurrence and petro-physical properties, were deeply investigated and published in many papers [45]-[50]. Prospective basins and concessions assigned along those basins are presented on Fig. 6a and Fig. 6b-f.

VIII. CONCESSIONS

During last few years, after a period of great interest in shale gas prospecting and exploration in Poland, there have been significant changes [39]. From the beginning of 2013, total number of concessions started to decrease (Fig. 5). According to Polish law, the Polish Ministry of the Environment, was issuing two types of concessions related to exploration for shale hydrocarbons. One concession was for prospecting and/or exploration of both: conventional and unconventional hydrocarbon deposits in Poland. A second concession was issued for prospecting and/or exploration of unconventional hydrocarbon deposits in Poland (authors' analysis does not apply to concessions for prospecting and/or exploration: only for conventional hydrocarbon deposits, coal-bed methane (CBM) deposits and "tight gas" deposits). Since January 1st, 2015, when the amended mining and geological law came into force, types of concession has been modified [51]. Currently these two types of concessions were expanded for production opportunity.

Within this paper, when shale gas concessions are taken into consideration, both types of concessions mentioned above are taken into account.

The first shale gas concession was issued by the Polish Ministry of the Environment in 2007. At the beginning of 2013 ("peak time") there were 113 concessions, whereas at April 1st 2015 there were 47 concessions issued by the Polish Minister of the Environment. These 47 concessions were granted to 12 Polish and foreign capital groups [43]. Most concessions - 11 - had PGNiG SA., Orlen Upstream Sp. z o.o had 8 concessions and Lotos Petrobaltic SA - 7 concessions (only offshore).

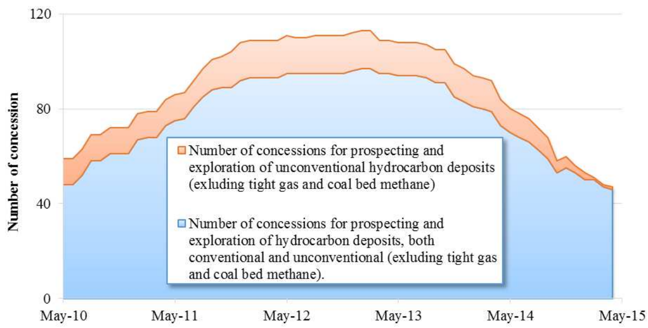

Fig. 5 Change in number of shale gas concessions in Poland (own study, based on MoE [43])

The decrease in the number of concessions is mainly caused by an exit from the Polish market of several important investors. Reasons for a loss of investors may be found in the absence of spectacular exploration and production success, unfavorable legal and bureaucratic environments, natural gas and oil prices.

At the beginning of 2013, there were active 19 capital groups which held 113 concessions. By April 1st 2015 the number of concession holders decreased to 12 and number of concessions dropped to 47.

At the beginning of 2015, Chevron Corp. the second-largest integrated energy producer in the US, announced an investment abandonment in Poland [52]. Chevron Corporation is not a first global player to quit exploration of hydrocarbons in Polish shale deposits. Exxon Mobil Corp. abandoned Polish shale in 2012 after drilling unsuccessful wells. Canadian Talisman Energy Inc. and U.S. Marathon Oil Corp. quit in May 2013. Eni SpA and French Total left in early 2014. At beginning of 2015, only ConocoPhillips, one of the biggest U.S. oil and gas producer, was still active in Poland holding 3 concessions for hydrocarbon exploration in Polish shale deposits. Fig. 6b-f provides an overview of investors' withdrawal from acquiring gas concessions in Poland.

Table VI shows the decreasing number of shale gas concessions held by a decreasing number of capital groups.

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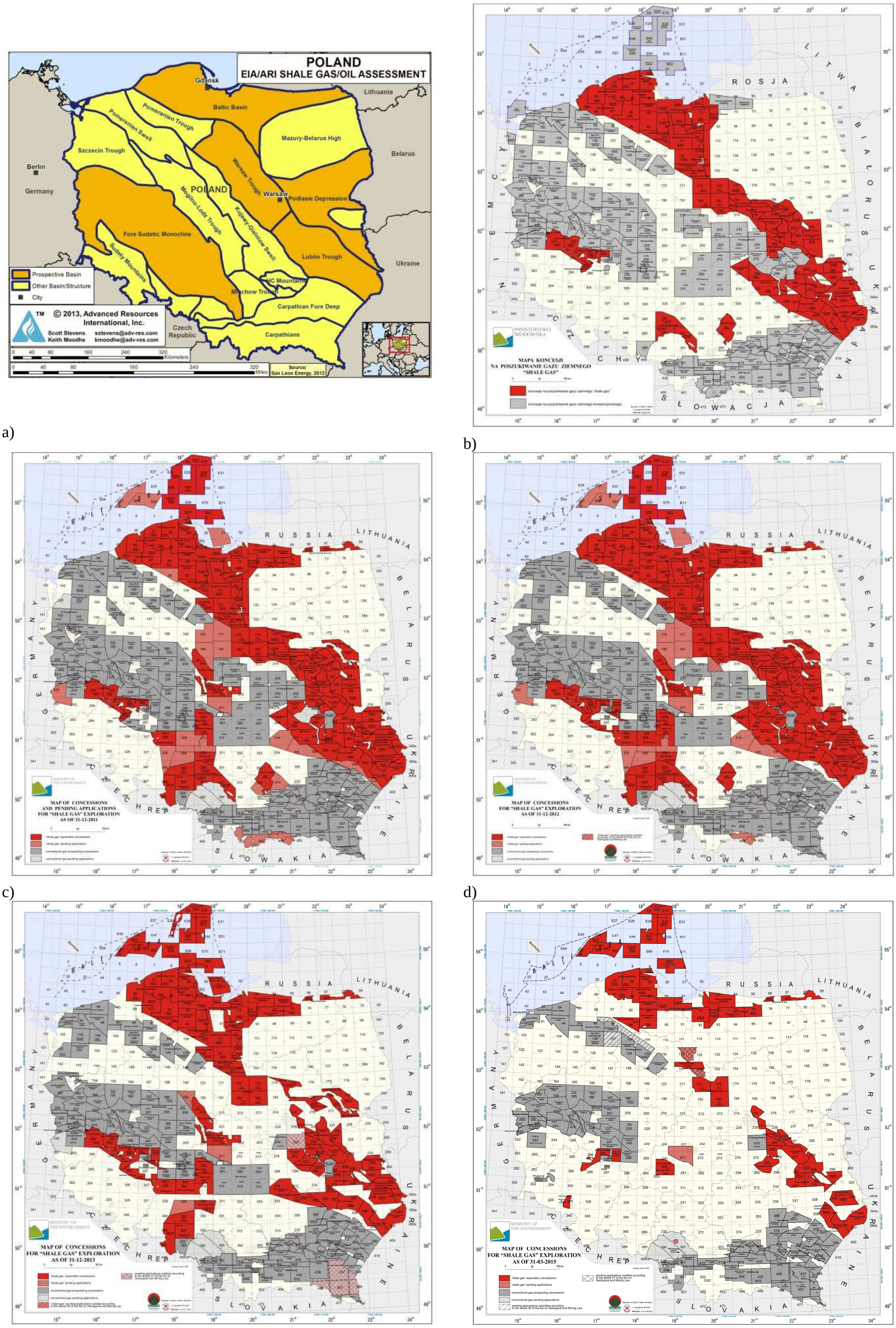

a) b) c) d) e) f)

Fig. 6 a) Major Shale Gas Basins in Poland. Maps of concessions for shale gas exploration: b) as of 08/2010; c) as of 12/2011; d) as of 12/2012; e) as of 12/2013; f) as of 03/2015 (own study, based on ARI/EIA [32] and MoE [43])

Table VI Capital groups which holds concessions* for prospecting or exploration of shale gas in Polish deposits (own study, based on MoE [43])

Capital group	2013-01-01	2015-04-01
PGNiG S.A.	16	11
Polski Koncern Naftowy Orlen S.A.	7	8
Grupa LOTOS S.A.	7	7
San Leon Energy Plc	-	4
Wisent Oil & Gas Plc	4	4
ConocoPhilips B.V.	-	3
Stena AB	-	3
Chevron Corporation	4	2
PPI Chrobok S.A.	-	2
BNK Poland Holdings B.V. & Kaynes Capital S.a.r.l.	-	1
Cuadrilla Resources Limited	3	1
Palomar Capital Advisors Limited & San Leon Energy B.V.	-	1
San Leon Energy Plc & LNG Energy LTD	-	-
Marathon Oil Company	11	-
San Leon Energy & Realm Energy International	10	-
3Legs Resources Plc	9	-
PETROLINVEST S.A.	9	-
Basgas Pty Ltd	6	-
ExxonMobil Corporation	6	-
Emfesz	5	-
BNK Petroleum	6	-
Eni SpA	3	-
Talisman Energy Polska	3	-
Aurelian Oil and Gas PLC	2	-
Mac Oil Spa	1	-
Milejów LLP	1	-
TOTAL no. of capital groups	**19**	**12**
TOTAL no. of concesion*	**113**	**47**

*- concessions for prospecting and exploration of hydrocarbons (conventional and unconventional) in Polish deposits. Presented summary does not apply to entities that holds concessions for prospecting for or exploration: only for conventional hydrocarbon deposits, coal-bed methane (CBM) deposits, "tight gas" deposits)

IX. Exploration & Production Companies in Poland - Key Players and Their Capacities - Outlook for Development

Until 2010 E&P services in Poland have been provided exclusively by several PGNiG's (or POGC's) subsidiaries that were working independently. In February 2013 POGC finalized the completion of the formal and legal integration of the five providers of drilling and oilfield services of the PGNiG Group, which were merged to become a single entity – Exalo Drilling S.A.. Previously independent services companies of the PGNiG Group were: PNiG Kraków S.A., PNiG JASŁO S.A., PNiG NAFTA S.A., PN Diament Sp. z o.o. and ZRG Krosno Sp. z o.o. [53].

In spite of entry into the Polish market of companies (eg. Schlumberger, Weatherford, Halliburton (Including Baker Hughes acquired in 2014), or the United Oilfield Services), the dominant role of the PGNiG still remains unthreatened. It should be emphasized that the scale of action related to exploration and further production of natural gas from Polish shales requires an acceleration in drilling activities.

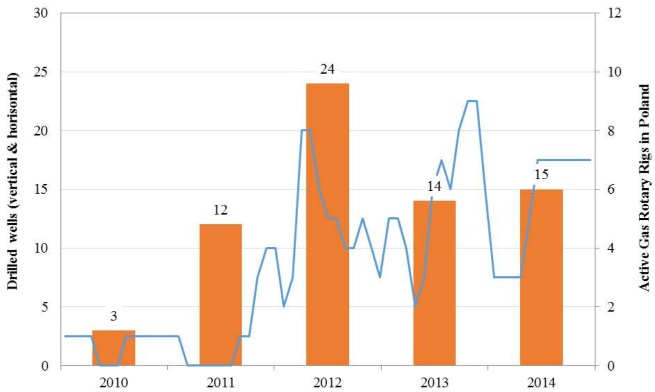

Fig. 7 Drilled exploration wells in Polish shale deposits and number of active gas rotary rigs in Poland (own study based on MoE, 2015 [43] and BHI, 2015 [54])

Since 2010, the number of wells drilled for shale gas extraction has grown (see, Fig. 7), but since 2013 drilling activity has declined and the growth rate has slowed down. Companies started to send their rigs elsewhere, both within Europe and beyond. Companies like MND, KCA Deutag, Ensign changed their plans: Czech MND rig went to Serbia, the Canadian Ensign rig was moved to Iraq, UK KCA Deutag rig returned to Western Europe [55]. Even, mention above, Polish service company Exalo Drilling S.A. has sent brand new walking rig to do work abroad. Other companies, such as Phoenix, who have a presence in other markets in Europe and Russia, and wanted to enter the Polish market, have reconsidered their plans [56].

At the beginning of 2015, apart from UOS which has a new CE-ATEX certified 2000 HP AC Pad Drilling Rig [57], only Exalo Drilling S.A. has ability to drill 3500+ m depth wells in Silurian shale formations [53].

From 2010 to the end of March 2015, 70 shale gas wells were completed (16 of this wells were horizontal; see fig. 7). In first quarter of 2015 another 2 exploration wells were drilled: Rawicz 12 SL-1 on Rawicz concessions held by San Leon Rawicz Sp. z o.o. and Pęclin - OU1 on Wołomin concession held by Orlen Upstream.

In the near future it is planned to start drilling another two wells for shale gas exploration: Jackowo LEP-1 (LEP 1ST1H) concession Lebork, investor: Lane Energy Poland Sp. z o.o. and Lewino-2h concession Gdańsk W, investor: Baltic Oil & Gas Sp. z o.o.

To perform initial assessment of shale gas production possibility, special treatments were applied. Hydraulic fracturing was performed at 25 wells (includes 12 horizontal wells). Fracture Injection Diagnostic Test (DIFT) was performed in 4 wells. Special treatments was not applied in 41 wells [43; entry date April 2015].

X. Conclusion

Several recent papers discussed profitability of American shale gas production [58]-[63] as well as European (Weijermars, 2013) [64]. Weijmars ranked European shale gas basins in accordance with expected benefits from production. Ranking methodology was described in details in article. Sequence of the most prospective (attractive) European shale basins is as follows: Silurian Poland, Shale Austria, Posidonia Germany, Shale Turkey and Alum Sweden. Weijmars estimated NPV for each country on following assumptions: development of 100 shale gas wells, specified EUR/well ratio, initial production rate, decline curve types, well CAPEX, OPEX, royalty and corporate taxes and depreciation, as well as discount rate. Including given parameters described in details in article, NPVs for each country amounts to: 737 M$ for Alum Sweden, 1497 M$ for Silurian Poland, 953 M$ for Posidonia Germany, 2427 $M for Shale Austria and 565 $M for Shale Turkey [64]. After consideration of other economics parameters as: IRR (different in various country), largest negative cash flow requirement and payback, Polish Shales were ranked at the first place and Weijermars pointed them as the most promising target to start European shale revolution. In mentioned article, Weijmars, implemented US shale gas wells as an analog to EU wells. He also assumed initial gas rate equal, for Polish Silurian, to 0,5 Bcf/year (1,37 Mcf/day; 0,38 Mcm/day) for single well [64], what is extremely optimistic values, as showed example from Polish wells described

So far, the biggest gas flows from Polish shale formations was announced by Lane Energy Poland (owner: ConocoPhillips) in Łebień LE-2H well (0,008-0,0011 Mcm/day) [65], [66] and Lublewo LEP-1STH (0,00145-0,00112 Mcm/day for shale gas and 157 bbl/day of light oil) [67], San Leon Energy on Lewino-1G2 (0,000843-0,00169 Mcm/day [68]-[70], after cleaning the well expected to 0,00566-0,011 Mcm/day) on BNK Petroleum Gapowo-B-1A (at the beginning 0,03 Mcm/day, later drop to 0,000006-0,000011 Mcm/day) [71], [72]. But still - the hydrocarbon flow is not sufficient for commercial and profitable exploitation.

By the end of March 2015, 70 exploration wells had been drilled in Poland for shale hydrocarbons, but none of them started production. Polish shale formations are different than US shale geological formations [73]. Previously it was assumed Poland, like the US, has one continuous broad shale belt. However, as it turns out Poland might have many areas where commercial extraction of shale gas and other hydrocarbons will be possible. Scale of exploration in Poland is much smaller than in the US [52]. So far, wells drilled in Poland amount to a small fraction of those drilled in the US. To estimate the amount of shale gas in Poland at least 20 and upwards of 100 pilot wells need to be initiated during the next two years. Though not regarded as a commercial phase [74] it would go a long way to ending any thought that the shale gas revolution has passed by Poland. Some would agree it only just begun.

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Changes in Budgeting and Planning practices: comparative study of Czech and North American Companies

Boris Popesko, and Vendula Šocová

***Abstract*—** Budgeting and planning belongs to the traditional tools of management accounting which are essential for the successful control of the business organizations. In recent decades we observe growing dissatisfaction with traditional budgeting concepts, based on annual bases and control functions. Traditional budgeting methods are very often criticised for the inflexibility and strong focus on resource allocation. Many research studies points at the necessity of adopting more sophisticated budgeting methods, which could contribute to better performance management and control of business organizations. Current trends lie in adopting flexible, decentralized budgeting systems, focused on the use of key performance indicators (KPI). The paper presents the initial results of the survey of Czech enterprise budgeting practices. The objective of the study was to compare firm´s approach to their budgeting systems and intention of abandoning the traditional way of budgeting. The first part of the paper presents the current state of knowledge in the field of modern budgeting methods utilization and defines the general specifics of the Central European region. The main part of the study presents the results of the questionnaire survey of the Czech enterprises' budgeting practices performed by the authors. The final part of the paper discusses the differences between the Czech and North American companies. The objective of the study is also to identify strong tendencies in the Czech budgeting practices and analyse the related problems.

***Keywords*—**budgeting, planning, managerial accounting, performance management.

I. Introduction

BUDGETING and planning belongs to the basic management accounting tools used worldwide by different types of organization and historically played center stage in most organizations systems of management control (Otley, 1994). Traditional theory of budgeting and planning has been presented in detail by the fundamental Management Accounting books (Drury 2000, Kemp and Dunbar 2003). These sources state that traditional short-term budgets are mostly based on annual accounting periods and are connected with the forecast of the elementary financial indicators. Many authors state, that traditional budgeting is based on the mechanical transformation of the non- financial forecast into the financial statements, without taking into account the real needs of an organization (Doyle 2006). Doyle (2006) state, that most important limitation of the traditional budgets is inflexibility and inability to absorb the changes in the business environment occurred throughout the year. Strong criticism of the traditional budgeting mechanisms was presented by the Hope and Fraser (2003). Their criticism was mostly focused on the traditional budgeting mechanisms inability to support the performance measurement of an organization. They also state that traditional budgets often results in dysfunctional behaviour and consume large amounts of management time. Criticism of the traditional budgeting systems led into the introduction of the new modern budgeting methods such as Activity-Based Budgeting (Drury 2001) or Beyond Budgeting (Hope and Fraser 2003). These methods are mostly based on abandoning of traditional annual budgets for each department and setting up the decentralized system based on selected performance indicators.

This study presents the initial results of the questionnaire survey performed in the selected Czech manufacturing enterprises during autumn and winter 2014. Authors try to compare the results of the survey with the similar research performed in U.S. and Canada in 2009 by Libby and Lindsay (2009). Study was based on the field survey of 145 Czech medium and large industrial companies, where the trade and service organizations have been excluded. Overall aim of the study is to enlarge the knowledge about the Czech organization budgeting practices and compare the results with the similar study performed in North America by Libby and Lindsay (2009).

II. Literature review

Budgeting and planning is considered as the fundamental feature of the management accounting by many authors (Drury 2001, Garrisson et al 2009, Kemp and Dunbar 2003). While planning is considered as the design of a desired future and of effective ways of bringing it about (Ackoff 1981), the budgets is considered as the detailed plans (Drury 2001) or as the plans transformed into currency units (Král 2010).

Many studies present the problems related to the traditional budgeting systems. Drury (2001) for instance explains the

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B. Popesko is the associate professor at the Department of Business Administration, Faculty Management and Economics. Affiliation Tomas Bata University in Zlin, nám. T.G.Masaryka 5555, 76001 Czech Republic. (e-mail:popesko@fame.utb.cz).

V. Šocová is the Ph.D. student at the Department of Business Administration, Faculty Management and Economics. Affiliation Tomas Bata University in Zlin, nám. T.G.Masaryka 5555, 76001 Czech Republic. (e-mail:popesko@fame.utb.cz).

conflict role of the budgets, which is caused by the use of the budgets for the several purposes such as motivation and planning. Jensen (2001) considers the traditional budgeting “broken”. Gurton (1999) describes the budgeting as “a thing of the past”. Deepest criticism of traditional budgeting was presented by Hope and Fraser (2003).

Recently, the academic research into budgeting is focused on participative budgeting and reliance on budgetary targets for performance evaluation (Hartmann, 2000). Libby and Lindsay (2009) in their research states that such academic initiatives are disconnected from the concerns made by the practitioners. Libby and Lindsay (2009) also wonder why so many organizations use the traditional budgets for control purposes (i.e. managerial motivation and performance evaluation), in situation when Hope and Fraser (2003) presented so strong criticism of use of traditional budgets for control.

Taken together, Libby and Lindsay (2009) state that we do not possess a robust understanding of budgeting that is capable of explaining the mechanism or process giving rise to satisfactory or unsatisfactory of budgeting systems. If we can indicate such lack of knowledge in conditions of developed North American economies, it seems evident, that such knowledge is not present in condition of still developing central European economies.

In conditions of Czech Republic, we can indicate the lack of published studies focused on the analysis of budgeting practices of Czech organizations. Many studies are focused on the problems related to the public budgets (see Mansfeldova 2005, Grebeniček et al 2013). Horová and Hrdý (2007) published the results of the survey focused on the strategic financial management of Czech enterprises, which includes also some findings from the budgeting field. Study showed that most common type of budgets are focused on the annual perspective (78.9 % of the surveyed sample). System of the rolling budgets is used by the 24.4% of the organizations and 55.6% of the organizations are not using the optional budgets. Study published by Knápková et al. (2014) investigated the adoption level of Balanced Scorecard approach, which could be seen as the way how to implement the performance measurement system which could replace the traditional budgeting. Study indicated the 13.1% adoption level.

III. Methods

Data was collected via web-based questionnaire. Firstly, the data from the ALBERTINA database was collected in order to set the investigated sample of organizations and to get the contact data of the selected organizations representatives. The medium and large companies from industrial sector were chosen, excluding the service and trade organizations. In following step the selected persons form the database, in most cases the financial directors, had been contacted by the telephone. Surveyed person had been asked about their willingness to participate on survey. If they agreed to participate, they were sent email with web-connection to the survey.

A. Sample statistics

We addressed 1139 companies and 513 of them agreed to participate in this survey. It was filled 145 questioners. Return of the questionnaire is 28 percent. High return rates the questionnaire we attribute to telephone contact. The total return of the questionnaires of all companies surveyed is 12.6 percent

IV. Results

In a recent review, Hansen et al. (2003) observe, that the dissatisfaction with budgeting in practice is occurring on two fronts: those that wish to abandon budgeting altogether and those that wish to improve it. Hope and Fraser (2003) presented several studies of European companies which successfully abandoned the traditional budgeting systems and replaced it by performance measurement system based on performance indicators. On the other hand, Eckeholm and Wallin (2000) report that only 15% of the Finnish companies they surveyed indicated the intention to abandon the traditional way of budgeting whereas 61% aimed to improve the current budgeting system and 24% reported they are not planning any changes in used budgeting system. Libby and Lindsay (2009) surveyed the 346 Canadian and 212 U.S. companies about their budgeting practices. They indicated that in total 79% of the surveyed companies use the budgets for control purposes. Within the group using budgets for control, 94% indicated they were not planning to abandon the use of the budgets for control in the near future while 5% indicated they were possibly considering doing so, and only 1% indicated that they were definitely planning to do so within next two years. Results were similar across the Canadian and US samples.

Table 1 presents the results of the question related to the use of the budgets for control and comparison with results published in 2009 by Libby and Lindsay (2009) in US and Canada. As we can see, use of the budgets for control is higher than in in North American sample, what we can interpret as the lower percentage of the firms in Czech sample, which has abandoned the traditional budgets and use the more advanced control systems.

Are the budgets used for control?	Czech rep.		US and Canada	
	Freq	%	Freq	%
Yes	127	87,6%	440	78,9%
No	18	12,4%	118	21,1%
Total	145	100,0%	558	100,0%

Tab.1 Use of budgets for control (1st part)

Table 2 shows the results of the question if the organizations plan to abandon the use of the budgets for control.

Do you plan to abandon the use of budgets fro control?	Czech rep.		US and Canada	
	Freq	%	Freq	%
Yes	4	3,2%	4	0,9%
No	120	95,2%	414	94,1%
Possibly	2	1,6%	22	5,0%
Total	126	100,0%	440	100,0%

Tab.2 Use of budgets for control (2st part)

As we can see, result of this question is relatively similar to the North American results. In our survey we can observe slightly higher portion of the organization, which plan to abandon the use of the budgets for control.

Table 3 reports on organization´s intention to make any changes in budgeting system in following two years.

Do you plan any changes in budgeting system?	Czech rep.		US and Canada	
	Freq	%	Freq	%
Yes	44	30,3%	257	46,1%
No	101	69,7%	301	53,9%
Total	145	100,0%	558	100,0%

Tab.3 Use of budgets for control (3st part)

As we can see, slightly lower of the organizations in Czech Republic indicates the intention to make any changes in the traditional way of budgeting. This finding is connected with the lower adoption rate of the more advanced budgeting methods and not developed discussion about the limitation of traditional budgets. On the other hand the 30% of the organizations which declared the intention to make the changes in budgeting system is relatively significant portion which indicates the dissatisfaction with contemporary budgeting practices.

V. Discussion and conclusion

Budgeting and planning practices are facing dramatic changes in contemporary business environment. Traditional annual budgets are very often replaced by the more flexible systems focused on measurement of performance of individual segments of business. Causes of this trend are in the lack of flexibility of traditional budgets and its inability to serve as the relevant performance measurement system. Limitations of the traditional budgets and the growing dissatisfaction with the budgeting systems had been widely discussed by many studies (Neely et al, 2003; Eckholm and Wallin, 2000). Hope and Fraser (2003) accurately argued that the budgets often impede firms from being flexible and adaptive in the increasingly unpredictable environment.

Hope and Fraser (2003) argued that use of the traditional budgets for control purposes could lead into “performance trap”, where higher pressure on achieving the budgetary targets doesn´t lead into increase in performance. Performed research showed the significant similarity of the Czech budgeting practices with the North American ones. In conclusion, the results showed that the traditional use of the budgets for control will not be eliminated in near future. Most firms in our sample planned to improve their budgeting systems and not to abandon them. In our sample we had also observed the significantly higher portion of the firms, which use the budgets for control in Czech sample than in North American sample, which could be explained as the lower adoption rate of modern performance management methods in Czech environment. Interesting result is also the lower portion of firms in Czech sample which plan any changes in the budgeting system. This could lead into assumption, that the satisfaction with the traditional budgeting in Czech conditions is higher due to the lower perception of the traditional budgets limitations. On the other hand the portion of the firms which plan to abandon the use of the budgets for control is higher in the Czech sample. Absolute frequency of this type of answers is too low for any assumptions.

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Model to measure marine engines emission

Giuseppe Langella, Paolo Iodice, Amedeo Amoresano, Adolfo Senatore

Abstract— This study analyses the production and the dispersion of air pollutants produced by marine engines of large size during the approach phase to the ports. According to current regulations, different scenarios have been analyzed, taking into account the possibility of fuel change-over, from heavy fuel oil (HFO) to marine gasoil (MGO), approaching the ports. After characterizing the emissions during the switch from HFO to MGO, and taking into account the most frequent routes, we analyzed the specific case of the port of Naples. For this case-study we evaluated different scenarios of pollutants dispersion from ships arriving and departing, by using the Gaussian model ISC and considering in particular the effect on the coastal zone adjacent to the port. The results are represented graphically and provide valuable insights about the impact of marine traffic on air quality. Such information may be seen as useful tools for the improvement of maritime legislation on emissions, since emission of air pollutants from ships of large size is a key factor in air quality state in the surrounding areas to ports.

Keywords—Marine diesel engines, pollutant emission and dispersion, fuel change-over.

I. Introduction

MARITIME transport is a vital sector for the global economy since over 80% of freight is transported by ships [1]. That is also the most energy efficient and sustainable mode of transportation of goods from an environmental perspective, whereas CO_2 emissions required to carry a ton of freight per kilometer by sea are just 25% of those on road transport for the same distance, and only 1% of those provided by the air transport. Ports represents certainly a concentrated area of marine transport, so they are a major and growing source of pollution, and can impose significant health risks on nearby communities [2].

Emissions by ship traffic are becoming a significant source of air pollution in cities near major ports, also considering widespread actions world-wide to reduce emissions deriving from road transport sector during the last years [3]. Recent evaluations of global sulfur and nitrogen oxide emissions from international shipping report 6.49 Tg S and 6.87 Tg N, respectively[4]. Although ship emissions nowadays constitute only a small fraction of total global emissions, they could have relevant environmental influence on coastal areas near ports with heavy ship traffic as highlighted in studies for regions in Europe, Asia and North America [5],[6],[7],[8],[9],[10].

However, today ships represent a major unregulated source category. Furthermore, emissions from shipping activities are growing. Ship emissions will increase significantly in next 10–40 years owing to expanding international commerce [11]. As a result, it is necessary to understand atmospheric impacts of these emissions, especially on regional air quality.

This study evaluates the environmental impacts of ship emissions on the coastal zone nearby the port of Naples (South Italy) which is one of the busiest Italian port. In particular, the study covers emissions from large size two-stroke diesel engines. In order to calculate the polluting concentrations from ships and to assess the resulting air quality state in the area surrounding the port of Naples, this analysis was carried out by using the Gaussian model ISC. The modelling approach presented in this study can be considered as an important assessment tool for the local environmental authorities [12], since it can be applied in order to evaluate both the compliance of air quality with the limit values established by current legislation, and the influence of various scenarios of pollutant emission from arriving and sailing ships on the local air quality state.

II. Ship Emission and Fuel Change-Over

As widely known, the air emissions from marine traffic are regulated by Annex VI of MARPOL 73/78 (Marine Pollution), promulgated by the IMO in 1997 and subsequently amended. This regulation has been transposed in Europe by Directive 2005/33 / EC and in Italy by DM. 205 of 6 November 2007. In particular, these regulations govern SOx and NOx emissions which are present in the exhaust gases of internal combustion engines for ships of large size.

The limits on the emission of SOx are two, one more compelling relative to ports and SECA areas and one less compelling relative to all other areas. Ships that do not have systems to reduce SOx emissions, such as sea water scrubbers, must therefore be prepared using two different types of fuel, HFO and MDO (or MGO), the first for areas not subjected to emission control, the second for emission control areas and ports.

When a ship is going to pass through an emission control area, it has to start a fuel change over procedure, in time and in such a way that the engine will be burning MGO at the inlet of

Giuseppe Langella is with the Dipartimento di Ingegneria Industriale (DII), Università degli Studi di Napoli Federico II, 80125 ITALY (e-mail: giulange@unina.it).

Paolo Iodice is with the Dipartimento di Ingegneria Industriale (DII), Università degli Studi di Napoli Federico II, 80125 ITALY (e-mail: paolo.iodice@unina.it).

Amedeo Amoresano is with the Dipartimento di Ingegneria Industriale (DII), Università degli Studi di Napoli Federico II, 80125 ITALY (corresponding author, phone: +390817683273; fax: +390812394165; e-mail: amoresan@unina.it).

Adolfo Senatore is with the Dipartimento di Ingegneria Industriale (DII), Università degli Studi di Napoli Federico II, 80125 ITALY (e-mail: senatore@unina.it).

the area.

Fuel change-over must be performed carefully in order to avoid engine failure [13],[14]. There is not a universal procedure to do it but some items must be monitored:

- Fuel viscosity must be kept within the range 2-20 cSt;
- Fuel temperature variation rate at fuel pump inlet, should not exceed 2 ° C / minute.

A low value of viscosity can cause:

- reduced lubricant effectiveness, resulting in excessive wear and possible failure of the injection pump;
- fuel leaks from pumps, valves and piston rings, preventing the ship to reach the maximum power.

About the temperature of the fuel, typically, HFO is heated to about 150 °C and has to be changed to MGO, used at about 40 °C, so the temperature gap is about 110 ° C. Considering the allowed rate of change of 2 °C/minute, the process of replacing the fuel should last a minimum 55 minutes to carry out safely.

A quick change from HFO to MGO can cause overheating of MGO which causes a rapid loss of viscosity and gassing in the fuel system. Likewise, a too rapid a change from unheated MGO to HFO can lead to excessive cooling of HFO and therefore excessive viscosity to the injectors resulting in possible loss of power or shutdown. Therefore it is recommended to make the change of fuel with the engine at low power levels. The load, however, should not be too low otherwise the mixing time of HFO and MGO in the service system increases with a consequent risk of precipitation of asphaltenes, clogging of filters and therefore loss of power or engine failure. Once the propulsion system has stabilized with the use of new fuel and all the components are at normal operating temperatures, the propulsion plant can be brought back to the normal power level and the ship can proceed in port areas and in those subject to restrictions.

Another issue related to the use of low sulphur fuels, is the need to use a lubricating oil with different Base Number (BN). Because of the high acid levels on the cylinder liner when using heavy fuel oil with a 2% sulphur content, a lubricating oil with BN (or TBN) of about 70 is recommended. Such BN value ensures the neutralization of sulphuric acid (H2SO4) and sulphur trioxide formed by SO2 and SO3. In case of long-term operation with low sulphur fuels, it is recommended to switch to a lubricating oil with BN (or TBN) 40 or 50. It is generally recommended to use a lubricant with BN (or TBN) 40 50 or even for the short term operation if the sulphur content is less than 1%.

Before starting the changeover procedure form HFO (120° C) to MGO (room temperature) it is necessary to close the fuel heating lines until the output temperature at the fuel pumps decreases from 120° C to about 80 ° C; it takes about 2-3 hours. In order to protect the fuel injection system against rapid temperature changes, which can cause the bonding of the fuel valves, piston fuel pump and intake valve, the changeover is performed as follows:

- preheating of diesel fuel in the tank at about 50 ° C, if possible;
- interruption of steam to fuel preheating system;
- reduction of engine load at 3/4 load MCR (Maximum Continuous Rating);
- transition to MGO when the heavy fuel oil temperature in the preheater has dropped by about 25 °C but, in any case, not less than 75 °C.

So, in summary, in order to complete the fuel change-over, assuring that all HFO residue is consumed in the fuel system, the procedure must begin, in general, at least 3 hours before the SECA area and the fuel line should be started to be heated at least 2/3 hours before the start of procedure.

III. Case Study: the Port of Naples

The present work has been focused on pollutant emitted by merchant ships transiting in the port of Naples. Analysis domain (Fig.1) is a 10 km x 10 km area including the piers for large ships, the coastal area adjacent and the sea area interested by ship manoeuvres approaching the port.

The domain has been discretized with a 32x32 elements square grid and three main routes have been considered for ships entering and exiting the port. We used a Gaussian model ISC [15] to assess the production and dispersion of NOx, SOx and PM along the routes.

The meteorological data needed to run these simulations like wind speed, wind direction, temperature, humidity, etc., properly processed, were collected at the Naples airport weather station;

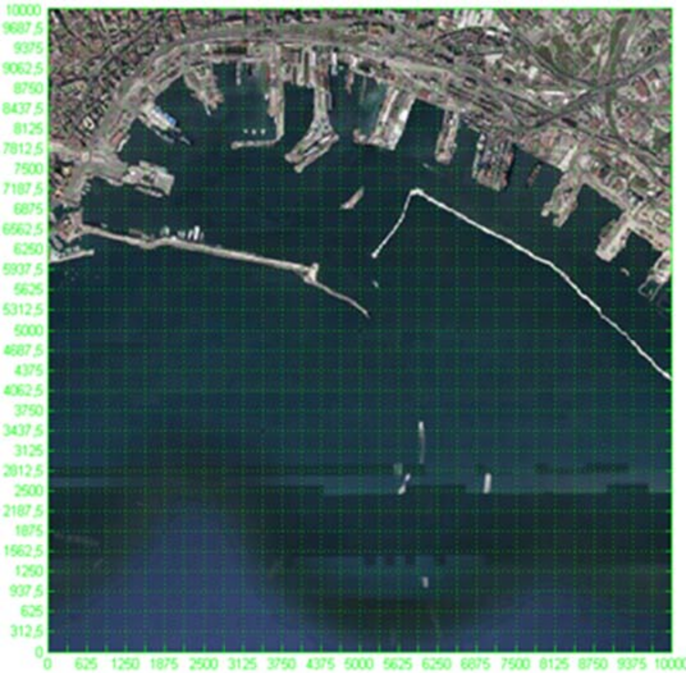

Fig. 1 The port of Naples and the analysis domain

However, in general the modelling approach adopted has certain inherent limitations, both concerning the evaluation of emissions and atmospheric dispersion. Gaussian dispersion modelling, in fact, does not allow for the detailed structure of buildings and obstacles, and in general for complex orography; the computed concentrations should be interpreted as spatially averaged values, while for instance, inside a street canyon the actual concentrations can vary substantially. On the other hand, the use of fairly simple dispersion model facilitates the evaluation of the hourly time series of meteorological and emission conditions for one year, which is required for the computation of statistical concentration parameters, defined in national health-based air quality guidelines.

This modelling approach, therefore, can be considered as an important assessment tool for the local environmental management, because it can be applied in order to assess the compliance of air quality with the guidelines and limit values (together with the measured concentrations) and the influence of various emission activities on air quality.

The chimneys of the vessels are not fixed but moving sources, so they have been simulated by a number (60, 20 for each main route) of fixed emission sources along the main routes, emitting the same total amount of NOx, SOx and PM produced by the ship traffic.

Starting from traffic data acquired by Maritime Coastal Authority of the Port of Naples, we consider about 10500 (2014 data) ships entering the port in a year. That means 30 ships entering and 30 ships leaving in a day.

The total emission of each pollutant emitted in the in a day area, i.e. for SOx, can be calculated by:

$$E_{SOx,d}[\frac{g}{day}] = E_{SOx}[\frac{g}{kWh}] \cdot P[kW] \cdot \frac{L\,[km]}{v\,[\frac{km}{h}]} \cdot n_s[\frac{1}{day}] \qquad (1)$$

where E_{SOx} is the emission rate of the ship engine, P is the actual power rate of the ship engine, L is the route length, v is the ship velocity along the route and n_s is the total number of ships crossing the area in a day (30 + 30 in the case study).

We considered that ships entering and leaving the port have the main engine at 25% of its power rate and a low velocity of about 5 miles per hour (9 km/h).

Spreading the total emission along the routes, each virtual source point emits continuously with the following rate:

$$E_{SOx,vsp}[\frac{g}{h}] = \frac{E_{SOx,d}[\frac{g}{day}]}{n_{vsp} \cdot 24[\frac{h}{day}]} \qquad (2)$$

Once known the emission rates of of NOx, SOx and PM, the average height and diameter of the chimneys, the average temperature and speed of the exhaust gas, the model provided the concentration maps of such pollutants above the entire domain (10 km x 10 km). Three cases have been examined, as reported:

1. HFO Case. Burning HFO (0,6% Sulphur content) during the whole approaching manoeuvre to the port; in this case the fuel changeover takes place within the port;
2. HFO-MGO Case. Gradual fuel switch from HFO to MGO during the whole approaching manoeuvre;
3. MGO Case. Burning MGO (0,15 Sulphur content) during the whole approaching manoeuvre to the port; in this case the fuel changeover takes place before the approaching manoeuvre.

For the second case, we assumed a linear variation of emission rates between the values assumed for HFO and MGO.

The gas atmospheric dispersion was analysed on maps characterized by receptors positioned at 2 m altitude. Under these conditions the application of the dispersion model on the observed area has determined the pollutant concentrations due to the arriving and sailing ships. The main results of the simulations provided by the model are shown in the maps of the following figures, in which it's possible to evaluate the average concentrations in µg/m^3 of NO_X at ground level in the form of iso-concentration lines for the examined cases.

Similar simulations have been provided by the model for the average concentrations of SO_X and PM in µg/m^3. By the analysis of results the HFO-MGO case gives better results than those expected across the coastal zone. This can be recognized by comparing Figure 5 and Figure 6. In Figure 5 it is reported the average concentration value of the specific pollutant above the whole domain, while Figure 6 reports the same parameter but only across the coastal zone.

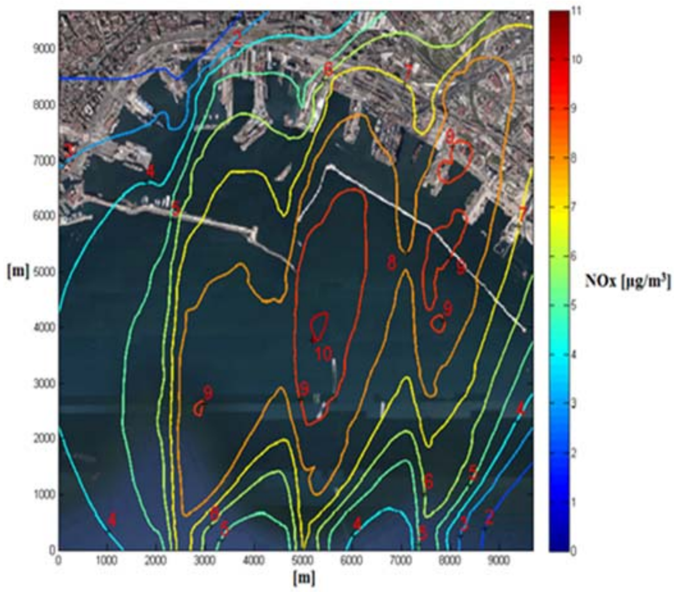

Fig. 2 NOx concentration. HFO Case

Across the coastal area, the average concentrations of NOx, SOx and PM for the HFO-MGO Case, does not have a linear

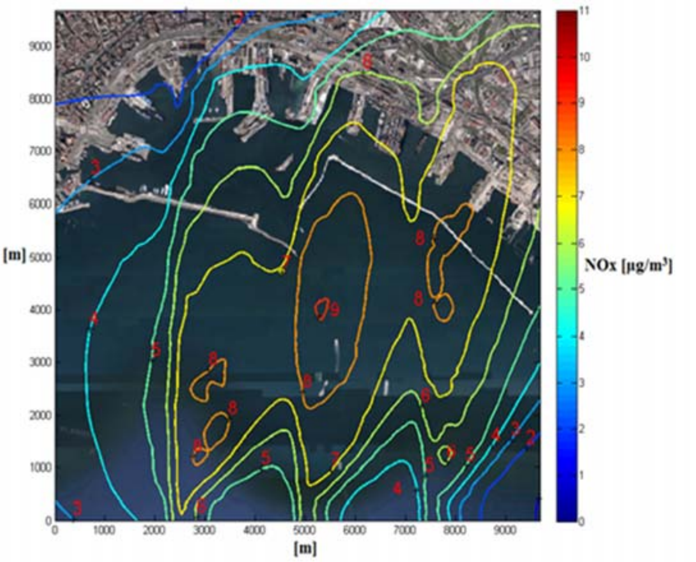

Fig. 3 NOx concentration. HFO-MGO Case

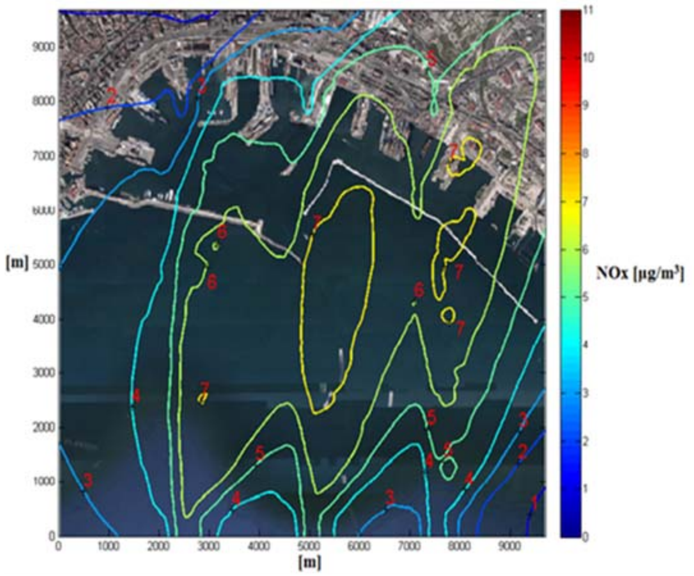

Fig. 4 NOx concentration. MGO Case

reduction as it was presumed and as it is for the whole domain. Therefore the change of the fuel during the entrance to the port involves a considerable benefit , greater than that expected, in terms of reducing the concentrations of SOx, NOx and PM.

IV. Conclusion

Ship traffic contributes significantly to pollutant emissions into the atmosphere. This issue is particularly important in the vicinity of coastal areas and especially in ports. The current regulations require that emissions in port areas are contained within narrower limits than the open sea. As seen, the standard can be met or by installing on board an emission abatement system (such as scrubbers), or by burning a "cleaner" fuel within those areas. The present study examined the latter case, by analyzing the problems related to the change-over of the

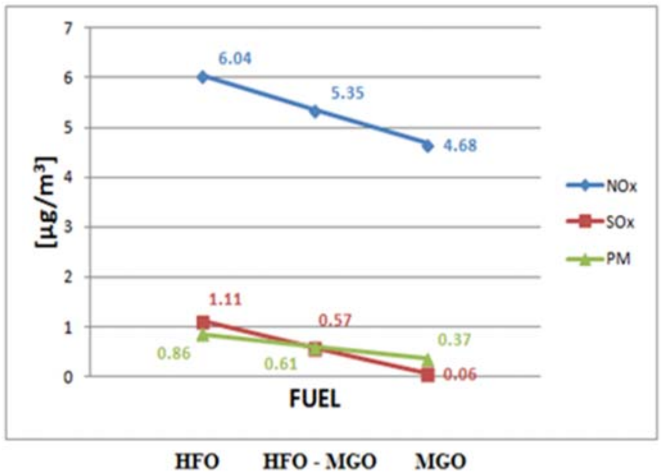

Fig. 5 Average pollutant concentration across the whole domain

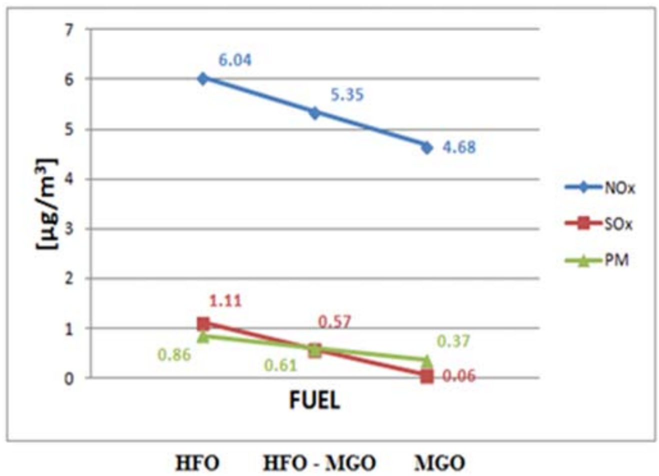

Fig. 6 Average pollutant concentration across the coastal area

fuel.

In particular we analyzed three different fuel change-over procedures, considering for each of them the ecological impact of vessel traffic on the port area. We examined the case study on the port of Naples, by calculating the production of SOx, NOx and PM connected to the traffic of merchant ships into and out of the harbor and evaluating their dispersion in the domain of inquiry and in particular in the coastal area.

The mode which operates fuel change-over during the approach to the port has shown environmental benefits higher than expected, especially with respect to the coastal area.

The methodology and all the results obtained in this study are important tools for studying air quality and to set up plausible remediation strategies in areas characterized by nonattainment of the limit values established by current legislation. Besides, the analysis method worked and the data collected can be of great help to the improvement of emission regulations on maritime traffic, especially for coastal areas.

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Amedeo Amoresano was born in Naples on October 27, 1963. He achieved his degree in Mechanical engineering at University of Naples Federico II in 1991. In 1994 he achieved his PhD in Thermomechanical and Energetic Systems discussing a thesis on the fluid dynamic of two phase systems. He is member of the ILASS Europe (Institute of Liquid and Spray Atomization Systems), AIVELA (Associazione Italiana Velocimetria Laser Doppler). In 1997 he became researcher at the University of Naples "Federico II" at DiME (Mechanical and Energetic Department). From 2001 he is Assistant Professor of Fluid Machinery and Energy Conversion Systems. From 1997 he is advisor for the Italian government on the Innovative Power Plant. In 2007 he was responsible of PRIN (National Research Program). Today he is Associated Professor at the Ateneo "Federico II" of the Naples University and responsible for it in the the EERA group. He is author of more of 100 publications in the field of two phase flow, Solar Energy, Combustion Diagnostic

Sensitivity analysis in optimal control of the Earth's climate system

Sergei A. Soldatenko and Rafael M. Yusupov

***Abstract*—**In this paper, we, in general terms, formulate the optimal control problem for the Earth climate system, and discuss sensitivity analysis methods applicable to estimate the impact of geoengineering (climate engineering) technologies on the climate system of our planet.

***Keywords*—**Climate change, climate engineering, optimal control, sensitivity analysis.

I. Introduction

Observed global climate change represents, apparently, one of the most significant environmental, social and economic challenges for the humanity in the XXI century. According to climate theory, and observational data and research findings, the global warming is a man-made phenomenon caused by the increase of concentrations of greenhouse gases (GHGs) such as carbon dioxide (CO_2) and methane (CH_4). Observations show that since the beginning of the 20-th century, the Earth's global average surface temperature has increased by almost 0.8 °C, with about two-thirds of the increase occurring since 1980. Presently, global warming is acknowledged by both the scientific community and majority of policymakers. The IPCC Fifth Assessment Report (AR5) [1] provides a distinct view of the up-to-date state of scientific knowledge regarding climate change. It is recognized, that mankind is causing global warming by anthropogenic CO_2 emissions generated by human activities through combustion of fossil fuel, mainly coal, oil, natural gas and wood. Due to the burning of fossil fuels and destruction of native forests, the concentration of carbon dioxide is increased from 280 to more than 400 parts per million (ppm) since the beginning of the so-called Industrial Revolution (~1750).

The most appropriate solution to reduce global warming is cutting down the anthropogenic emissions of GHGs. However, this is hardly achievable because the world economic growth and increasing population require more and more energy resources generating more and more GHG emissions. Carbon dioxide-free renewable energy resources and energy efficiency measures at the moment are not the alternative because they are very expensive and require long time to achieve tangible results. Realizing that, scientific community proposed several solutions, known as geoengineering, to stabilize the global climate (e.g. [2]-[9]). In general, geoengineering is divided on two main categories: carbon dioxide removal technologies, and solar radiation management. A number of geoengineering solutions are offered to date, however all of them introduce uncertainties and unexpected consequences that must be explored.

Climate engineering is purposeful process, i.e. the process having a special purpose and, therefore, outcome, which can be formulated in various ways and should be achieved somehow. In this regards, climate engineering is, in essence, the process of controlling the climate system that can be examined from the standpoint of control theory [10]-[14]. Within the framework of control theory, climate system is considered as a self-regulating feedback cybernetic system, in which the climate system itself represents control object, and the role of controller is given to human operators. The Earth's climate system (ECS) is a complex, interactive, nonlinear dynamical system consisting of the atmosphere, hydrosphere, cryosphere, lithosphere and biosphere. The state of the ECS at a given time and place with respect to variables such as temperature, barometric pressure, wind velocity, moisture, precipitations is known as the weather. Climate is usually defined as "average weather" or, in other words, as an ensemble of states traversed by the climate system over a sufficiently long period of time. Commonly, this period corresponds to ~30 years, as defined by the World Meteorological Organization. Since the ECS is a unique physical object with a large number of specific features [15]-[18], control of physical and dynamical process occurring in the ECS is an extremely complex and difficult problem. Synthesis of control systems of such natural objects represents a multidisciplinary research area which is developed on the ideas and methods of optimal control theory, dynamical systems theory, technical cybernetics, climate physics and dynamics, and other academic disciplines.

It is clear that the success of climate engineering strongly depends on the understanding of physics, chemistry and dynamics of climate processes as well as the availability of enabling technologies. However, we also need to know the ECS response to geoengineering. The estimation of the effectiveness of climate engineering approaches and the assessment of their impact on the climate system can be performed by the method of mathematical/numerical modeling

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S. A. Soldatenko is with the Institute of Informatics of the Russian Academy of Sciences, St. Petersburg 199178 (phone: 7-931-354-0598; e-mail: soldatenko@iias.spb.su).

R. M. Yusupov is with the ITMO University, St. Petersburg (e-mail: yusupov@iias.spb.su).

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since the ability of laboratory simulations of the ECS are, with rare exceptions, very limited. In general, synthesis of optimal control systems is based on a performance measure to be optimized and a mathematical model of the dynamical system to be controlled. It is very important that the performance of optimally controlled process depends on the accuracy, reliability and adequacy of the model used. Mathematical models of the ECS used in variety of applications are derived from a set of multidimensional nonlinear differential equations in partial derivatives, which are the equations of fluid dynamics and thermodynamics that describe dynamical, physical and chemical processes in the ECS. Thus, the ECS refers to a class of the so-called distributed parameter systems (e.g. [19]-[21]). Note that ECS models are mostly deterministic with a large phase space dimension [22]-[24]. Apparently, due to their complexity, equations that describe the evolution of the ECS cannot be solved analytically with an arbitrary set of initial conditions, but only numerically using various types of finite-dimensional approximations such, for example, as Galerkin projection or finite-difference methods.

In mathematical models, large-scale intervention in the ECS can be described parametrically, or, in other words, effects of geoengineering activities can be parameterized using conventional parameterization schemes of sub-grid physical processes, first of all schemes that describe radiative processes (short-wave solar radiation, long-wave emissions of the Earth) in the ECS. Thus, the impact of geoengineering methods can be estimated by studying the sensitivity of the ECS with respect to parameters that reflect the influence of external forcing on physical processes occurring in the ECS [25]-[28]. However, dynamical systems used to model the ECS, essentially nonlinear and under certain conditions they exhibit aperiodic oscillations, which are known as the phenomenon of deterministic chaos [29]. For such systems, the conventional methods of sensitivity analysis are not sufficiently effective, since calculated sensitivity functions are uninformative and inconclusive [30]-[33]. In this context, the exploration of sensitivity of nonlinear models of the ECS with respect to their parameters and external forcing require special consideration.

In this paper, we, in general terms, formulate the optimal control problem for the ECS and discuss sensitivity analysis approaches applicable to estimate the impact of geoengineering methods on the ECS.

II. Sensitivity Analysis of Climate Models

A. *Formal Model of the Earth Climate System*

Let us consider the continuous dynamical system, which formally describes the evolution of the ECS in the bounded space-time domain $\Omega_t = \Omega \times [0,\tau]$, where Ω is the space domain representing the earth's sphere and $[0,\tau]$ is the time interval:

$$\frac{\partial \varphi(r,t)}{\partial t} = L(\varphi(r,t), \lambda(r,t)),\ \varphi(r,0) = \varphi_0 . \qquad (1)$$

Here $\varphi \in Q(\Omega_t)$ is the state vector of a system, where $Q(\Omega_t)$ is the infinite real space of sufficiently smooth state functions satisfying some problem-specific boundary conditions at the boundary $\partial\Omega$ of the domain Ω; $r \in \Omega \subset \mathrm{R}^3$ is a vector of spatial variables; $t \in [0,\tau]$ is the time; L is a nonlinear operator that describes the dynamics, dissipation and external forcing of the system; $\lambda \in G(\Omega_t)$ is the system parameter vector, where $G(\Omega_t)$ is the domain of admissible values of the parameters; and φ_0 is the initial state estimate. In order to obtain a system with a finite number of degrees of freedom the equations (1) can be projected onto the subspace spanned by the orthogonal basis $\{\psi_i\}$ so that

$$\varphi(r,t) \approx \sum_{i=1}^{n} x_i(t)\psi(r) . \qquad (2)$$

Substituting (2) into (1) and using then the Galerkin method, we can obtain the dynamical system that is described by the set of ordinary differential equations (ODEs):

$$\dot{x}(t) = f(x,\alpha),\ t \in [0,\tau 0],\ x(0) = x_0 , \qquad (3)$$

where $x \in X \subseteq R^n$ is the state vector, $\alpha \in P \subseteq R^m$ is the vector of parameters, $f \in R^n$ is a nonlinear vector-function defined in the domain $X \times P \times [0,\tau]$, and x_0 is a given initial conditions. The finite-dimensional dynamical system (3) can be obtained by discretization in space of the equations (1).

Given the system state x_0 at time $t = 0$, we define the trajectory of x_0 under f to be the sequence of points $\{x_k\}$, $k \in Z_+$, such that $x_k = f^k(x_0)$, where f^k indicates the k-fold composition with itself, and $f^0(x) \equiv x_0$. Thus, given the vector-function f and the initial conditions x_0, equation (3) uniquely specifies the orbit of a dynamical system. For the ECS, the vector-function f is nonlinear. This nonlinearity arises from numerous feedbacks existed in a broad spectrum of oscillations and external forcing caused by natural and anthropogenic processes. Furthermore, nonlinear motions in the atmosphere, which is the most fast-oscillating component of the ECS, under certain conditions demonstrate a chaotic behavior. The ECS is a dissipative dynamical system, which possess a global attractor. This implies that there exists an absorbing set which is bounded set is the phase space that attracts any trajectory of the system. In other words, the norm of the solution of the model equations with arbitrary initial conditions, from a certain moment of time t^*, does not exceed some fixed value: $\|x(t)\| < c_0, t \geq t^*$. Usually, in many applications, the ECS evolution is considered on its attractor assuming that the system is ergodic.

Since the right-hand sides of climate system equations (3) include a large number of various parameters, the problem occurs of the system stability with respect to changes in the parameters. This problem is closely related to the parametric sensitivity analysis of dynamical systems.

B. *Conventional Methods of Sensitivity Analysis*

To analyze the sensitivity of the system with respect to parameter variations let us introduce a response function:

$$J(x,\alpha)=\int_0^{\tau} F(t;x,\alpha)dt\,, \qquad (4)$$

where F is a (nonlinear) function of state variables x and parameters α. Let α^0 be the unperturbed parameter vector, and x^0 be the state vector which is obtained by solving the equation (1) with $\alpha=\alpha^0$. The impact of parameter variations on the system performance is quantified by the gradient of the response function with respect to α around the unperturbed point (x^0,α^0):

$$\nabla_\alpha J\left(x^0,\alpha^0\right)=\left(\frac{dJ}{d\alpha_1},\ldots,\frac{dJ}{d\alpha_m}\right)^{\mathrm{T}}\Bigg|_{x^0,\alpha^0}. \qquad (5)$$

Particularly, the influence of parameter α_j is calculated as

$$\frac{dJ}{d\alpha_j}=\sum_{i=1}^{n}\frac{\partial J}{\partial x_i}\frac{\partial x_i}{\partial \alpha_j}+\frac{\partial J}{\partial \alpha_j}=\sum_{i=1}^{n}S_{ij}\frac{\partial J}{\partial x_i}+\frac{\partial J}{\partial \alpha_j}\,,$$

where $S_{ij}\equiv \partial x_i/\partial\alpha_j$ are the sensitivity coefficients [28]:

$$S_{ij}=\lim_{\delta\alpha_j\to 0}\left[\frac{x_i\left(\alpha_j+\delta\alpha_j\right)-x_i\left(\alpha_j\right)}{\delta\alpha_j}\right]$$

The first order sensitivity estimate for variations in the parameter α_j is given by

$$\frac{dJ(x,\alpha)}{d\alpha_j}\Bigg|_{x^0,\alpha_j^0}\approx\frac{J\left(x^0+\delta x;\alpha_1^0,\ldots,\alpha_j^0+\delta\alpha_j,\ldots,\alpha_m^0\right)-J\left(x^0,\alpha^0\right)}{\delta\alpha_j}.$$

This equation approximates the derivative of the first order; therefore the accuracy of approximation essentially depends on the choice of the parameter variation $\delta\alpha_j$. Generally, this selection is made arbitrarily bearing in mind that the value of $\delta\alpha_j$ is bounded below by the round-off error. Introducing the Gâteaux differential [26], the sensitivity analysis problem can be considered in the differential formulation that eliminates the need to set the value of $\delta\alpha$. The Gâteaux differential is defined as

$$\delta J\left(x^0,\alpha^0\right)=\int_0^{\tau}\left(\frac{\partial F}{\partial x}\bigg|_{x^0,\alpha^0}\cdot\delta x+\frac{\partial F}{\partial\alpha}\bigg|_{x^0,\alpha^0}\cdot\delta\alpha\right)dt\,, \qquad (6)$$

where δx is the variation in the state vector due to the variation in the parameter vector in the direction $\delta\alpha$. Linearizing the model (3) around the unperturbed trajectory $x^0(t)$, we obtain the following system of variational equations for calculating $\delta\alpha$:

$$\frac{\partial\delta x}{\partial t}=\frac{\partial f}{\partial x}\bigg|_{x^0,\alpha^0}\cdot\delta x+\frac{\partial f}{\partial\alpha}\bigg|_{x^0,\alpha^0}\cdot\delta\alpha,\ t\in[0,\tau],\ \delta x(0)=\delta x_0. \quad (7)$$

The model (6) is known as a tangent linear model. Variations δx obtained from the equation (7) are then used in the equation (6) for evaluating the Gâteaux differential. Since $\delta J\left(x^0,\alpha^0\right)=\left\langle\nabla_\alpha J,\delta\alpha\right\rangle$, where $\langle\cdot,\cdot\rangle$ is a scalar product, then the model sensitivity with respect to the variations in the parameters can be estimated by calculating the components of the gradient $\nabla_\alpha J$. However, this "one-at a time" method, in spite of its simplicity, requires significant computational resources if the number of model parameters is large. The use of adjoint equations allows us obtaining the required sensitivity estimates within a single computational experiment, since the gradient can be calculated as [26]:

$$\nabla_\alpha J\left(x^0,\alpha^0\right)=\int_0^{\tau}\left[\frac{\partial F}{\partial\alpha}\bigg|_{x^0,\alpha^0}-\left(\frac{\partial f}{\partial\alpha}\bigg|_{x^0,\alpha^0}\right)^{\mathrm{T}}\cdot x^*\right]dt\,, \qquad (8)$$

where the vector-valued function x^* is the solution of the adjoint model:

$$-\frac{\partial x^*}{\partial t}-\left(\frac{\partial f}{\partial x}\bigg|_{x^0,\alpha^0}\right)^{\mathrm{T}}\cdot x^*=-\frac{\partial F}{\partial x}\bigg|_{x^0,\alpha^0},\ t\in[0,\tau],\ x^*(\tau)=0\,. \quad (9)$$

The adjoint equations (9) are integrated backward in time.

As discussed in [28], general solutions of sensitivity equations for oscillatory nonlinear dynamical systems grow unbounded as time tends to infinity; therefore, sensitivity functions calculated by conventional approaches have a high degree of uncertainty. The reason is that nonlinear dynamical systems that exhibit chaotic behavior are very sensitive to its initial conditions. Thus, the solutions to the linearized Cauchy problem (3) grow exponentially $\left\|\delta x(t)\right\|\approx\left\|\delta x(0)\right\|e^{\lambda t}$, where $\lambda>0$ is the leading Lyapunov exponent. As a result, calculated sensitivity functions (coefficients) include a fairly large error, becoming uninformative and inconclusive [30-33].

C. Fluctuation-Dissipation Theorem

To estimate the ensemble-averaged response of the ECS to small external forcing Leith [34] has proposed using the fluctuation-dissipation theorem (FDT). According to the FDT, under certain assumptions, the response of stochastic dynamical system to infinitesimal external perturbations is described by the covariance matrix of the unperturbed system:

$$\left\langle\delta x(t)\right\rangle=\int_0^t C(\tau)C^{-1}(0)d\tau\cdot\delta\alpha^{ext}\,, \qquad (10)$$

where $\delta\alpha^{ext}$ is an external forcing, $\langle\cdot\rangle$ is the symbol means an ensemble average over realizations, and $C(\tau)$ is a τ–lagged covariance matrix of x. It is usually assumed that the system is close to thermal equilibrium and the probability density function of the unforced system is Gaussian. However, the climate system is characterized by a strong external forcing and dissipation, making it a system for which the standard assumptions of equilibrium statistical mechanics do not hold.

D. Sensitivity Analysis Based on Shadowing Property

In climate studies, the average values of sensitivity functions $\nabla_\alpha\left\langle J(\alpha)\right\rangle$ over a certain period of time are usually considered as one of the most important measures of sensitivity, where J is a generic objective function (4). However, the gradient of J with respect to α cannot be correctly estimated within the framework of conventional methods of sensitivity analysis since for chaotic systems it is observed that [30-33]

$$\nabla_\alpha\left\langle J(\alpha)\right\rangle\neq\left\langle\nabla_\alpha J(\alpha)\right\rangle.$$

This is because the integral

$$\mathcal{I} = \lim_{\tau\to\infty}\int_0^\tau \lim_{\delta\alpha\to 0}\left[\frac{J(\alpha+\delta\alpha)-J(\alpha)}{\delta\alpha}\right]dt \qquad (11)$$

does not possess uniform convergence and two limits ($\tau\to\infty$ и $\delta\alpha\to 0$) would not commute. The "shadowing" approach for estimating the system sensitivity to variations in its parameters suggested in [31] and [32] allows us to calculate correctly the average sensitivities $\langle\nabla_\alpha J(\alpha)\rangle$ and therefore to make a clear conclusion with respect to the system sensitivity to its parameters. This approach is based on the theory of pseudoorbit shadowing in dynamical systems [35], [36], which is one of the most rapidly developing components of the global theory of dynamical systems and classical theory of structural stability [37].

Naturally, pseudo- (or approximate-) trajectories arise due to the presence of round-off errors, method errors, and other errors in computer simulation of dynamical systems. Consequently, we will not get an exact trajectory of a system, but we can come very close to an exact solution and the resulting approximate solution will be a pseudotrajectory. The shadowing property (or pseudo orbit tracing property) means that, near an approximate trajectory, there exists the exact trajectory of the system considered, such that it lies uniformly close to a pseudotrajectory. The shadowing theory is well-developed for the hyperbolic dynamics, which is characterized by the presence of expanding and contracting directions for derivatives. The study of shadowing problem was originated by D.V. Anosov [38] and R. Bowen [39].

Let (*M*, dist) be a compact metric space and let $f: M\to M$ be a homeomorphism (a discrete dynamical system on *M*). A set of points $X=\{x_k : k\in\mathbb{Z}\}$ is a *d*-pseudotrajectory $(d>0)$ of f if

$$\mathrm{dist}\left(x_{k+1}, f(x_k)\right)<d,\ \ k\in\mathbb{Z}.$$

Here the notation $\mathrm{dist}(\ ,\ )$ denotes the distance in the phase space between two geometric objects within the brackets.

We say that f has the shadowing property if given $\varepsilon>0$ there is $d>0$ such that for any *d*-pseudotrajectory $X=\{x_k : k\in\mathbb{Z}\}$ there exists a corresponding trajectory $Y=\{y_k : k\in\mathbb{Z}\}$, which ε-traces *X*, i.e.

$$\mathrm{dist}\left(x_k, y_k\right)<\varepsilon,\ \ k\in\mathbb{Z}.$$

The shadowing lemma for discrete dynamical systems [35] states that for each $\varepsilon>0$, there exists $d>0$ such that each d-pseudotrajectory can be ε-shadowed. The definition of pseudotrajectory and shadowing lemma for flows (continuous dynamical systems) are more complicated than for discrete dynamical systems [35]. Let $\Phi^t:\mathbb{R}\times M\to M$ be a flow of a vector field *X* on *M*. A function $g:\mathbb{R}\to M$ is a d-pseudotrajectory of the dynamical system Φ^t if the inequalities

$$\mathrm{dist}\left(\Phi^t\left(t, g(\tau)\right), g(\tau+t)\right)<d$$

hold for any $t\in[-1,1]$ and $\tau\in\mathbb{R}$. The "continuous" shadowing lemma ensures that for the vector field *X* generating the flow Φ^t, the shadowing property holds in a small neighborhood of a compact hyperbolic set for dynamical system Φ^t. However, the shadowing problem for continuous dynamical systems requires reparameterization of shadowing trajectories. This is the case because for continuous dynamical systems close points of pseudotrajectory and true trajectory do not correspond to the same moments of time. A monotonically increasing homeomorphism $h:\mathbb{R}\to\mathbb{R}$ such that $h(0)=0$ is called a reparameterization and denoted by *Rep*. For $\varepsilon>0$, *Rep*(ε) is defined as follows [35]:

$$Rep(\varepsilon)=\left\{h\in Rep : \left|\frac{h(t_1)-h(t_2)}{t_1-t_2}-1\right|\le\varepsilon\right\} \text{ for any different } t_1, t_1\in\mathbb{R}.$$

To illustrate the applicability of this method, let us consider the continuous one parameter dynamical system $\dot{x}=f(x,\alpha)$ on the time interval $[0,\tau]$. The sensitivity analysis aims to estimate the sensitivity coefficient $S_\alpha=\partial x/\partial\alpha$. Let $x'(t)$ be the pseudo-orbit obtained by integration of the system equations with perturbed parameter $\alpha'=\alpha+\delta\alpha$, where $\delta\alpha$ is the variation in α. Since the pseudotrajectory $x'(t)$ stays uniformly close to the "true" orbit $x(t)$ obtained with unperturbed parameter α, the integral (11) is convergent and the average sensitivities $\langle\nabla_\alpha J(\alpha)\rangle$ can be easily estimated. Let us introduce the following transform $x'(x)=x+\delta x(x)$. It can be shown that $\delta f(x)=A\delta x(x)$, where $A=\left[-(\partial f/\partial x)+(d/dt)\right]$ is a "shadow" operator. Thus, to find a pseudo-orbit we need to solve the equation $\delta x=A^{-1}\delta f$, i.e. we must numerically invert the operator A for a given δf. To solve this problem, we decompose functions δx and δf into their constituent Lyapunov covariant vectors $\upsilon_1(x),\ldots,\upsilon_n(x)$:

$$\delta x(x)=\sum_{i=1}^n \psi_i(x)\upsilon_i(x),\quad \delta f(x)=\sum_{i=1}^n \varphi_i(x)\upsilon_i(x),$$

and then compute the Lyapunov exponents λ_i and vectors $\upsilon_1(x),\ldots,\upsilon_n(x)$. By executing the spectrum decomposition of δf along the trajectory $x(t)$ we can obtain $\varphi_i(x)$, $i=1,\ldots,n$ and then calculate the expansion coefficients $\psi_i(x)$, $i=1,\ldots,n$ using the equations

$$\frac{d\psi_i(x)}{dt}=\varphi_i(x)+\lambda_i\psi_i(x),\ i=1,\ldots,n,$$

which are derived from the dynamical system equations. The expansion coefficients $\psi_i(x)$ are used to compute δx along the trajectory. By averaging δx over the time interval $[0,\tau]$ we can obtain the desired sensitivity estimate $S_\alpha=\langle\delta x\rangle/\delta\alpha$.

III. Optimal Control Problem Statement

Let the controllable climate system on the time interval $t\in[0,\tau]\subset\mathbb{R}^+$ is described by the following set of ordinary differential equations

$$\dot{x} = f(x,u),\ x(0) = x_0, \qquad (12)$$

where $u \in U \subset \mathbb{R}^m$ is a control vector. Note that in (12) uncontrolled parameters are omitted. We assume that control parameters belong to a set of admissible controls $u \in \mathcal{U} \subset U$ and depend on the system state, i.e. $u(t) = g(t, x(t))$, which implies that equations (12) describe a closed-loop control system, representing the ECS. The set $\mathcal{U}$ is defined on the basis of physical and technical feasibility taking into account the specific properties of the ECS as a control object. Under certain conditions [40] the Cauchy problem (12) has a unique solution defined on a time interval in $\mathbb{R}^+$. However, we cannot a priori determine whether the ECS is controllable or not. Conclusion concerning controllability of the system can only be made by solving a specific problem.

The main objective of the problem considered is to synthesize the control law that ensures the achievement of the desired results. Since these results are expressed in terms of extremal problem, we are specifically interested in synthesis of an optimal control. Stabilization of the ECS around the reference phase space trajectory in order to weaken the global warming represents one of the most important problems relevant to the optimal control of climate processes. For this particular class of problems, the differential equations (12) are linearized with respect to the natural (reference) trajectory $x^0(t)$ caused by external natural unperturbed forcing $u^0(t)$:

$$\frac{d\delta x(t)}{dt} = \left.\frac{\partial f}{\partial x}\right|_{x^0,u^0} \cdot \delta x(t) + \left.\frac{\partial f}{\partial u}\right|_{x^0,u^0} \cdot \delta u(t),\quad \delta x(0) = 0, \qquad (13)$$

where δx is the perturbation of natural orbit of the ECS due to anthropogenic disturbances, δu is a control vector to ensure the stabilization of the ECS' trajectory, $\partial f/\partial x$ and $\partial f/\partial u$ are the Jacobian matrices. Naturally, we have to assume that

$$u = u^0 + \delta u,\ \ |\delta u| << |u^0|;\ x = x^0 + \delta x,\ \ |\delta x| << |x^0|.$$

The optimal control problem is formulated as follows:

Find the control vector

$$\delta u^*(t) \in \mathcal{U} \qquad (14)$$

generating the correction of the natural orbit

$$\delta x^*,\ \ x^0 + \delta x^* \in \mathcal{X} \subset X \qquad (15)$$

such that the performance index J is minimized:

$$\delta u^* = \arg\min_{\delta u \in \mathcal{U}} J(\delta x, \delta u), \qquad (16)$$

$$J = \frac{1}{2}\delta x^{\mathrm{T}}(\tau) G \delta x(\tau) + \frac{1}{2}\int_0^\tau \left[\delta x^{\mathrm{T}}(t) W \delta x(t) + \delta u^{\mathrm{T}}(t) Q \delta u(t)\right] dt \qquad (17)$$

where $W(t)$ and G are weighting positive semi-definite $n \times n$ matrices, normalizing the energy of the ECS per unit mass, $Q(t)$ is a weighting positive define $m \times m$ matrix, normalizing the energy of control actions per unit mass.

The stabilization problem is solved, given the fact that the system travels along its natural trajectory that is subject to external natural forcing. The control objective is to keep $\delta x(t)$ close to zero using control actions $\delta u(t)$. The information on the ECS state $x(t)$ is obtained by measurement devices and instruments followed by the processing using data assimilation procedure. The problem (14)-(16) includes a set X at which the functional J is defined, and constraints on the model state given by the subset $\mathcal{X}$ of a set X. The dynamic constraints are given by equations (13). There are several methods available for solving the problem (14)-(16): classical methods of the variational calculus, dynamical programming, the Pontryagin's maximum principle and other methods.

It is important to underline that the formulation of performance index (17) depends on the problem under consideration and there are no universal approaches how it can be specified.

IV. Application of sensitivity methods to the low order climate modeling system

In order to explore the applicability of geoengineering methods and technologies to climate manipulation, we have to choose the system parameters that can be considered as control variables. Then, sensitivity analysis, discussed in Section II, allows us to establish the reaction of the dynamical system onto changes in these control variables and to define their range of values. A wide spectrum of climate models of various complexity is used in simulation of the ECS. The exploration of the ECS requires considerable computational resources. For simple enough low dimensional models, the computational cost is minor and, for that reason, models of this class are widely applied as simple test instruments to emulate more complex systems such as the ECS. In this paper, to simulate the ECS we will use the following low order coupled nonlinear dynamical system, which is composed of fast (the "atmosphere") and slow (the "ocean") subsystems [41]:

$$\dot{x} = -y^2 - z^2 - ax + aF, \qquad (18)$$

$$\dot{y} = xy - cy - bxz + G + \alpha X, \qquad (19)$$

$$\dot{z} = xz - cz + bxy + \alpha Y, \qquad (20)$$

$$\dot{X} = -\omega Y - \beta y, \qquad (21)$$

$$\dot{Y} = \omega X - \beta z, \qquad (22)$$

where x is the intensity of the symmetric, globally averaged westerly wind current (equivalent to the meridional temperature gradient); y and z are the amplitudes of cosine and sine phases of a series of superposed large scale eddies, which transport heat poleward; F and G represent the thermal forcing terms due to the average north-south temperature contrast and the earth-sea temperature contrast, respectively. The term b represents displacement of the waves due to interaction with the westerly wind. The coefficient a, if less than 1, allows the westerly wind current to damp less rapidly than the waves. The time unit of t is estimated to be ten days.

This low order coupled system allows us to mimic the atmosphere-ocean system and therefore may serve as a key element of a theoretical and computational framework for the study of various aspects of ECS including geoengineering. Note that the atmospheric system described by equations (18)-(20) represents a chaotic Lorenz system [42], while the ocean system is a simple harmonic oscillator.

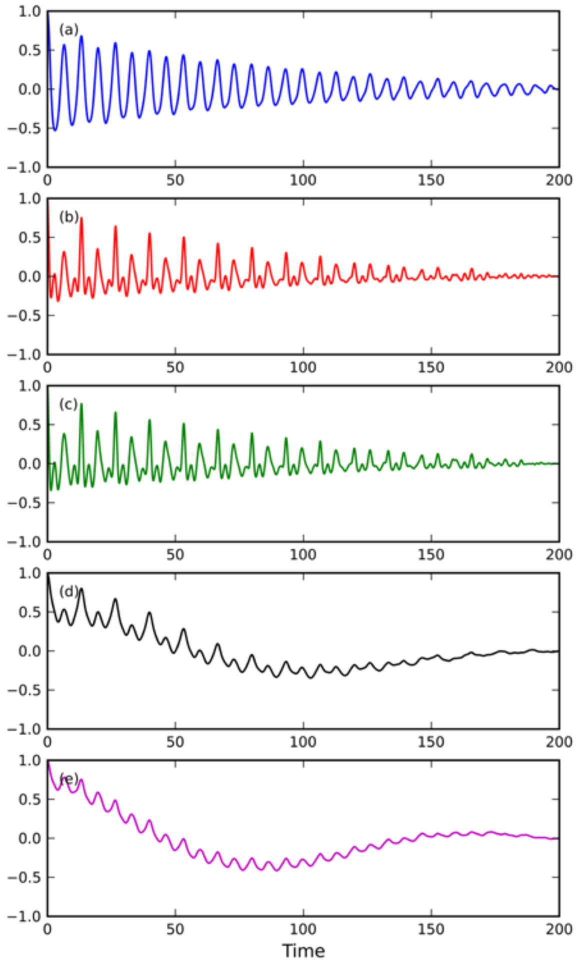

Fig. 1 Autocorrelation functions for variables *x* (a), *y* (b), *z* (c), *X* (d) and *Y* (e)

Let us consider some results of numerical experiments. Sensitivity theory shows that general solutions of sensitivity equations for oscillatory nonlinear dynamical systems grow unbounded as time tends to infinity; therefore, sensitivity functions calculated by conventional approaches have a high degree of uncertainty. The reason is that nonlinear dynamical systems that exhibit chaotic behavior are very sensitive to its initial conditions. Thus, the solutions to the linearized Cauchy problem (3) grow exponentially as $\|\delta x(t)\| \approx \|\delta x(0)\| e^{\lambda t}$, where $\lambda > 0$ is the leading Lyapunov exponent. As a result, calculated sensitivity coefficients contain a fairly large error. Application of conventional sensitivity analysis methods to the system (18)-(22) confirms this point: envelopes of calculated sensitivity functions (coefficients) grow in time while sensitivity coefficients themselves exhibit oscillating behavior. Thus, obtained sensitivity coefficients are inherently uninformative and misleading, and we cannot make a clear conclusion from them about system sensitivity to variations in the model parameters.

The FDT also cannot provide clear information about the system sensitivity with respect to its parameters. In Fig. 1 autocorrelation functions (ACFs) are presented for realizations of all dynamic variables of the model (18)-(22). Using ACFs we can easily calculate the system response functions. However, for oscillatory ACFs calculated response functions are uninformative.

Using the shadowing method allows us to calculate the average sensitivity functions (coefficients) that can be easily interpreted. However:

(1) The shadowing property of dynamical systems is a fundamental feature of hyperbolic systems, but most physical systems are non-hyperbolic. Despite the fact that much of shadowing theory has been developed for hyperbolic systems, there is evidence that non-hyperbolic attractors also have the shadowing property. In theory this property should be verified for each particular dynamical system, but this is more easily said than done.

(2) The applicability of the shadowing method for sensitivity analysis of modern climate models is a rather complicated problem since these models are quite complex and they contain numerous input parameters. Thus, further research and computational experiments are required. We are confident that by using the basic ideas of the shadowing method, it is possible to better understand the sensitivity analysis of climate models of various levels of complexity.

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SOLAR ASSISTED LNG ENERGY CONVERSION POWER PLANT (SALTEC)

ASAD SALEM
Weisberg Division of Engineering
Marshall University
Huntington, WV

Faisal Al-Balooshi
Department of Mechanical Engineering
Rochester Institute of Technology-Dubai
Rochester, NY

USA

salema@marshall.edu
fja2650@rit.edu

Abstract: The scope of research is to utilize LNG to increase the overall efficiency of Concentrated Solar Thermal Power generation systems (CSP). A cryogenic Rankine bottoming cycle is incorporated within the CSP power standard vapor Rankine cycle named as topping cycle. A thermodynamic analysis is carried out for the two different models, the first model is the simple cycle from the Concentrated Solar Power technology, and the second model which includes the cryogenic cycle named as combined cycle. The analysis showed the power out of the combined cycle can be increased by 66% of the original power produced by steam cycle, while, the efficiency of the combined cycle can be increased by 45% over the original simple cycle.

Key-Words:- Concentrated Solar Power; LNG; Propane cycle.

1 Introduction

The demand for Liquefied Natural Gas (LNG) in power generation is increasing and the trend is expected to further increase in the years to come. The major suppliers of natural gas are concentrated in the Middle East, Russia, and Australia. The transport of NG to major importing destinations like Japan, Europe, USA, etc. would be in the form of LNG. It is here that this SALTEC model would come into the picture [1].

The liquefied natural gas, which is mainly Methane-CH_4, is transported from exporting production terminals to the importing terminals by containers, pipelines or in liquid form. Cryogenic tanks are used to transport the liquid form of natural gas. The main benefit of liquefaction of natural gas is the reduction in volume of about $1/600^{th}$ of natural gas which results in more energy per volume. The burning of natural gas is much cleaner when compared to other fossil fuels [2].

One of the main concerns in the natural gas industry is the regasification of the LNG (Liquefied Natural Gas. The common techniques adapted by the industry have been a challenge to both power generation and receiving terminals of the LNG. The shipped gas is received via either onshore or offshore receiving terminals [3]. There are about 40 existing LNG exporting liquefaction terminals and about 100 existing LNG import or regasification terminals throughout the world. Countries are looking at more efficient ways to generate power and also looking at the best possible fuel it.

CSP is being widely commercialized. There are in excess of 7600 MW of generating capacity worldwide and the growth is expected to continue at a fast base. Concentrated-solar systems use mirrors with tracking systems to focus a large area of sunlight onto a small area. The concentrated solar energy is then used as heat or as a heat source for a conventional power plant. A parabolic trough consists of a linear parabolic reflector that concentrates light onto a receiver positioned along the reflector's focal line. The receiver is a tube positioned directly above the middle of the parabolic mirror and filled with a working fluid.

The goal of this work is to utilize LNG to increase the overall efficiency of Concentrated Solar Thermal Power generation systems (CSP). In order to achieve this goal, we are proposing to incorporate a cryogenic Rankine bottoming cycle within CSP power standard vapor Rankine cycle named as topping cycle.

The proposed SALTEC model (Figure1) uses concentrating solar thermal power (CSP) technology and has a capacity of 100 MW. The system consists of a parabolic trough, and natural gas (NG) booster, pumps, and a heat exchange, to exchange thermal energy to the topping Rankine cycle. The CSP system uses liquid metal as working fluid. The liquid metal heated to about 500^oC and then used to heat steam in a standard turbine generator. The liquid metal is then cooled before it is returned to the receiver tubes. During the availability of solar energy, the energy to heat the liquid metal is mainly solar; natural gas is used during night and when good quality of solar energy is inadequate. In this SALTEC model a cryogenic Rankine bottoming cycle are incorporated in order to enhance the efficiency and increase power generation. The topping cycle which uses concentrated thermal solar energy as an energy source to generate steam is coupled with the bottoming cycle working on the heat rejected from the topping cycle. The bottoming cycle uses propane as the working fluid to utilize the low grade heat energy rejected from the bottoming cycle. The heat rejected from the bottoming cycle is utilized in re-gasifying LNG to NG. This enables the SALTEC system to utilize the cold energy available in LNG as the heat sink.

One of the difficulties in maintaining CSPs is the harsh desert itself; while damaging sandstorms are relatively low, the troughs must be tilted away from wind if it reaches a certain speed. Keeping the troughs clean is essential to the operation of CSP systems. Due to the dusty conditions, about 2% degradation every day in performance is witnessed. Therefore, CSPs need to be cleaned daily. Currently, water is used both to cool the heat transfer fluid and clean the array. For a100 MW CSP system, it is estimated more than 10, 000 gallons of demineralized water are needed each day for cleaning across the whole site.

This proposed setup offers many benefits and advantages over the existing technology. First of all it results in power savings and also helps to cut the cost of maintaining a separate heat sink and air cooling unit for the system. The low temperature evaporated NG can be utilized in many ways to enhance the efficiency of the entire system. The low temperature NG can be used to cool the ambient air below the due-point temperature in a dehumidification process to produce demineralized water needed to clean the troughs. It is estimated for a 100 MW system and in weather conditions like Dubai-UAE, around 60,000 liters of demineralized water can be produced daily [4]. The cool and super dry air which resulted from the dehumidification process can be used to enhance the NG combustion which help to bring down the emissions the system. During operation the turbine-generators produce substantial amounts of heat, and unless it is dissipated, the generators are unable to operate at maximum efficiency. The low temperature super dry air, and the chilled water produced by heat exchange with the low temperature and saturated NG can both used to cool the generator as well as the turbine stator.

Salem and Hudiab [4&5] developed a 20,000 ton/day LNG re-gasification plant that is powered by a renewable energy source and to utilize the synergy of the LNG to enhance the efficiency of power generation systems and to couple the regasification plant with water desalination system. Concentrated solar energy was used to heat ambient air, this heated ambient air is, then, introduced to a humidification process. During this exchange of energy the evaporation of the LNG will take place and the saturated hot air is cooled below the dew point were fresh water is produced as a result of this energy exchange. The evaporated NG will go through additional heating, and then introduced o gas turbines along with cold dry air for combustion.

Salem et.al [6] developed a LNGTEC Power Plant which works by re-gasification LNG and incurp-orating bottoming cycles to generate power by recapturing the waste heat and utilizing the cold energy available in LNG to be used as a heat sink for the system. In the LNGTEC model, exhaust heat from the topping (Brayton) cycle is absorbed by a high temperature Rankine bottoming cycle which uses steam as the working medium. The waste heat rejected from bottoming Rankine cycle is absorbed by a low temperature Rankine bottoming cycle with propane as the working medium. The heat rejected from this low temperature Rankine cycle is used to re-gasify LNG to NG thus, this unit works as the heat sink for the LNGTEC. The cold energy available in NG after vaporization of LNG is further used to cool ambient air to the inlet of the Gas Turbine (GT) thereby fully utilizing the cold energy that was contained in LNG. The NG required for combustion is provided from this regasification and the excess is stored in a reservoir which can be used as city gas. The LNGTEC power plant is modeled by considering the mass & energy balances. The model is tested under various conditions of temperatures and relative humidity. The results show that there is a substantial increase in the efficiency of the GT which translated to the efficiency of the power plant as a result of cooling the air that is fed to the GT. The LNGTEC attained a maximum efficiency of 63% at 5^0C and 60% relative humidity. At ambient air intake the LNGTEC efficiency was found to be 52%. Another observation from the simulations was, as the inlet air temperature to the turbine decreases the air fuel ratio decreases. Thus, the power plant model together with LNG regasification and air cooling, utilizes most of the heat energy which is rejected from the primary Brayton cycle to convert to useful work which would else be rejected to the atmosphere along with the flue gasses which would harm our atmosphere. This LNGTEC model is a mix of various technologies and a proposal for the better utilization of energy to generate power.

Shi & Che [7] evaluated the performance of a combined cycle using low temperature waste heat recovery of LNG. A good performance with net electrical and exergy efficiency for a typical operating condition were achieved. While, Y. Hisazumi [8] proposed a high efficiency power generation system with an LNG vaporizing system.

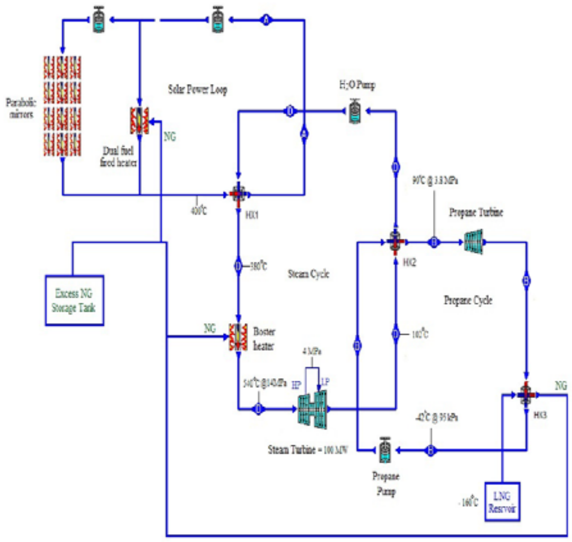

Figure 1: Schematic of proposed SALTEC model with LNG regasification and air cooling

2. Methodology

The main purpose of the proposed design is to maximize the output and efficiency of the CSP powered system and minimize any wasted energy. The proposed design covers four main areas, the solar energy loop, steam Rankine cycle, propane Rankine cycle, and the LNG vaporizing unit coupled to the design.

The LNG vaporizing unit is a very vital component in the system as it would facilitate the use of the cold energy available in LNG to be used as a heat sink for the propane cycle. The liquid metals in the concentrated solar power loop is heated using the parabolic mirrors and then it passes through heat exchanger (HX1) where the energy is transferred to the steam topping cycle. The heated steam is then expanded in the turbine of the steam cycle to produce power.

The spent steam from the turbine is then fed into another heat exchanger (HX2) where energy is transferred from the steam cycle to the propane bottoming cycle and thereby condensing the steam to water and heating up propane.

The heated propane is then expanded in the turbine of the propane cycle to produce energy. The spent propane exiting from the turbine is then fed into another heat exchanger (HX3) where energy is transferred from the spent propane to the LNG. This results in the vaporization of the LNG to NG, and condensation of propane to -160°C liquid form.

The NG is used to power the booster heater continuously, and also it powers the duel fuel fired heater in the back up time (for example, winter season, night time, cloudy days). The need for an expensive and inefficient thermal energy storage system (TES) is eliminated by using NG as an additional and supplementary energy source. It will, also, enables the proposed plant to counteract the unpredictability in system output due to unexpected shifts in the weather, extend the range of operation of the solar based system beyond daylight hours. The power produced throughout the day can be more efficiently harmonised with energy demand, therefore, enhancing the system operational envelope and increasing the value of the power as well as the total beneficial power output of the system at a given maximum turbine capacity.

The proposed model recovers almost all the energy carried away by the concentrated solar power with incorporation of the bottoming cycles. The LNG vaporization unit recovers the cold energy spent in liquefying NG to LNG by working as a condenser for propane cycle.

3. Analysis and Results

A thermodynamic analysis is carried out using two different models, The first model (option 1) is a CSP system coupled with a simple vapour Rankine cycle, and the second model is the proposed model with waste heat propane recovery cycle combined with the simple cycle as shown in Figure 1 (option II).

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Although the heat engine's efficiency increases with higher temperature, the overall efficiency of the CSP
system (Figure 2) does not increase steadily with the receiver's temperature. On the contrary, the receiver's efficiency is decreasing, as the amount of energy it cannot absorb grows by the fourth power as a function of temperature. Hence, there is a maximum reachable temperature.

Simple Cycle:

Overall Efficiency:

$$\eta = \frac{(W_{turbine} - W_{pump})}{(\dot{Q}_{HX} + \dot{Q}_{SH} + \dot{Q}_{pump})} \quad (1)$$

Another definition of efficiency is also possible:

$$\eta = \frac{(W_{turbine})}{(\dot{Q}_{HX} + \dot{Q}_{SH} + \dot{Q}_{pump})} \quad (2)$$

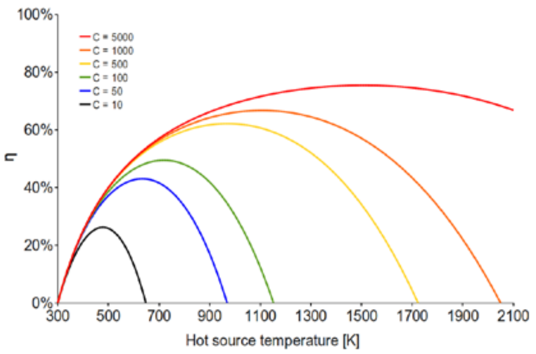


Figure 2: The overall efficiency of the CSP System [9]

The complete proposed combined cycle is shown in figure 1, where the heat energy transferred from solar loop to steam cycle via heat exchanger 1, to propane cycle via heat exchanger 2 and ends up with LNG vaporizing unit which is shown as heat exchanger 3 in the diagram.

$$\eta_{propane\ cycle} = \frac{(\dot{W}_{turbine} - W_{pump})}{(W_{pump})} \quad (3)$$

Overall combined cycle efficiency:

$$\eta = \frac{\left(\dot{W}_{t\,steam+propane} - \dot{W}_{p\,steam+propane}\right)}{(\dot{Q}_{HX} + \dot{Q}_{SH} + \dot{Q}_{pump})} \quad (4)$$

The power generation and efficiencies of both models where found using the above set of equations. The output power of the steam turbine was set at 100 MW due to the selection of the simple power plant (Option1) configuration. The combined cycle power measured as 166 MW, which is an increase of power by 66% of the original power produced by steam cycle as shown in Figure 3. Table 1 summarizes the analysis results for option1 and option II.

The bottoming propane cycle output and efficiency is limited to the heat recovered from the topping steam cycle, and most of the time it will remain approximately the same value as steam leaves the steam turbine in a saturation conditions. The efficiency of the combined cycle increases by 45% of the steam cycle efficiency as shown in Figure 3.

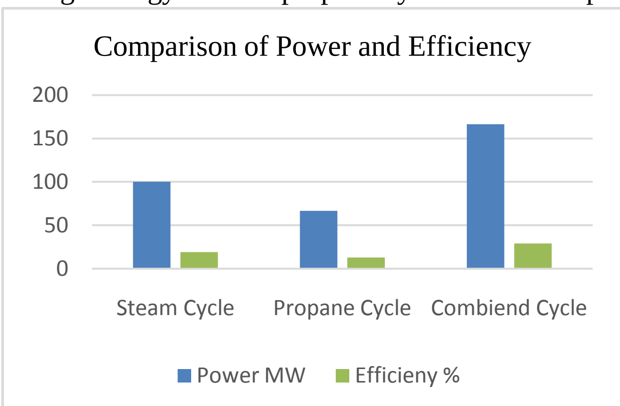
4. Conclusion and Future Work

From the analysis carried out in this study, it can be seen that the result of the proposed combined cycle has increased. The bottoming propane cycle together with LNG vaporization unit puts forward an efficient method of recovering the energy in the LNG power production.

Table 1: Thermodynamic Analysis of both Options

		T (°C)	P (kPa)	H (KJ/kg)	Work
Turbine 1	In (SH)	540	14000	3434.2	
	Out		4000		
Turbine 2	In				
	Out (Sat)	102	110	2678.0	
Total					100 MW
Condenser	In (Sat)	102	110	2678.0	
	Out (SC)	48	110	201.06	
Heat Out					385 MW
Heat Exch	In (SC)	48	14000	213.07	
	Out (SH)	380	14000	2918.3	421 MW
Super Heater	In (SH)	380	14000	2918.3	
	Out (SH)	540	14000	3434.2	80 MW
Propane Cycle					
Turbine 1	In	90	3800	337.98	
	Out	30	95	232.5	
Work-T1					66 MW
Condenser	In	30	95	232.5	
	Out	-42	95	-200.43	
Heat Out					321 MW
Heat Exch	In	-42	3800	-181.82	
	Out	90	3800	337.98	385 MW

The results of the proposed combine cycle design shown in F showed a maximum efficiency of 29% and a power output of 166 MW. It's clear that the rejected heat from the topping steam cycle has enough energy to run a propane cycle with an output



power of 66 MW.

Figure 3: Comparison of Power Output and Efficiency

The LNG vaporizing unit utilizes the maximum possible energy available from the system, In addition it helps in reducing the heat rejected to the environment which has a very adverse effect on the environment. Thus the proposed model has many advantages compared to the conventional setups.

The proposed model is a simple design of combined cycles which uses wasted heat as an energy input. More work will be done to enhance the design of the proposed combined cycle to reach commercialization level of production.

6 Nomenclature

HX	Heat Exchanger
η	Efficiency
W	Work
Q	Heat Transfer
CSP	Concentrated Solar Power
NG	Natural Gas
LNG	Liquefied Natural Gas

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Controlling electricity and heat flows in tertiary buildings

Gaetano Abbatantuono, Sergio Bruno, Massimo La Scala

***Abstract*—**Modern Smart Grids (SG) represent the new paradigm to plan and manage an efficient, secure and eco-friendly power system with multiple energy carriers. The shortage of traditional resources, the large diffusion of effective technologies based on Renewable Energy Sources (RES) and distributed generation and the liberalization of energy markets are transforming distribution systems into intelligent infrastructures in which every consumer can turn into a producer too. The need for an appropriate framework to forecast and organize RES generation, load demand, storage levels, market prices and many other issues necessary to realize a reliable power network leads to the Energy Hub (EH). In this paper we develop an EH model including electrical and thermal loads and supplies, RES generation and storage devices.. The core of the methodology is based on the formulation and solution of a non-linear discrete optimization problem aimed at optimizing input and output time trajectories for a set of combined power-generation and storage technologies. This model was applied for the demand response forecasting of an area of tertiary buildings but can be also fitted to a vast range of residential, commercial or industrial districts.

***Keywords*—**Energy hub; non linear discrete optimization; renewable energy sources; smart grids

I. Introduction

MODERN power distribution system requires always smarter and improved methodologies for its operational planning and management. The optimization of Distributed Generation (DG), Energy Storage Devices (ESD) and multiple, different energy carriers has to be matched with price inputs coming from liberalized energy markets and many other field data, in order to get the best economical results.

Energy Hub acts as an energy receiving, converting and storing unit in the consumer side; it includes a great variety of devices such as RES ,combined heat and power units (CHPs), transformers, power electronic equipments, heat exchangers, energy storage units etc. whose functioning is based on required output load.

Several studies have already underlined the qualities of EH approach and shown his mathematical and graphical architecture[1-4]. Figure 1 shows a single energy hub cluster consisting of converters and energy carriers coupling input and output ports.

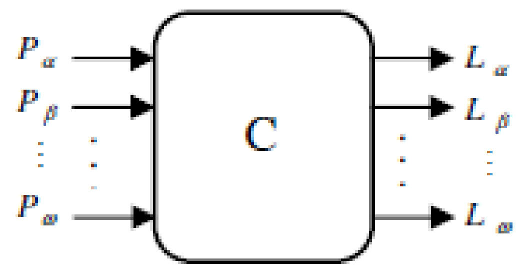

Fig. 1 - Power conversion through an Energy Hub

The coupling relation between the input and the output power vectors can be stated by the simple equation:

$$L = C * P \,. \qquad (1)$$

where P and L are the input vector and the output vector, respectively. Matrix C in this equation is the coupling matrix and its elements are coupling factors depending for example on technical or economical constraints.

Considering storage devices in energy hub modeling, equation (1) should be modified because they will affect the output energy flows. Equation (2) expresses the modified model of anenergy hub in which both converters and storage devices are considered:

$$L = C * P - S * E \,. \qquad (2)$$

where matrix S is the storage coupling matrix.

This formulation can be modified in many ways, according to the optimization scenery that has to be analyzed. In [5] the authors examine the influence of storage capacity and prediction horizon on the cost for the optimal multienergy supply of a single-family house and a network of three interconnected houses. In this case the EH concept is chosen to model the conversion and storage of the energy carriers (electricity, gas and heat); after that, a model predictive control is applied to reach the cost optimal control strategy of the available conversion and storage technologies. In [6] are provided very detailed optimization models of residential energy hubs which can be readily incorporated into automated decision making technologies in smart grids, and can be solved efficiently in a real-time frame to optimally control all major residential energy loads, storage and production components while properly considering the customer preferences and comfort level. Also, mathematical models of other components of a residential energy system including lighting, heating, and air-conditioning are developed, and generic models for solar PV panels and energy storage/generation devices are proposed. The developed mathematical models result in Mixed Integer Linear Programming (MILP) optimization problems with the objective functions of minimizing energy consumption, total cost of electricity and gas, emissions, peak load, and/or any combination of these objectives, while considering end-user preferences.

The scheduling problem of EH devices is well discussed in [7-9], where the authors present optimal scheduling of an extended energy hub for 24 hours under smart grid key drivers (RES, heat and electrical storages, demand response in deregulated market and so on). They propose an approach based on minimum cost solution can indicate when and how much of which carrier should be purchased, stored, interrupted or supplied by renewable resources to satisfy a commercial load.

One of the key points of the EH approach is that its flexibility can be extended for different problems [10-11]. Photovoltaic and storage without demand response (DR) are employed for an optimal power flow problem in multi carrier energy systems [12-13]. Plug in hybrid electric vehicle [14] are used as Electric Storage (ES) to smooth fluctuations of wind power without DR. Reference [15] investigates DR and ES influence in residential EH which is supplied with photovoltaic. Heat responsive demands are utilized in response to operation costs reduction with different biomasses in [16] and in response to simulated spot electricity price with Monte Carlo method in [17].

II. Energy Hub Model for Tertiary Buildings

The proposed model considers an Energy Hub that manages energy input and outputs in a system composed by two renewable and non programmable power generation sources (photovoltaic and wind), one programmable power source (a micro-turbine for cogeneration), electricity and heat storage facilities (BESS and pumping-hydro station) and a back-up heat generator (gas boiler). The EH will also take into account the possibility of shedding load whenever production costs are higher than load interruption costs.

The presence of multiple storage devices can be suitably treated through optimal control strategy. This depends on the fact that, whenever it must be decided which storage system has to be charged (or discharged), it is necessary to optimize resources across time. This influences the life-time of resources and their operation efficiency as well. Moreover, storage systems might have different response in time, due to their storable capacity and charge/discharge speeds. For such reasons, the methodology proposed is based on the forecasts of load and renewable generation over a reasonable observing time window. The whole system is represented through a double single-bus scheme as shown in fig.2;

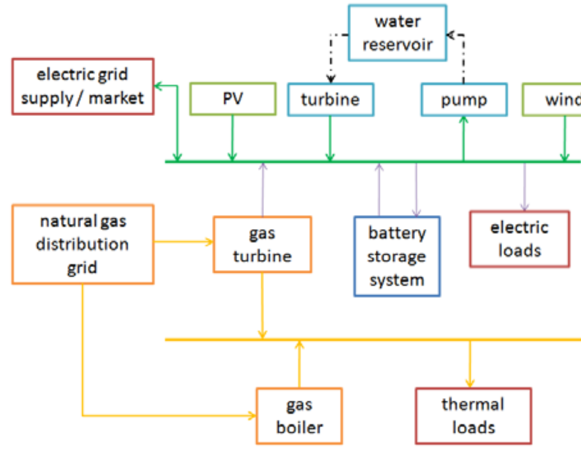

Fig. 2 - Schematic representation of developed supply system

Optimal dispatch of every resource is gained through the solution of a non-linear optimization problem aimed at minimizing overall cost of production, equipment wear and load shedding. Interruptible loads and interruption costs are also modeled, embedding the cost of unmet load into the cost analysis [18]. The optimality criteria adopted tend to assure sustainability of operating of the whole energy system in assuring the longest life-cycle and the maximum source utilization.

III. Mathematical Formulation

The optimization problem aims to minimize operative costs along a desired time window T. The cost function to be minimized is a non-linear function of power inputs and outputs:

$$\min_{p} \int_{t=0}^{T} \sum_{x} c_x\left(p_x(t)\right) \cdot \mathrm{d}t \qquad (3)$$

where x refers to the generic power source/demand, p_x is the instant injected or demanded power, and p is the vector of control variables collecting each p_x. In general functions c_x are non-linear.

The variables in the optimization process must cope with equality and inequality constraints. The first two constraints are given by the energy balancing equations which derive from a single bus representation of the electric network [19] and from the thermal energy balancing equation:

$$\begin{aligned} &\sum_{x} ke_x \cdot p_x(t) = 0 \\ &\sum_{x} kt_x \cdot p_x(t) = 0 \end{aligned} \qquad \forall t \qquad (4)$$

where coefficients ke_x and kt_x assume different values according to variables' weight in the energy balance of electric and thermal load, respectively.

Inequality constraints take into account technical limitations (for example technical minimum power output or maximum rated power, etc.):

$$p_{\min x} \leq p_x(t) \leq p_{\max x} \qquad \forall t, \forall x \qquad (5)$$

The presence of storage units requires the introduction of state variables referred to the quantity of energy stored. If *s* denotes the generic storage system, and q_s the energy stored, the following differential equations and constraints must be added to the formulation:

$$\dot{q}_s = f_s(\boldsymbol{p}(t), q_s(t)) \quad \forall s \qquad (6)$$

with $q_s(0) = Q_s^0$

and $$q_{\min s} \le q_s(t) \le q_{\max s} \quad \forall t, \forall s \qquad (7)$$

where Q_s^0 is the initial charge and f_s is a generally non-linear function that associates power inputs and outputs to energy stored, taking also into account conversion and standby losses. Inequality constraints (7) also have to consider the limitations on storing capability. The minimum charge level can be zero or, as for BESS, can be kept above a given threshold.

The optimization problem (3)-(7) can be solved through discretization, by assuming that along the generic time step *i*, state and control variables remain constant. The size of a single time step is denoted in the following as Δt, whereas n_T is the overall number of time steps. Consequently, the energy stored for system *s* at the end of time step *i*, is reformulated as follows:

$$Q_s^i = Q_s^0 + \sum_{k=1}^{i} \boldsymbol{F}_s \cdot \boldsymbol{P}^k \cdot \Delta t \quad \forall i, \forall s \qquad (8)$$

where $\boldsymbol{P}^k$ is the set of all power inputs and outputs during the time step *k*, Q_s^i is the energy stored at end of time step *i*, $\boldsymbol{F}_s$ is a constant matrix that, through efficiencies and the coupling relations due to the single bus assumption, associates stored energy to charging and discharging power. Under such hypothesis and through discretization the overall problem is therefore formulated as:

$$\min_{\boldsymbol{P}_x} \sum_{i=1}^{n_T} c_x(P_x^i) \qquad (9)$$

subject to (8) and to:

$$\left.\begin{aligned} \sum_x ke_x \cdot P_x^i = 0 \\ \sum_x kt_x \cdot P_x^i = 0 \end{aligned}\right. \quad \forall i \qquad (10)$$

$$p_{\min x} \le P_x^i \le p_{\max x} \quad \forall i, \forall x \qquad (11)$$

$$q_{\min s} \le Q_s^i \le q_{\max s} \quad \forall i, \forall s \qquad (12)$$

This formulation of the problem is characterized by a non linear objective function, whereas all equality and inequality constraints can be expressed under the linear form $\boldsymbol{A} \cdot \boldsymbol{x} \le \boldsymbol{b}$ through simple mathematical manipulations. The formulation of equations (8)-(12) is given in the following subsections.

A. *Grid supply*

The research center is in every case connected to electric distribution system for two basic reasons: to avoid any possible power failure buying energy from the grids and to keep the possibility to sell electric energy to the grid itself in those periods of time in which the cluster generation exceeds power demand. We also assume the facility as connected to the natural gas distribution system .

The hub should get price signals from the market using efficient and smart energy meters and then decide through an Energy Managemen System (EMS) if or when is less expensive to generate or buy power. If c_{gen} is the generic generation cost and c_{grid} is the market price, the algorithm will decide to:

- buy energy from the grid when $c_{gen} > c_{grid}$;
- sell energy to the grid when $c_{gen} < c_{grid}$

B. *RES generating units*

Since RES production is characterized by a negligible marginal price, the power produced by PV and wind is considered costless. This means that the optimizer will exploit renewable generation as much as possible. This power input, named $P_{PV,W}^i$, is constrained only by maximum available power output, as forecasted. It is assumed that whenever RES production exceeds load plus storage charging power, generation can be curtailed or dump loads can be activated. Equation (9) is given by

$$0 \le P_{PV,W}^i \le P_{PV,W\max}^i \qquad (13)$$

C. *Gas turbine and gas boiler*

For our optimization purpose, we also assume the presence of a gas turbine. Clearly, the formulation is general enough to be extended to any other generator. The power output of the gas turbine P_{GT} is limited in (9) considering the existence of technical-economical feasibility limits:

$$P_{GT}^i = \begin{cases} \overline{P}_{GT}^i & \text{if} \quad P_{GT\,min} \le \overline{P}_{GT}^i \le P_{GT\,max} \\ \text{otherwise } 0 \end{cases} \quad \forall i \qquad (14)$$

Costs have been associated to natural gas consumption and are modeled considering the non-linear dependence of efficiency with respect to electrical power output. Such dependence can be formulated by interpolating efficiency/power output data found in technical sheets. Having fixed the cost of natural gas c_{gas} and said η_{GT} the efficiency as a function of power output, cost in (9) is calculated as

$$c_{GT}(P_{GT}^i) = c_{gas} \cdot \eta_{GT}(P_{GT}^i) \cdot \Delta t \qquad (15)$$

The amount of thermal energy produced through co-generation is considered having a linear relation to the electric energy produced by the gas turbine. The boiler thermal output is limited by its rating

$$0 \le P_{Bt}^i \le P_{Bt\,max}^i \qquad (16)$$

whereas gas consumption costs are easily derived considering the efficiency η_{Bt} of the boiler.

D. Battery

The quantity of power exchanged with the BESS at each time step is here described with two variables: P_{CB}^{i} and P_{DB}^{i} that represent respectively BESS charging and discharging power. Each variable is limited by maximum charge and discharge power.

$$0 \le P_{CB}^{i} \le P_{CB\,max} \qquad (17)$$

$$0 \le P_{DB}^{i} \le P_{DB\,max} \qquad (18)$$

Charge-related inequality constraints are aimed at limiting the State Of Charge (SOC) of the battery. Roundtrip efficiency is adopted, accordingly to the assumption of a single bus model. Under these assumptions equations (8) and (12) are

$$Q_{B}^{i} = Q_{B}^{0} + \sum_{k=1}^{i}\left(\eta_{B\,rte} \cdot P_{CB}^{i} - P_{DB}^{i}\right)\cdot \Delta t \qquad (19)$$

$$q_{\min B} \le Q_{B}^{i} \le q_{\max B} \qquad (20)$$

where $\eta_{B\,rte}$ is the BESS round trip efficiency and Q_{B}^{0} is the initial charge of BESS.

Knowing the maximum rated BESS capacity $Q_{B\,max}$, the two charging limits in (20) can be derived having fixed a minimum and maximum SOC:

$$\begin{aligned} q_{\min B} &= \mathrm{SOC}_{\min} \cdot Q_{B\,max} \\ q_{\max B} &= \mathrm{SOC}_{\max} \cdot Q_{B\,max} \end{aligned} \qquad (21)$$

The maximum and minimum SOC can be set so that the lifespan of the battery is maximized and a good level of reserve is always kept during real time operation. Usually, minimum SOC sets an expected life number of cycles $n_{life\,cycles}$.

From these quantity, it is possible to calculate what is defined battery throughput and represents the expected value of energy that will be cycling through the battery, completing a charge/discharge cycle, before the battery has to be substituted. BESS life throughput can be conservatively evaluated as:

$$Q_{tpB} = Q_{B\,max} \cdot (1 - \mathrm{SOC}_{min}) \cdot n_{life\,cycles} \qquad (22)$$

The BESS throughput is used in order to asses wear costs of the battery. Wear cost is simply formulated as the ratio between the substitution cost of batteries and the total throughput. In the proposed model, wear cost is associated to the discharge phase only, so that battery charge has no cost and it is always maximizes. The cost function appearing in (9) is formulated as:

$$c_{B} = \frac{\text{BESS substitution cost}}{Q_{tpB}} \cdot P_{DB}^{i} \cdot \Delta t \qquad (23)$$

E. Water pumping storage system

Pumping storage system formulation is very similar to the one that is developed for BESS. Pumped and generated powers are limited by pump and hydroelectric turbine requirements:

$$0 \le P_{CW}^{i} \le P_{CW\,max} \qquad (24)$$

$$0 \le P_{DW}^{i} \le P_{DW\,max} \qquad (25)$$

In the pumping system, the role of the maximum SOC is played by the maximum level of water storable in the reservoir. Roundtrip efficiency is also introduced, taking into account losses in pump, pipes, and turbine. Constraints in (8) and (12) can be written as:

$$Q_{W}^{i} = Q_{W}^{0} + \sum_{k=1}^{i}\left(\eta_{W\,rte} \cdot P_{CW}^{i} - P_{DW}^{i}\right)\cdot \Delta t \qquad (26)$$

$$q_{\min W} \le Q_{W}^{i} \le q_{\max W} \qquad (27)$$

where $\eta_{W\,rte}$ is the pumping storage round trip efficiency and Q_{W}^{0} is the initial charge. Minimum and maximum storable energy is expressed as function of minimum and maximum volume of storable water and geodetic drop. As done before, a cost c_W, associated to the sole discharging phase. This cost can be estimated considering the average number of working hours before a major maintenance intervention is necessary.

F. Loads and interruptible loads

In the proposed methodology, chronological load curves (i.e. P_{L}^{i} at each time step i) are assumed as inputs of the optimization problem. It is also assumed that load is known at each time step and that a certain quantity of such load ($P_{L\,int}^{i}$) is characterized by lower interruption costs. The amount of load to be shed (P_{LS}) is a control variable limited by the actual total demand at a specific time. Interruption costs can vary according to the quantity, interruption duration, and typology of curtailed load. A simple, but not limiting, hypothesis consists in assuming that interruptible and firm loads have two different constant interruption costs. More complex, non-linear, relationships between the overall amount of load shedding and interruption costs, or time dependent formulation of interruption costs, can be assumed. It is clear that more complex formulations are credible only if a fine and detailed knowledge on the nature and distribution of loads is available. The problem formulation is general enough to adopt any interruption cost formulation.

$$0 \le P_{LS}^{i} \le P_{L}^{i} \qquad (28)$$

$$c_{LS} = \begin{cases} c_{L\,int} & \text{if } 0 \le P_{LS}^{i} \le P_{L\,int}^{i} \\ c_{L\,firm} & \text{if } P_{L\,int}^{i} \le P_{LS}^{i} \le P_{L}^{i} \end{cases} \qquad (29)$$

IV. Implementation and Test Results

The EH model has been applied to a real existing group of tertiary buildings, normally used for scientific research activities. The site includes eight different buildings on a total area of 3900 m^2. Each one of them has just one floor, except for a single building that also has an underground level.

The main gas boiler of the cluster has a total capacity of 21 MWt and is placed in a stand-alone building. The connection with main electric grid is assured by an electric station which feeds the entire facility (the described eight buildings plus another three floors office building).

In order to satisfy energy requests it's been decided to place PV strings on every building roof for a total maximum generation of 315 kWe and one wind turbine capable to generate up to 200 kWe. The hourly generating profiles of these RES devices has been estimated considering historical data about weather conditions (wind speed and solar radiation) above the area during the weeks that were chosen to simulate the optimization process [20].

The real electric and thermal loads data used for the optimization work refers to two different meteorological sceneries: one winter week in January 2013 and one summer week in July 2013. In the first timeframe, electric load goes from 50 kWt during night hours up to 250 kWt, while thermal load goes from 0 to a single peak of 13 MWt. During the summer period electric demand is very higher than before (from 200 to 470 kWe) while thermal needs are almost in the same range.

The cogeneration unit is provided with a gas turbine rated 200 kW. The minimum power output of the cogeneration unit is 30% of rated power, whereas efficiency is 0.6 of maximum efficiency at 25%, 0.9 at 50%, 1.0 at 75%, and 1.0 at 100%. It was also assumed that for each kWh of electricity produced by the gas turbine, 1.5 kWht are co-generated. Other efficiencies are η_{Brte} =0.8, $\eta_{W\,rte}$ =0.5. It was also assumed the presence of a 300 kWh BESS system with a charge/discharge time of 4 hours, a 50 kWh pumping storage unit with a charge/discharge time of 5 hours and a 10 MWt gas boiler.

For the BESS a 30% SOC_{min}, a total number of 2400 cycles before substitution and a wear cost of about 0.12 €/kWh were hypothesized. Other substitution costs are negligible with respect to BESS wear cost. Interruption costs were set at 0.5 €/kWh for interruptible and 2.5 €/kWh for firm loads. It was assumed a 0.70 €/Nm^3 gas cost, a 0.20 €/kW electricity buying cost and a 0.08 €/kW electricity selling price. Simulations were made considering a 24 hours timeframe, but this time period can be extended up to 168 hours for weekly forecasting and optimization.

A. *Winter Scenery*

The results of the discrete optimal control approach for a January day are shown in the following figures (4-8). RES production was so abundant that EH has no need to buy electric power from external grid. No load curtailments were experienced throughout the day; storage units are set at minimum capability at the starting hour of simulation (0 A.M.) and managed in such way that they are charged even in late afternoon, when renewable PV power is not available. This strategy allows to minimize the quantity of imported energy in the last hours of the day.

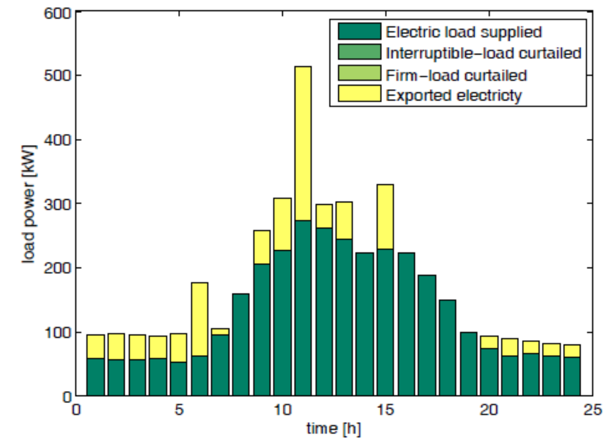

Fig. 4 - Electric power supplied/sold (winter scenery)

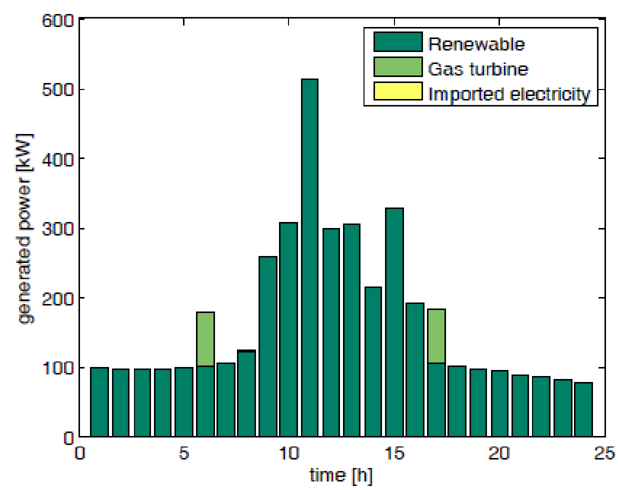

Fig. 5 - Generated electric power (winter scenery)

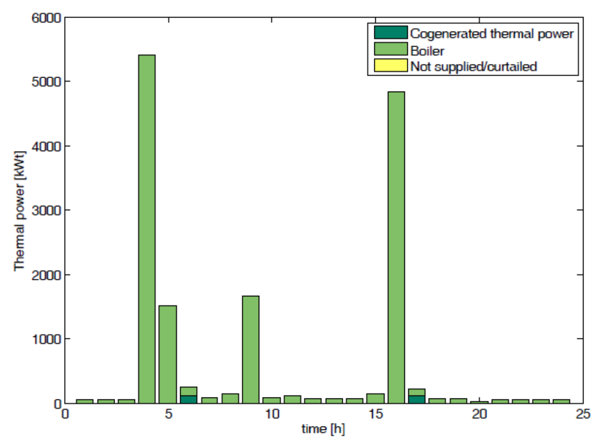

Fig. 6 – Generated thermal power (winter scenery)

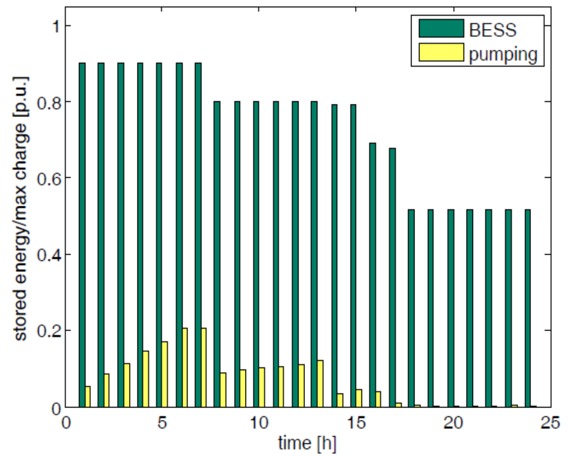

Fig. 7 - Stored energy (winter scenery)

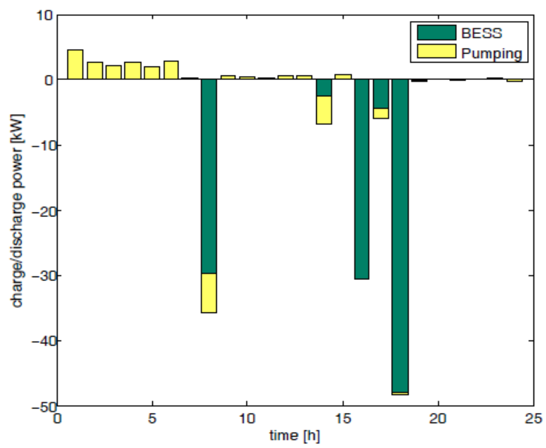

Fig. 8 - Charge/discharge power of storage systems (winter scenery)

Electric power is exported only during almost every hour of the day: this is due to the fact that the RES peak is higher than the sum of electric load and storage maximum charging power. It should be noted how pumping storage system is in charge for the most of the time and is used for discharge just in the same time slots when BESS system is also providing energy to the hub.

Thermal loads are mostly provided by gas boiler: cogeneration unit is kept running only for two hours. In this scenery a total economical profit of 25 € has been gained: this result is due to optimization and to the fact that relevant contribution to generation is given from renewable sources.

B. Summer Scenery

The second simulation concerns a summer day in July. In this case RES production was not enough to fulfil whole electric request. Still there isn't load curtailments but EH needs to buy electricity for the major part of the day and can sell electric power to the grid just from 10 a.m to 12 a.m.. The gas turbine was used much more than before for cogenerating purpose. In this case total costs (marginal cost plus wear costs) are equal to 790 €. Results are shown in following figures (9-13).

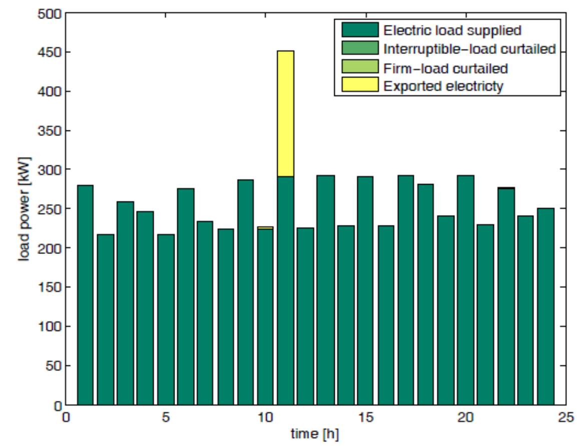

Fig.9- Electric power supplied/sold (summer scenery)

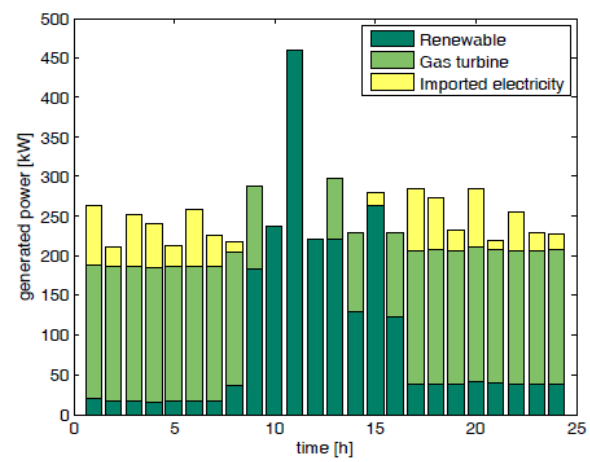

Fig. 10 - Generated electric power (summer scenery)

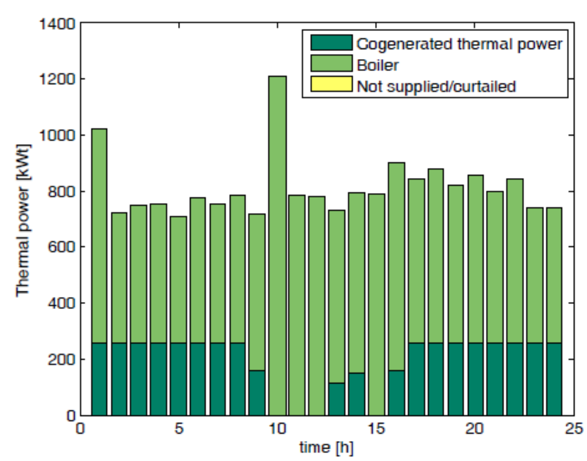

Fig. 11 - Generated thermal power (summer scenery)

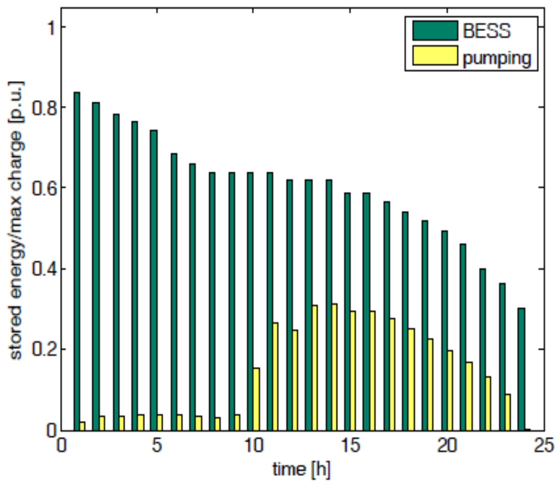

Fig. 12 - Stored energy (summer scenery)

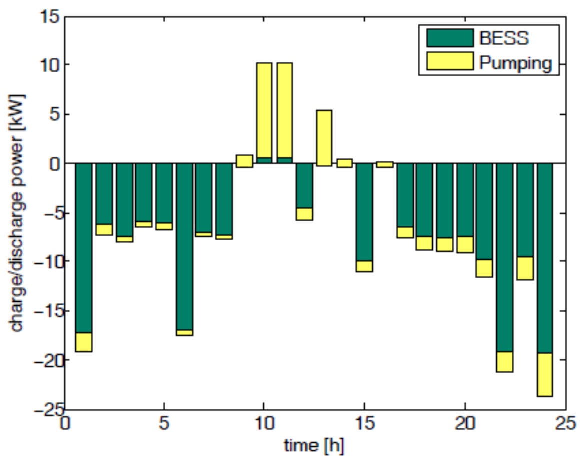

Fig. 13 - Charge/discharge power of storage systems (summer scenery)

V. CONCLUSIONS

Optimal energy management is the main goal for a modern and efficient Smart Grid. The Energy Hub approach could represent a perfect mean to reach this target and create a powerful and reliable interface between renewable generation, load forecasting and energy markets signals for multi-energy carriers. The availability of multiple dispatching options also requires the adoption of optimal control routines aimed to optimize overall technical and economical objectives.

In this paper, a methodology for the optimal dispatch of energy sources in an Energy Hub has been developed. The methodology has been modeled upon the energetic demand of tertiary buildings used for scientific research purposes, during both winter and summer periods. Results showed how this methodology could achieve remarkable economical and technical results.

The methodology presented is general enough to be implemented in any distributed network of enterprises in order to manage a wide range of energy sources and requests.

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Innovations in the loan process for SME segment. The findings and experience from the Czech and Slovak banking sectors.

J. Belás, J. Doležal, R. Hlawiczka

Abstract—Small and medium enterprises (SME) fulfill important tasks in the economic system, because they create jobs, contribute to the GDP and engage in other important activities within the socio-economic system. However, these companies have limited access to credit sources when compared to large enterprises. The aim of this paper was to introduce an innovated model of the loan process in relation to the segment of small and medium-sized enterprises (SMEs). In this context, the status and importance of open problems of internal rating models (IRM) of commercial banks in the process of SME credit risk management was analyzed.

Furthermore, we examined the opinions of experts on the IRM role in the loan process, the opinions of entrepreneurs on the commercial banks´ approach to their financing and their level of knowledge of the criteria used in the loan process.

In the final phase our own innovative methodological proposal for loan process management for SMEs was introduced. A model of the loan process has been designed to ensure optimization of credit decisions, a reasonable rate of effectiveness of lending practices and a reasonable rate of individual commercial banks approach to the SME segment. In this process there were used a qualitative and quantitative research methods. The results of our study have shown that the accuracy of the IRM in the banking sector is relatively low and optimal adjustment of the loan process can bring additional bank interest income.

Keywords—commercial banks, SME credit risk, internal rating models, loan processing.

I. Introduction

THE issue of credit risk for small and medium-sized enterprises (SME) is currently the actual theoretical field of research and practical applications in the process of credit risk management of commercial banks. [18]

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J. B. Author is with Tomas Bata University, Faculty of Management and Economics, Department of Enterprise Economics, Mostní 5139, 760 01 Zlín, Czech Republic (phone: +420576032410; e-mail: belas111@gmail.com)

J. D. Author is with Tomas Bata University, Faculty of Management and Economics, Department of Enterprise Economics, Mostní 5139, 760 01 Zlín, Czech Republic (e-mail: dolezal@fame.utb.cz)

R. H. Author is with Tomas Bata University, Faculty of Management and Economics, Department of Enterprise Economics, Mostní 5139, 760 01 Zlín, Czech Republic (e-mail: hlawiczka@fame.utb.cz)

Optimised management of the credit risk represents one of the most significant opportunity of a better financial performance for commercial banks.

The opinions of experts as for the banks´ interest in the SME segment differ substantially. Some authors declare that the SME financing is a very profitable segment for the commercial banks due to an intensified competition in other services to the corporate sector [11], [20]. Others state that commercial banks are not interested in SME financing because of the high risk and high supervision cost associated with this type of lending. [30]

The global financial crisis has caused considerable concerns as to what the banks' practices will be in relation to the loan financing of corporate sector. Current signals confirm that banks in the Czech Republic and Slovakia respond to their clients by tightened conditions. From the perspective of companies, very unfavorable situation can be occurred because of restricts situation of business community in relation to financing by bank instruments. [18]

The financing of SME segment is an issue of many discussions in the Czech Republic and Slovakia. Some signals confirm that banks have surpluses of cash which they cannot allocate efficiently. Using too harsh criteria for lending could be one of the reasons of this situation.

In this article, the role and the importance of internal rating models (IRM) in commercial bank lending process is examined. At the same time, we examined the opinion of entrepreneurs on the commercial banks´ approach to their financing and their level of knowledge of the criteria used in the loan process. Based on the qualitative and quantitative analysis, we present proposals to optimize the parameters of the credit policy of commercial banks. Given the importance of SMEs in the economic system and their persistent problem in the access to financial resources, it is important to address this issue.

II. Theoretical background.

Credit risk is the most important and the biggest risk for commercial banks because of its primary focus, which is the collection of deposits and lending. It can be defined as the risk that counterparty fails to meet its obligations, this means that it will not return borrowed money on time and in full amount. The height of credit risk is determined by the ability and

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willingness of counterparties to meet their commitments. [28], [5]

Small and medium sized companies face many disadvantages in comparison to large companies. Disadvantages in the area of financing are affected primarily of lesser availability options to finance especially for individual entrepreneurs. The main funding source is a self-financing. The most important borrowed capital is a bank loan and supplier credit. Relatively higher cost of lower volume of loan and higher risk of the lender do not make companies the most popular clients of banks' institutions. [1], [3], [4] Other disadvantage in the area represents the fact that small and medium sized companies do not have a high value of intangible and tangible fixed assets because of depreciation which could create the space for continuous reinvestment. [11]

Companies in SMEs segment are smaller, have higher information opacity, carry greater risk [22], and they are more dependent on a commercial credit and a bank loan. [14]

Internal models for credit risk assessment of the client represent significant and an important part of credit risk management in the commercial bank. These models showed of very dynamic development and have become an essential part of the assessment of credit risk in banks in the last period.

By using credit models, banks are now willing to provide more loans to SMEs due to easier default measurement of the borrowers. [9]

Internal rating systems are used to quantify the credit risk of individual borrowers. The credit rating score is assigned to individual borrowers by using different methods and indicates the level of credit quality. Validation of the rating system is closely linked with the validation of other risk parameters that are derived from the rating provisions of Internal Rating Based Approach of Basel II and which largely determine the amount of required equity. The aim of internal rating models is to estimate risk parameters such as Probability of Default (PD), Loss Given Default (LGD), Exposure at Default (EAD), and Effective Maturity (M) which are based on the quantitative and qualitative variables. [13]

Internal rating of the client is assigned by the bank according to its risk characteristics and risk characteristics of the contract which is based on specific rating criteria from which estimated PDs are derived. As part of the credit approval process, each borrower is assigned to a rating class where PD is assigned to individual class by the bank. The rating evaluation of the client determines its access to credit sources and their cost.

The major factors for SMEs default are classified according to high indebtedness, low profit, and low liquidity. [17] Profitability and bank relationship with a borrower has a inverse relationship for predicting the probability of default. The longer the relationship with bank the lowers the probability of default. Firm size and number of employees have inverse relationship with the probability of default. [22] In this context Psillaki, Tsolas, and Margaritis state that firm performance is negatively related with default. By using a DEA (Data Evolvement Analysis) they have also shown that firm efficiency has enough explanatory power to perform better than financial indicators. They have found that more efficient firms are less likely to fail. A 0.1 unit increase in the inefficiency score increases the probability of default on average by about 2 percent. They also find that a one percentage point fall in profitability increases the probability of default by about 1 percent. Similarly, a one percentage point fall in intangible assets is expected to increase the probability of default by about 0.25 percent. They also find that solvency ratio is a poor predictor of a company´s default. [29] The one interesting thing is that a lot of SMEs has tendency to extract money from the loan for their personal use, and the higher the number of money extraction for personal use the higher is the possibility of default. [22]

Agostino, Gagliardi and Trivieri [1] discovered that bank concentration seems to positively (and significantly) affect SMEs default risk when credit relationships are very concentrated; that is when firms borrow heavily from their main bank and have few credit relationships with other intermediaries. A possible interpretation being that, as debt from the main bank increases and firms do not resort to multiple banking connection (in the attempt to induce competition among lenders(, entrepreneurs might remain locked into lending relationships and so, become exposed to the potential negative effects of concentrated markets. The results suggest that a detrimental effect of bank market structure on firm default probability would emerge when lending relationships are highly concentrated, and it would be stronger the longer the duration of bank-firm relations.

In the theory, there are a lot of various approaches to credit risk management of SMEs.

The relationship between the bank and the client is determined by the credit techniques which can be characterized as the relationship lending or the transactional lending. The lending relationship is primarily based on a soft information (soft information: personal character, quality of management in the company, business strategy, ownership structure, etc.), that the bank acquires in direct contact with the client, in the local territory and on the base of the long-term observations of the company's performance. The transactional lending is based on hard data (the quantitative data) such as: return on equity, profitability, operating cash flow, interest coverage, liquidity, etc. [25] Ono and Uesugi [26] indicate that the relationship lending is common mainly in lending to small businesses, because small businesses typically rely on bank loans which represent a very important part of their financial needs, but also tend to be informational opaque. In this context Behr and Guttler state that relationship lending is more convenient to reduce the asymmetric information problem. [4] Ono and Uesugi [26] highlight the importance of the collateral, which is a common tool in the credit process between banks and small companies around the world. In the context of information asymmetry between banks and the credit applicant the collateral is seen as an option for reducing the problem of improper selection and moral hazard.

According to internal documents of the largest Slovak bank, within the rating process a following rule is applied: the smaller the company, the more important soft information is. Personality characteristics of the owner of the company are very important in relation to the financial performance of the company, which determines the level of credit risk in the SMEs segment. [6] Witzany [33] states that accounting data have low explanatory power in relation to SMEs and that an expert system is very important in the rating process. In this context, Altman, Sabato and Wilson reported that the use of non-financial variables of function of default annunciators significantly improves the quality (predictive power) of rating models. [2]

According to Beck, Demirguc-Kunt and Pería [2] who compared credit involvement of large international banks and local banks in the SME segment, soft information is evaluated by foreign banks as the less important one compared to domestic banks where they use more decentralized processes within credit approval and also work more with risk management. According to authors, foreign banks are placing more importance on the collateralization of loans and less importance on soft information.

The age of owner, the inquiry frequency of owners´ credit information for post-loan risk management and pro-loan approval purpose, and the proportion of overdue loans are the extreme significant variables which are valuable indicators in default risk estimate model. [32]

In this context Canton, Grilo, Monteagudo, and Zwan [10] find that the youngest and smallest SMEs have the worst perception of access to bank loans. Better accounting information, firm size and firm age found a positive relationship for getting bank loan.

In Fig. 1 is shown a diagram of a typical loan process, which is used in the Czech and Slovak commercial banking.

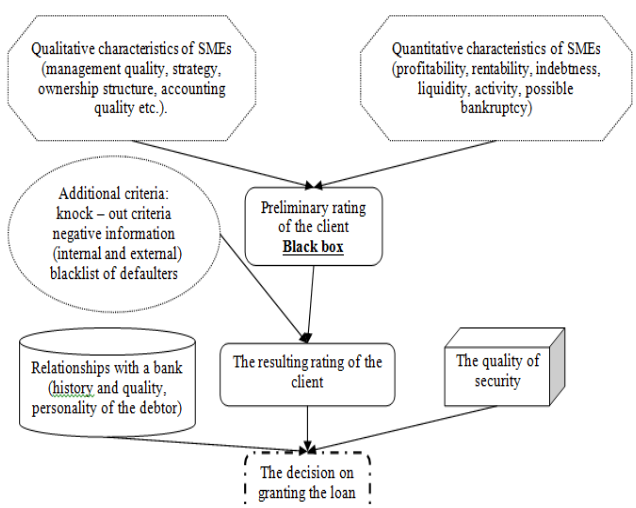

Fig. 1 Diagram of a typical loan process in relation to SMEs

In the document of the European Committee [16], 75% of the total number of large and medium-sized banks in the survey of McKinsey & Company state that the debt of SMEs is considered as the most important quantitative factor of internal rating; 50% of the banks give equal importance to indicators such as liquidity and profitability. From the wide range of possible quality factors around 50% of medium-sized and large banks give high or very high priority to the quality of management of SMEs and then there are other factors such as: the market situation of SMEs and its legal form. According to the document, qualitative factors have a greater influence on the rating in the case of larger SMEs and larger loans. In the case of start-up companies, the weight of these factors represents 60% on the overall rating. In the case of companies with a sufficiently long business history (minimum 2 years) the weight of qualitative indicators is significantly lower and represents only 20-30% of the overall rating.

III. Objectives, Methodology and Data

The aim of this article was to present an innovative model of lending process toward the segment of small and medium sized companies. In this context, the status, importance and shortcomings of internal rating models of commercial banks in relation to credit risk measurements have been analyzed. At the same time, opinions of entrepreneurs in selected regions of the Czech Republic and Slovakia were examined.

Our own methodological proposal for the management of the lending process have been presented.

Criticism of IRM is focused on various aspects of their operations. In practice, the perfect rating systems do not exist [13]; their explanatory power in relation to the assessment of the quality of the client and its risk profile is significantly limited. [15]

Quality and relevance ability of internal rating systems are different. [12] Current models to measure credit risk are not perfect and do not give quite reliable results. In this context, Kuběnka, Králová indicate that the inaccuracy of the model in predicting of financial distress is 27.5% and the success rate to classify a financially healthy company to the group of prosperous ones represents 89.2%. [21]

According to the results of our research [7] the accuracy and quality of IRM has been experimentally verified. This model is used by a significant Czech bank and it does not have sufficient quality because it evaluates an excellent company as a negative one and in the same time, it evaluates various negative changes in the financial performance of the company by the same rating. The model is less sensitive to significant changes of important financial indicators that determine the loan repayment which is especially evident when assessing the profitability of different variants, respectively loss-making firms.

The findings obtained from the sources have inspired us to formulate the following four scientific hypotheses:

H1: IRM have a dominant position in the process of granting the loan to the client. If the result of the client’s rating is negative the bank does not give him a credit loan.

H2: IRM have a limited accuracy. According to the credit specialists' evaluation the average value of the accuracy of the IRM in the Czech banking sector is below 80%.

H3: Entrepreneurs of the SME segment in the Czech Republic and Slovakia do not assess the commercial banks approach to their financing positively. Less than 50% of them think banks accept their needs and behave appropriately towards them.

H4: The level of knowledge of the lending criteria by Czech and Slovak entrepreneurs is low. Less than 60% of them stated they know the lending criteria of commercial banks.

H5: Optimization of the process of granting the loan leads to a higher credit acceptance of SME by at least 20%.

In our research the process was as follows.

Through a structured interviews there was investigated the role of IRM in the credit policy of commercial banks and what is their accuracy degree. The data was obtained from the bank managers and credit specialists. As a part of this research there was contacted 10 banking executives and credit specialists working in the Czech corporate banking sector, and 10 managers and specialists who work in Slovakian banks. In the Czech Republic there were members of staff from the three largest banks who have participated in this research, and in Slovakia there were workers of the 3 medium-sized and of the 7 big banks who have participated in this research.

The samples of the respondents could be considered as representative for the following reasons: employees from the leading commercial banks in the Czech Republic and Slovakia have participated in this research, banks apply a unified credit policy, so if a representative of the bank has indicated a certain fact that applies throughout the entire bank, which eliminates the need to have a large number of respondents. In both countries these banks have a market share for loans greater than 70%. An important factor is also the fact that banks consider their IRM as a business confidentiality, which they do not inform the public about, so any quantitative search with a large sample of respondents is excluded.

Research on basic determinant of the financial stability of SMEs was carried out in 2013 in selected regions of the Czech Republic and Slovakia through a questionnaire survey. In the Zlin region data from 180 SME was collected and in the Zilina region data from 164 SME was obtained in total. Data for companies was provided by their owners.

Zlin region has an area of 3.964 square km, has an about 600.000 inhabitants, GDP per capita is around 11.720 EUR; unemployment in 2012 was about 8%.

Zilina region has an area of 6.800 square km with total population of 700.000 and the population density of 102 inhabitants per square kilometer. Unemployment in 2011 was raised to 11.91%. GDP per capita in the Zilina region was 10.794 EUR in 2011.

In our survey in the Zlin region (CR) was the largest share of SME, which undertook the business activities (35%), followed by manufacturing firms (29%), construction companies (12%), transport companies (4%) and agricultural holdings (3%). Rest was presented by firms, which undertook in other sectors.

In Zilina region (SR), the structure of companies was as follows: in manufacturing and production was involved 17%, in trade activities 21%, 17% were construction companies, transport enterprises 6%, only 1% was presented with agricultural holdings and the largest share was formed by companies, which undertook in other sectors (38%).

The associations in contingency tables were analyzed by Pearson statistics for count data. Calculations have been performed in statistical packages XL Statistics and R. There were also used the tools of descriptive statistics: percentages, averages and indexes.

In the process of creation of the upgraded model of the loan process, the loan documents of three commercial banks have been examined and two IRMs which were used by commercial banks in the Czech Republic have been analyzed.

IV. Results and Discussion

The results of the survey on status and importance of IRM in the credit policy of the Czech and Slovak banks are listed in Table 1. These results were found by the structured interviews method.

TABLE I
THE IMPORTANCE OF IRM USED IN THE PROCESS OF GRANTING A LOAN

What importance the results of the rating of corporate client have in the process of granting a loan?	CR	SR	Index CR/ SR
1. dominant – when a client fails rating, the loan is not granted in any case.	0	8	0.000
2. substantial – if the client fails rating, the possibility of granting a loan is very limited	8	2	4.000
3. important – rating of the client is considered to be an important part of the loan process, but the quality of security equipment or quality of relationships with the client, or other factors may change the rating results.	2	0	-
4. have no relevance		0	-
5. other evaluation		0	-

The majority of the bank managers and loan specialists in Slovakia have confirmed that the rating has a dominant position in the credit process, because if the client fails rating, the loan is not provided by this bank in any case.

Our study suggests that the Czech banks probably apply a different approach (which was also confirmed by the value of the relevant index), because the vast majority of the respondents stated that the rating outcome has substantial importance in the process of granting a loan. As a part of structured interviews there was emerged that the majority of the Czech banks realizes the importance of a correct perception of economic indicators of companies and also some space for improvement in their own staffing, on which they want to focus in their future activities. These banks consider improving the quality of the knowledge of an own employees in the field of financial analysis not only as an important prerequisite for the proper credit evaluation of the client, but also as a potential growth in loan transactions.

The Hypothesis 1 was confirmed in Slovakia and it was partially established in the Czech Republic.

In Table 2 are presented the results of research in the context of the accuracy of the IRM.

TABLE II
THE ACCURACY OF THE IRM USED

What is the accuracy of the internal models at your bank?	CR	SR	Index CR/SR
1. 81% and more	4	7	0.571
2. from 70 to 80%	0	3	0.000
3. from 50 to 69%	0	0	-
4. less than 50%	0	0	-
5. I do not know	6	0	-

In Slovakia most of our respondents agreed that these models were very accurate, because most of them thought that their accuracy was higher than 80%. In the Czech Republic 4 respondents have stated that the accuracy of these models was higher than 80%, however most of them could not answer on the corresponding question.

The Hypothesis 2 was not confirmed.

Table 3 presents the research results in the field of the commercial banks approach to SME financing.

TABLE III
THE COMMERCIAL BANKS APPROACH TO SME FINANCING

How do you assess the commercial banks approach to SME financing?	CR	SR	p-value
1. Banks accept our needs and provide full assistance	8	5	0.4965
2. Banks behave appropriately	70/ 43*	33/ 23*	***0.0001***
3. Banks behave unhelpfully	16	23	0.1336
4. Banks use too harsh criteria for lending	47	61	***0.0271***
5. I cannot judge	39	42	0.3898

* the share of the first two answers (in %)

The Hypothesis 3 was confirmed. Only 43% of entrepreneurs in the Czech Republic and 23% of entrepreneurs in Slovakia stated banks accept their needs or behave appropriately. We also found statistically significant differences between the entrepreneurs of the Zlin and Zilina regions in some answers. The entrepreneurs from the Zlin region declared more often than their counterparts from the Zilina region that banks behave appropriately and less often that banks use too harsh criteria for lending.

Financial crisis and gradual recovery of economies in the European Economic Community brought deterioration of the business environment.

In our research [8] the most important business risks which were perceived by entrepreneurs in the Czech Republic and Slovakia were as follows: market, financial and personnel risks. Market risk was identified as a key risk by the largest number of entrepreneurs, that means 79.44% of them in the Czech Republic and 80.49% in Slovakia. Average value of market risk which was identified by entrepreneurs in the Czech Republic was 56.00% and 51.30% in Slovakia. Amount of adjusted average value (average of whole data set) in the Czech Republic was 44.49% and 41.29% in Slovakia. Average performance decrease is represented by 15.80% in the Czech Republic (weighted average of upper values of individual intervals). Average performance decrease was 18.78% in Slovakia.

Table 4 then contains the results of the survey as for the entrepreneurs´ knowledge of lending criteria of banks.

TABLE IV
THE LEVEL OF KNOWLEDGE OF THE BANKS´ LENDING CRITERIA

Do you know the criteria used to rate clients in the lending process of banks?	CR	SR	p-value
1. Yes	79/ 44*	5/ 34*	0.0488
2. No	26	29	0.4122
3. I have some idea	75	80	0.1868

* the share of the first two answers (in %)

Hypothesis 4 was confirmed. The level of knowledge of the banks´ criteria in lending process was lower than 60% among the surveyed entrepreneurs.

During the structured interviews with experts we also confirmed our assumption that IRM represent an important part of the loan process and are thus a trade secret of commercial banks.

In this context, for example Behr and Güttler [4] see the solution on companies' part that understood banks' approach within the evaluation of creditworthiness and also they were able to evaluate their expected probability of default (PD) using rating model. This fact could help firms to understand their position from the bank's position. Also this fact would lead to provide necessary document about themselves for better assessment of their creditworthiness and also it would lead to the possibility of further negotiations between the bank and the company about credit conditions. According to author, knowledge of own PD also allows to increase transparency in credit process. As well as it allows potential use for searching of external funding sources. If SMEs have knowledge about their creditworthiness, they may affect management decisions in favor of new sources of external funding due to the expanding range of financing options.

The testing of Hypothesis 5 was realised by qualitative research.

IRMs which are used by commercial banks have a variety of limits. Tőzsér [31] states that in the context of world financial and economic crisis, criticism of risk management models continually and more frequently heard in academic circles.

Stable operation of financial systems represents, if not impossible, but at least a very complex matter. This is due to the imperfection of the used models of risk measurement, which give very unreliable results. Today, the vastly increased application of the statistical models to measure and predict the risk ironically, even more contributes to the growth of endogenous risk of the system. They promote pro-cyclical changes in financial leverage of banks, thereby contributing to pro-cyclical tendencies of the entire financial system. [23]

Credit risk management models represent an effort of accurately defined complex of economic processes through mathematical respectively statistical models. These models despite their highly sophisticated approaches fail and cannot accurately show the complexity of the economic system, which is determined by significant non-quantifiable variables (attitudes, expectations, preferences of individual economic entities, etc.). [5]

Mitchell, Van Roy [24] reported that 20% of companies that have been evaluated by different models have vastly different ratings. One model assessed them as bad clients, while another model assessed them as good clients. The results of our research have confirmed that the model failed to properly assess the financial health of the company. When the distinctive character of the model was compared with the real data about the default of companies, it was found out that our model has badly judged more than 20% of companies in the segment of SME. [7]

Data collected from the Credit management research centre of the University of Leeds containing all financial and non-financial data show Auroc kurve 0.74 for micro firms, 0.77 for small firms and 0.76 for medium firms. [19]

Based on the qualitative analysis there was confirmed the validity of the Hypothesis 5. This finding allows us to assume that the optimal incorporation of IRM to the credit policy of commercial banks leads to a higher credit acceptances of SMEs by at least 20%.

The facts given, point to the need for appropriate use of IRM in the lending process of commercial banks as the bank can lose a significant amount of revenue because of not providing a loan to a good client (error of the 1st type).

While in case of an error of the second type, the bank may compensate the revenue dropout by monetization of securing means, in the case of an error of the first type is a non-recoverable loss of income.

In this context, it is necessary to define a comprehensive approach to managing the credit risk of the client, which lies in the fact that there is created an approach which will ensure fair and effective assessment of the possibilities, abilities and tastes of the client to return borrowed money to the bank in the agreed mode.

Methodological procedure of the proposed loan process is shown in Fig. 2.

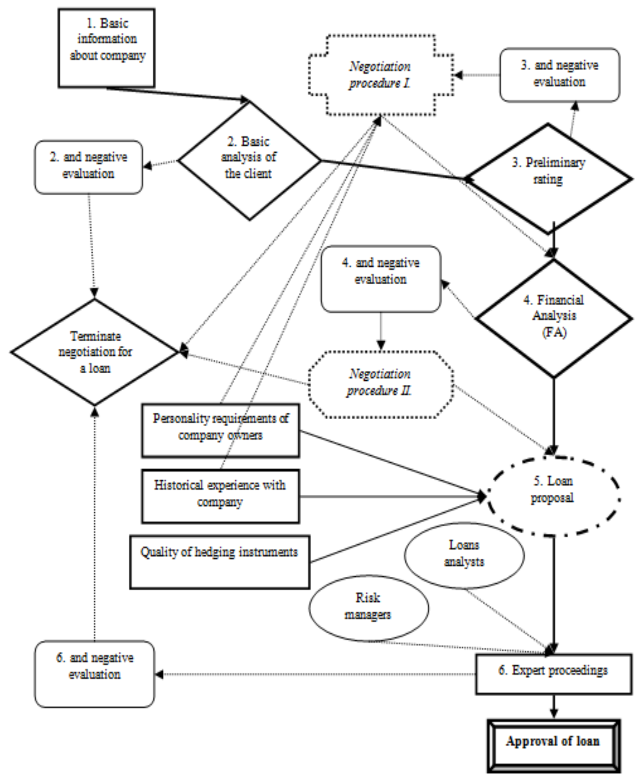

Fig. 2 Methodical procedure of the loan process

Our theoretical contribution consists in the fact that there was proposed to incorporate a Negotiation procedure I and Negotiation procedure II to a standard loan process.

In the case of a negative outcome of the preliminary rating of the client, it was proposed by us to apply a Negotiation procedure I, within which the bank should obtain information to verify, respectively modify the results of the preliminary assessment. If this procedure goes with a negative result, the credit process will be terminated. If the result is positive, the bank continues with the lending process. The procedure proposed by us should allow the removal, respectively making the rating process softer in the context of defined limits and limitations of quantitative rating and incorporation of positive personality characteristics of the company owners, respectively positive historical experience with the firm before the lending process.

In the case of a negative result of the analysis, it is proposed to hold Negotiation procedure II. A financial analysis should be seen also as one of the processes that can help to a good quality credit decision, however the results are also not one hundred percent guaranteed (successful development of the company in the past does not necessarily mean a successful future). For example, in this context, Pavelková, Knápková [27] define a number of weaknesses in the financial analysis. In the case of negative, respectively inconclusive results, the bank's analyst must consider the significant determinants of the financial analysis in the context of credit risk.

The process of the financial analysis, despite its primary exact character, requires a certain amount of imagination,

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professional knowledge and experience of this process from a credit analyst because for example, same numbers can lead to different results or indicators of profitability of the company may be subjectively biased by the massive "tax optimization." Paradoxically, if the business grows too quickly, also the risk of growth management grows too. The company does not handle the enormous personnel, managerial, capacity, logistical growth in relation to management of customers, or in the area of complaints.

There are still many factors that need to be considered in an assessment of the future financial health of the company.

V. Conclusion

The aim of this article is to introduce an upgraded model of the loan process in relation to the segment of small and medium-sized enterprises, which would respond more appropriately to their credit requirements and would assess their credit worthiness more correctly.

Theoretical analysis and practical verification of the quality of internal rating models created by us has shown that these models have a limited quality and a number of outstanding problems.

Rating models are important for the bank, but they should not have a function of the credit machine.

For that reason there was introduced an innovative model of the credit process in the SME segment, which should bring the optimization of credit decisions, a reasonable level of efficiency of credit processes through quantification and optimization of operating costs in the context of an individual approach to SMEs. Our collective assumes that at least 20% of the companies are incorrectly graded by the IRM model, which means that with the proper use of the methodology for the credit process proposed by us, the bank may provide a significant amount of safe loans.

In the next phase of our research, our team will focus on the quantification of the effects of our model on the financial performance of commercial banks. We are planning to conduct quantitative research dedicated above all to find out how many non default clients were refused in the lending process due to harsh criteria currently used by commercial banks.

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The extraordinary contribution in General Regulatory Plan of Rome

O. Campo[1,a]
[1]Department of Architecture and Design (DIAP) - Sapienza, University of Rome
[a]oraziocampo@virgilio.it

***Abstract*—**Among the innovations introduced by the new General Regulatory Plan for Rome, is the introduction of the so-called "Extraordinary Contribution" to urbanisation, an amount in addition to the costs of primary urbanization and those related to building permits borne by the promoter of urban transformation or development projects.

However, at a distance of eleven years after the adoption of the new General Regulatory Plan for Rome and more than six after its final approval, the regulation for the calculation of the Extraordinary Contribution still has not been formally approved by the Rome City Council. One of the reasons for this delay is identified in the legal basis of the additional financial obligation of the project developer, and an appeal brought before the Regional Administrative Court of Law [T.A.R.] was put to rest with the Legislative Decree No. 78/2010 converted into Law No 122/2010 where Article 14(16) permits the introduction of Extraordinary Contribution with the exact wording of the technical conditions of the new GRP for Rome and with the decision of the Council of State, Section IV No 4545 of 13/07/2010.Several attempts have been made to regulate this additional cost, the last of which was the approval by the Board of Councillors in February 2014 of a regulation stating, in summary, that the real estate value to which the extraordinary contribution for urbanisation must be applied, i.e. at the rate of 66.6% as described in Article 20(3) of the Rule for Implementation [Norme Techniche di Attuazione, NTA], is equal to the difference between two distinct transformation values (below VT) of the property transformed: VT1-VT, i.e. the difference between the Value of the Transformation of the property, calculated taking into account the additional construction foreseen by the proposed intervention (VT1), subtracted from the Value of Transformation of the same property under normal urban regulations without further negotiations, so setting the parameters and the method of calculation.

***Keywords*—** extraordinary contribution, general regulatory plan, value of trasformation

I. The Introduction of the Extraordinary Contribution and Technical Problems Inherent in the Calculation

The General Regulatory Plan (hereinafter "GRP") for Rome, adopted with City Council Deliberation (CCD) No 33/2003 and approved with CCD No 18/2008, in the part concerning the criteria for equalization, i.e. Article 17(2)(B) extraordinary contribution (hereinafter "CS" [contributo straordinario]) states: "In the existing urban settlement system, the majority of the leading real estate valuations generated by new urban development projects are subject to the payment of an extraordinary financial contribution that the City Council shall use to finance public works and services in distressed urban areas, with the aim of urban regeneration";

The successive Article 20(3) specifies that the CS is an additional charge and is established in an amount equal to 2/3 of the real estate value achieved with the increase of gross usable surface (SUL [superficie utile lorda])[1] and/or changes in the intended use compared to planning regulations previously applicable. Paragraph 9 successively adds that the City Council defines criteria and procedures for the estimation in a separate regulation.

The Co-planning Conference[2] report identifies, in the guiding factors and regulations, that the economic value gained by the new GRP (through additional building rights and changes of intended use) is for the most part "returned" to the City (the community) through the payment of extraordinary financial contributions.

This new and onerous obligation on the implementing body prompted an appeal to the TAR[3] in which the applicant challenged the legitimacy of the CS in view of the lack of the necessary legal basis at both State and regional levels The judgment of 04/02/2010 accepted the applicant's argument on the issue. The first Judge, in fact, considered the introduction of CS to be without legal basis, believing that the methods adopted in this manner for the pursuit of the objectives of urban (and financial) equalization violated the principle of legality because the extraordinary contribution would constitute a property tax, albeit of non-tax nature, and it as such lacked an express basis for calculation and therefore was in breach of the legal reservation *ex* Article 23 of the Italian Constitution.

As a result of Article 14(16)(*f*), Decree Law 31 May 2010 No 78, converted into Law No 122/2010, the introduction of the CS was permitted when formulated exactly as in the

[1] Article 4(1) of NTA Gross floor area (SUL): measured in square meters. The sum of the gross floor areas of the building unit, including within the outer perimeter of the walls, excluded from the calculation are stairwells, hallways, elevator shafts, technical volumes, not completely closed spaces, basements, parking space outside walls over 30 cm, glass- or greenhouse surfaces, fireplaces and ventilation surfaces.

[2] According to Article 66-bis of Regional Law 38/99, the co-planning conference must be convened to reach an agreement on the approval of the GRP, and that the managers of the of the City Council, Regional and Provincial technical facilities must participate.

[3] General Registry Appeal No 6274 of 2008.

technical regulations of the new Rome GRP. It seemed to have been issued by the municipality of Rome with the express purpose of legitimizing *ex post* the estimations of the CS.

The judgment of the Council of State No 4545 of 13/07/10 recognizes conclusively the legitimacy of the estimates of the CS for urbanisation, stating that it constitutes a levy applicable to the determined higher value of the building in the area upon completion of the construction negotiation process and the definition of indirect intervention programmes, or upon issue of the qualifying title; and also that the authoritative predetermination of the CS does not affect the "optional" nature of institution but rather respects the need to "ensure a level playing field between the owners of the soil in urban regulatory matters" by defining the terms and conditions which the parties to the agreement pursuant to Article 11 of Law 241/90 must guarantee to the city administration in exchange for the increased building volume that the GRP permits them [1, 2, 3, 4].

II. Method of the calculation the CS (Departmental Circular 13/04/2013)

With the legal issues now solved, the City Council Executive Committee passed the resolution with Decision No 20/2013 entitled: "Rules for the determination of the extraordinary contribution" and, pending approval by the City Council, a departmental circular was issued illustrating the method of calculation.

Summarised, the calculation method to be used was the Value Transformation, an analysis with the following requirements:

the market valuesof reference were based on the list of the Property Market Observatory of the Italian Internal Revenue Service (hereinafter “OMI” [Osservatorio del Mercato Immobiliare dell’Agenzia dell’Entrate]);

the commercial surface area is not less than 8% of the SUL;

in determining the technical cost of construction, a parametric assessment of the costs was deduced using the costing lists complied by the Engineers and Architects of Milan and available from DEI publishing house, and, in case of the renovation of a building, this total has been estimated through the bill of quantities and on the basis of regional price lists;

the costs of preparing the site (land reclamation, construction site, connections, archaeological surveys, geological, etc.) may affect the cost of the technical realization by 2-5%;

the costs of marketing may affect the estimated Market Value of the completed project by 2-3%;

the profit of the property developer of 15-25%;

borrowing costs have been estimated through the analysis of the cash flows.

The percentage valuesreferring to the individual cost items are properly reformulated within the percentage thresholds indicated above in accordance with the specificity of the individual urban measures.

The Value of Transformation is then calculated with the formula:

$$VT = Vmt - \Sigma\, iKi$$

where:

VT is the Value of Transformation of the property;

Vmt is the Market Value of the object of the property development project;

Σ iki is the summation of all the processing costs incurred during the property development.

The value then subject to the CS for urbanisation at a rate of 66.6% as defined in Article 20(3) of the NTA in force is equal to the difference between the Value of the Transformation of the same property calculated using the normal urban regulations in force and the Value of Transformation calculated using the proposed development of the building as basis.

The tax base for the application of the CS for urbanisation at the percentage established by the rules is therefore equal to the difference between two distinct Valuesof Transformation of the property development project: VT1 – VT2.

The Value Transformation (VT1) is calculated in the manner described in this Circular, using the proposed development of the property affected by the order as the basis.

The Value Transformation (VT2) is calculated in the manner described in this Circular, theorising the development of the same property on the basis of urban estimates previously in force, namely the realization of the intervention categories and building dimensions (SUL) for which, using the GRP in force, the extraordinary contribution for urbanisation is not due.

In the event that the development relates to existing buildings, the value of Transformation (VT2) is calculated in the manner described in this Circular, theorising a construction project involving the preservation of uses and forms of conduct and management of the property in force at the time of the presentation of the proposed intervention.

III. The new method of calculation of CS (To replace Departmental Circular 13/04/2013)

The Rome City Council was not able to approve the method as intended before the end of their mandate of government, and the new administration therefore prepared a new draft resolution for presentation to the City Council, approved in Committee in February 2014, which follows the pattern established by previous resolutions. The part of the document related to the calculation of the CS is reproduced below.

In particular, the method of calculation, criteria and coefficients to be used for the calculations of the greater financial value of the development project are defined consistently and clearly for all the actuators.

The benchmark on which to base the improved real estate value achievable with the implementation of the planned development, and consequently to determine the amount of the extraordinary contribution due by the implementing body, is made up of the feasible real estate value of the property in question on the basis of normal urban estimates, i.e. based on the building not subject to an extraordinary contribution as established by the urban planning instruments in force.

To ensure full compliance with the principles of fairness, consistency, uniformity of treatment and impartiality, the estimated real estate value achievable is to be calculated with the analytical method for the value of transformation, as normally applied in cases of economic benefit [5, 6]. This method is commonly accepted and practised, and having specific scientific validity, it allows objectivity, consistency and reliability.

The method is the subject of much literature and its inequalities are the subject of mathematical formulation research.

The parameters which govern and collate the values for all the actuators are described and defined below, in order to ensure the correct application in compliance with Article 20 of the NTA of the GRP, in particular with the requirements of paragraph 9.

It must always be assumed in every case that the transformation plan is both consistent with the characteristics of real estate (buildings, areas) and is within the limits of what may be feasibility developed.

The analytical method of Value Transformation considers the property affected by the transformation as a product from which - through the expenditure of a certain amount of capital which constitutes the cost of development or transformation - a final product is attained, i.e. the developed or transformed building [7, 8].

The Value Transformation (Vt) of the property is given by the difference between the Market Value of the building product achieved by the transformation (Vmt), less the processing cost consisting of the sum of the costs (K) incurred in the related transformation, and the Market Value of the building product in the ordinary conditions (Vma), where Vt > Vma.

<u>The Market Value of the finished building product</u> (Vmt) is taken from the latest figures released by the OMI. If this published data is used, the OMI, an agency of the Italian Internal Revenue Service, must be quoted as the source.

The V(mt) for objects in a condition conservatively defined as "normal" corresponds to the "maximum" real estate Market Value per square meter of marketable surface of the building.

Where OMI quotations are related to a real estate conservative defined as "optimal", in the case of new constructions, the Market Value of the finished building product (Vmt) of reference is that described as "maximum". In cases of interventions on existing buildings, the Market Value of the finished building product (Vmt) where the conservative state may now be defined as "optimal" the value of reference is to be the average of the values "minimal" and "maximum".

It should be noted at this point that studies of a considerable number of cases have shown that the commercially marketable surface (SCV [Superficie Commerciale Vendibile]) cannot be less than 8% of the gross usable surface in the case of properties destined for residential use. For details relating to destination definitions must see "Land Agency - glossary of technical definitions in use in the real estate sector." [Agenzia del Territorio – glossario delle definizioni tecniche in uso nel settore economico immobiliare]

Appurtenant car parks, pursuant to Article 41sexies of Law 1150/42, paragraph 2, are freely tradable, contributing therefore as real estate units to the calculation of the Market Value.

In the event that the interventions are undertaken on existing buildings, the value of the transformation is calculated on the basis of the proposed construction project involving the preservation of uses and forms of conduct and management of the property in force at the time of presentation of the proposed action;

In the event that the proposed interventions are undertaken on existing buildings, and/or foresee the construction of buildings destined for usage categories not included among those for which the OMI provides Market Value data, the market values required for the calculation of the transformation values should be determined with indirect or analytical estimation procedures (by applying the income generated by the operation and management of the property as a result of the transformation of the asset, and that generated by the operation and management of the property in the event of a preservation of the intended use and the forms of tenure and management in force at the time of submission of the proposal).

<u>The cost of transformation</u> (K) is the sum of the costs (Σ iKi) incurred in carrying out the development or transformation, which are the following:

the cost of the construction work itself;

the cost of preparing the site and of utility connections;

costs relating to the charges pursuant to Article 16 of Presidential Decree No 380/2001;

the cost of professional services - unforeseen technical and related costs;

marketing expenses;

financial expenses;

profit or gross margin of the developer.

The cost of the building construction work is to be estimated parametrically using the valuesper square meter of the building as in the price list for buildings published by the College of Engineers and Architects of Milan (referring to the latest edition available from DEI at the time of the estimate), with reference to the specific use destinations. In the case where relevant parameter valuesare not available, the calculations by analogue, referring to the category most similar; in the case of demolition and reconstruction the cost of the demolition of existing buildings should also be considered in addition to the parameter value derived by the price lists quoted; in the case of restructuring, the construction cost is derived from an itemised bill of quantities based on rates in force in the Lazio Region and duly sworn to by the person responsible for the design of the urban transformation/construction project.

The cost of preparing the site and of utility connections may constitute from 2% to 5% of the building construction work cost and offset all reclamation, site preparation and connections, and investigation archaeological, geological, etc. undertaken. The evaluation shall take into account the average of the values, the differences should be adequately justified, and it remains understood that the minimum and maximum amounts will not be exceeded.

Costs relating to the charges pursuant to Article 16 of Presidential Decree No 380/2001 include charges of primary and secondary urbanisation and contributions to the construction cost, calculated according to the values established by the Rome City Council in the Council Deliberation in force when calculating the extraordinary contribution for urbanization.

Professional-technical costs and related-unforeseen costs include all costs of a technical-professional nature (urban, architectural, structural and plant engineering studies, safety services, works supervision, performance testing, cadastral requirements etc.). The value is estimated as a percentage of the cost of the works to be carried out when calculated as the sum of the technical cost of construction of the building, the cost of site preparation and of archaeological surveys. From trial calculations carried out using previously applicable professional fees (Ministerial Decree 04/04/2011) and the Ministry of Justice Decree No 140, 20.07.2012, taking into account the current low values present in the real estate market, it is seen that the percentage can vary between 8% and 12% of the cost of the building construction work, the cost of site preparation and of utility connections. The evaluation shall take into account the average of the values, the differences should be adequately justified, and it remains understood that the minimum and maximum amounts will not be exceeded.

Financial expenses are the costs of the capital employed in the investment. This cost is a function of the amount of capital required, the duration of exposure and the rate of interest payable.

The borrowing costs are calculated considering the cost of debt capital during a planning and construction time horizon when the interest on the debt is the sole responsibility of the project supervisor. The time horizon is fixed at five years unless otherwise justified by the size of the project.

The debt cost or the interest rate to be applied is equal to the Euro Interest Rate Swap EurIRS/Euribor spread for a final term loan of fifteen years.

EurIRS is the Euro Interest Rate Swap, the index of fixed rate mortgages; Euribor is the index of the variable-rate mortgages. The source for nominating the EurIRS and Euribor values shall be the Italian financial daily *il sole 24 ore* or the web site www.Euribor.it.

The spread (deviation or margin) is a percentage value that fluctuates on average between 2.50% and 3.50% and is dictated by the major European banks such Deutsch Bank, BNP Paribas, Credit Agricole. It represents the remuneration for the credit institute granting the loan.

Unless another value is justified, only the pre-amortisation period of five years as follows will be considered:

first year 10% (construction permits issued);

second year 30% (advance for early intervention implementation);

third year 40% (advance for early intervention implementation);

fourth year 20% (balance on project realisation);

fifth year 0% (marketing).

The percentages reflect the gradual assumption of risk on the part of the lender relative to the progressive completion of the works placed under warranty.

The interest on the debt accumulated as the five year period progresses constitutes the financial burden of the investment. In practice, the advance paid in the first year is equal to 10% of the total requested and the interest is for all five years of construction, in the second year the bank advances 30% and the interest accumulated is calculated for four years, and then progressively 40% for three years and 20% for two years.

The burden of the financial charges can thus be calculated for each of the phases of pre-amortisation according to the table attached below, evaluating the interest rate to be applied at the moment of loan request.

From the sixth year, the interest on the debt becomes the burden of the purchasers.

The profit or gross margin of the developer is the total profit that the promoter of the project derives from the use of all funds in the real estate transaction. In appraisals using the Value Transformation method, and using the Operation Manual of the Italian Territorial Real Estate Agency estimates, the profit of the developer is expressed as a percentage of revenues in relation to a number of variable factors both for external conditions and for the intrinsic characteristics of the project: general economic conditions, industry intervention, market trends, financing methods, type of real estate transaction (location, size, intended use), cost forecasts and revenues and their reliability, commencement of the time of return, as well as additional variables specific to a real estate transaction.

The detailing of these values according to the specific characteristics of the project, provided with adequate justification, allows for an exact evaluation of each case. The default levels for the lower threshold are set in any case at 15%, and the upper threshold at 25% of the Market Value of the finished building product (Vmt).

The percentage values referring to the individual cost items shall be adequately modulated in order to respect the above percentage thresholds, with reference to the specificity of the individual urbanisation projects.

The Value of Transformation is then calculated with the formula:

$VT = Vmt - \Sigma\, iKi > Vma$

where:

VT is the Value of Transformation of the property;

Vmt is the Market Value of the object of the property development project;

Σ iKi is the summation of all the processing costs incurred during the property development.

Vm is the Market Value of the building product under conditions in force

In conclusion, the value subject to the CS for urbanisation, defined as 66.6% in Article 20(3) of the NTA, is equal to the difference between two distinct transformation values of the property in question: VT1-VT. That is to say, the difference between the Value of the Transformation of the property, calculated taking into account the additional construction foreseen by the proposed intervention, and the Value of Transformation of the same property under normal urban regulations without further negotiation processes.

The Value Transformation (VT1) is computed in the manner described above, on the basis of the proposed enhancement of the property in question, as a result of the negotiation process.

The Value Transformation (VT2) is calculated in the manner described in this Circular, theorising the development of the same property on the basis of urban norm estimates, namely the realization of the intervention urban construction categories and building dimensions (SUL) for which, on the basis of the existing urban norms, the CS for urbanisation is not due.

In the event that the proposed interventions are undertaken on existing buildings, and/or foresee the construction of buildings destined for usage categories not included among those for which the OMI provides Market Value data, the market values required for the calculation in the manner described in this report of the values of the transformation VT1 (related to the proposed enhancement of the property covered by the measure) and VT2 (the value relative to the same property assuming that the use destination and forms of tenure and management in force at the time of submission of the proposal) must be determined using indirect or analytical estimation procedures.

The scope of this methodology covers all direct or indirect development where the required urban planning permits have not yet been signed or where a required permit has not yet been issued.

IV. CONCLUSIONS

The first consideration is that despite the new GRP adopted by the City of Rome with CCD No 33 of 19/20 March 2003 and finally approved with CCD No 18 of 12 February 2008, the planned regulation for the calculation of the CS continues to lack the fundamental approval by the City Council necessary for it to be in force.

Continued uncertainty in this period has inevitably resulted in it not always being applied in a homogeneous manner. This includes by offices which deal with direct intervention projects and by those which work with programme agreements.

Another consideration is that inherent in the fact that the new GRP provides for compensation planning[4] (reduction and transfer of the volumes foreseen to another site) based on the equivalence of property values. These values could also be regulated using calculation methods analogue with the method designed for the calculation of the CS, as this compensation process also deals with the calculation of property values.

Last but not least is the fact that OMI calculations do not have probative value, and with Law 88/2009 the OMI values were demoted from legal presumption to mere indications of evasion. The values deduced from the OMI data base therefore constitute only a reference range, useful for the assessment of the value of the property. It would, however, be correct to refer to known prices of similar properties to that being valued. A market-oriented evaluation cannot make use of automatic and conventional calculations.

One is also left perplexed by the fact that the proposed calculations make no reference, considered within the rate of return of capital industrial (r^1), to the risk factors, market uncertainties, unpredictability, inflation, devaluation, anxiety linked to the complexity of the transformation within time horizons rarely much longer than five years, and of the unknowns in the lease market.

Finally, operators increasingly demand a change of use from commercial and tertiary sectors to residential, transformations which would seem uneconomical because the OMI values often identify higher values for non-residential use, resulting theoretically in a negative extraordinary contribution.

The summation of all the critical points mentioned above, if not corrected before approval by the City Council, could result in creating in values whichpenalize operators, or worse, could be damaging to the municipal revenue to the detriment of the entire community.

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Forecasting of the Annual Inflation Rate in the Unstable Economic Conditions

Josef Arlt, Markéta Arltová

***Abstract*—**Inflation is a very important macroeconomic indicator, which measures the change in the general level of prices of goods and services. The monthly time series of the annual inflation rate is defined as the growth rate of the monthly time series of the consumer price index with respect to the corresponding month of the previous year. The annual inflation rate might not always be the appropriate measure of inflation, mainly due to the fact that it does not provide up-to-date information on the level of inflation. The harmonic analysis shows that the annual inflation rate deforms and delays the information with respect to the monthly inflation rate. This conclusion can be extremely important in the forecasting of the inflation rate, as well as in the process of economic decision making. The new method for the construction of the annual inflation rate forecasts is proposed. The advantage is that it is able to catch breaks and other instabilities in the future development of the time series.

***Keywords*—**inflation rate, harmonic analysis, linear filtration, forecasting.

I. INTRODUCTION

INFLATION is a very important macroeconomic indicator, which measures the change in the general level of prices of goods and services consumed by households. It plays a crucial role in monetary policy, specifically in the targeting of inflation through the setting of interest rates. It is used for the calculation of real interest rates, the increase of the real value of assets as well as the valorization of wages, pensions and social benefits.

Due to the widespread use of inflation and its significant role in the economy, it is of the utmost importance to find a good way to measure of inflation, as well as a method for inflation forecasting. In this paper we argue that the widely used measure of inflation, specifically the yearly inflation rate (introduced below), might not always be the appropriate way to measure it, mainly due to the fact that it does not provide up-to-date information on the level of inflation.

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J. Arlt is with the University of Economics, Prague, Department of Statistics and Probability, nám. W. Churchilla 4, 130 67 Praha 3, Czech Republic (e-mail: josef.arlt@vse.cz).

M. Arltová is with the University of Economics, Prague, Department of Statistics and Probability, nám. W. Churchilla 4, 130 67 Praha 3, Czech Republic (e-mail: marketa.arltova@vse.cz).

II. MONTHLY AND YEARLY INFLATION RATE

Inflation is informally defined as the change in the consumer price index during the period of either one month or one year – this definition leads to either the monthly, or the yearly, inflation rate. The *monthly* time series of the *monthly* inflation rate can be defined as

$$IR_{m,t} \equiv \frac{CPI_t}{CPI_{t-1}}. \quad (1)$$

This definition implies that the time series of the monthly inflation rate is the growth rate (of the monthly time series of the consumer price index) with respect to the previous month. Similarly, the *monthly* time series of the *yearly* inflation rate can be defined as:

$$IR_{y,t} \equiv \frac{CPI_t}{CPI_{t-12}}. \quad (2)$$

This definition means that the time series of the yearly inflation rate is the growth rate (of the monthly time series of the consumer price index) with respect to the corresponding month of the previous year.[1]

Figure 1 presents the development of the natural logarithm of the harmonized consumer price index from January 1998 up to February 2012 – $HCPI_t$ – which is the indicator of inflation and price stability for the European Central Bank. In Figure 2 there is the logarithm of the monthly inflation rate from January 1998 up to February 2012 $IR_{m,t}$ which is based on the harmonized consumer price index. Figure 3 shows the development of the logarithm of the yearly inflation rate – $IR_{y,t}$ – from January 1998 up to February 2012, also it is computed from the harmonized consumer price index.

The logarithm of the monthly inflation rate is characterised by a relatively strong seasonal pattern in contrast with the logarithm of the yearly inflation rate. In this time series is clearly seen unstable behavior from 2007.

[1] The yearly inflation rate is defined as $(CPI_t - CPI_{t-12})/CPI_{t-12} = IR_{y,t} - 1 \approx \log IR_{y,t}$ and the monthly inflation rate as $(CPI_t - CPI_{t-1})/CPI_{t-1} = IR_{m,t} - 1 \approx \log IR_{y,t}$ (Arlt, J. (1998) and Arlt, J. & Arltová, M. (2013))

Fig. 1. The log $HCPI_t$ from January 1998 till February 2012

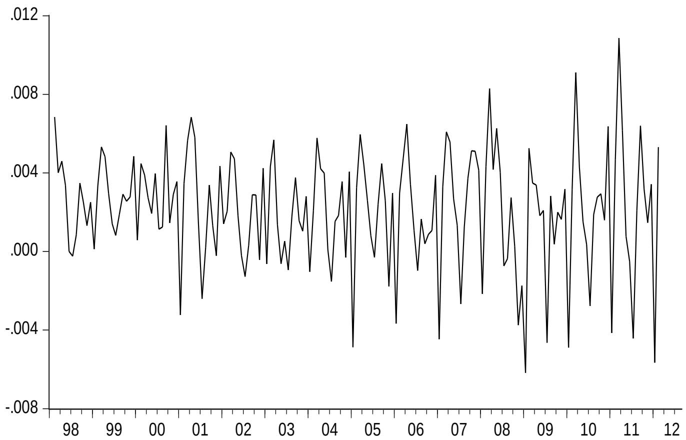

Fig. 2. The log $IR_{m,t}$ from January 1998 till February 2012

Fig. 3: The log $IR_{y,t}$ from January 1998 till February 2012

Data source: ECB (2013)

III. THE EFFECT OF THE YEARLY INFLATION RATE TIME DELAY

A crucial point to notice is that

$$\log IR_{y,t} = \log IR_{m,t} + \log IR_{m,t-1} + \log IR_{m,t-2} + \ldots + \log IR_{m,t-11}, \quad (3)$$

i. e., when coming from the log monthly inflation rate to the log yearly inflation rate, we take a moving sum of 12 numbers, which are spread uniformly from the time t – 11 to the time t, and assign the result to the time t. In other words: the aggregate information contained in the range of times from t – 11 to t is assigned to the endpoint of this range. The value of the log yearly inflation rate at time t, i.e., log $IR_{y,t}$, is thus a measure of the log inflation at its yearly level which effectively corresponds to time t – 5,5 (i.e. the center of the range t – 11 to t). This intuitively implies that the information in the log yearly inflation rate *must be delayed* behind the log monthly inflation rate, and the annualized log monthly inflation rate ($12^* \log IR_{m,t} = \log IR_{anualized,t}$) which truly corresponds to time t. This point was elaborated on in a rigorous way with the help of the concept of the spectral time series analysis in Arlt, Arltová (1999) and Arlt, Bašta (2008, 2010).

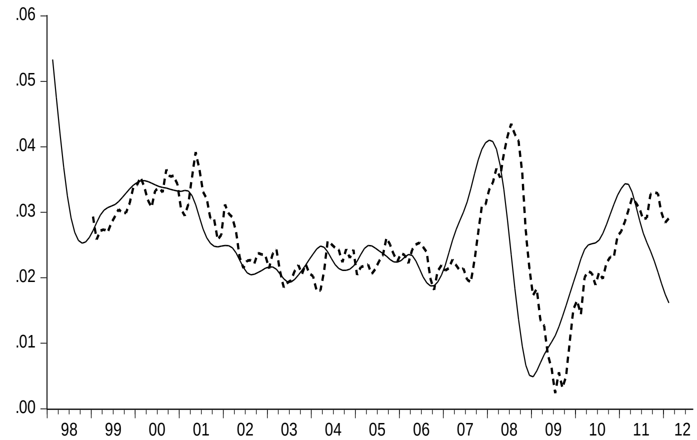

Fig. 3: The log $IR_{y,t}$ (dashed) and the smoothed log $IR_{annual,t}$

The yearly inflation rate, along with the smoothed and annualized monthly inflation rate in the log transformation; computed on the basis of $HICP_t$ from January 1998 to February 2012; are presented in Fig. 4. The smoothing of the annualized log monthly inflation rate is achieved by the Hodrick-Prescott filter. It is a two-sided linear filter that computes the smoothed series $s_t = \log IR_{annual,t}|_{smoothed}$ of series $y_t = \log IR_{annual,t}$ by minimizing the variance of yt around st, subject to a penalty of the second difference of st. The HP filter chooses s_t to minimize

$$\sum_{t=1}^{T}(y_t - s_t)^2 + \lambda \sum_{t=2}^{T-1}((s_{t+1} - s_t) - (s_t - s_{t-1}))^2 . \quad (4)$$

The parameter λ controls the smoothness of the series st. It is seen that the peaks and troughs, especially in the period of instability, are delayed in the log yearly inflation rate behind the smoothed annualized log monthly inflation rate..

IV. THE FORECASTING OF THE YEARLY INFLATION RATE

The yearly inflation rate is very frequently used in economic practice; more frequently than the monthly inflation rate and annualized monthly inflation rate. One of the arguments for the practical application of the yearly inflation rate is its relative smoothed shape in comparison with the annualized monthly inflation rate, which usually contains a strong seasonal pattern. As we mentioned above, the principle problem of the yearly inflation rate is the significant time delay in comparison with the monthly, and annualized monthly, inflation rate. In fact, the problem is only of a technical nature and can be solved by simply moving the yearly inflation rate back by six months. We know that this adjustment has not been implemented to date. It seems that the responsible people in the central institutions (for example in the central banks) do not perceive the seriousness of the problem. In the papers Arlt, Arltová (1999) and Arlt, Bašta (2008, 2010), we justified this issue in detail, but as yet, we have received no response; either positive or negative. In this rather provocative paper we will no longer draw attention to the problem of delayed information in the yearly inflation rate. Instead, we will use our knowledge for the proposal a new, nontraditional method of yearly inflation rate forecasting, with the horizons h = 1, 2, 3, 4, 5, 6.

The basic forecasting principle is extremely simple. It can be expressed in the following formula

$$\log IR_{y,T(h)} = \log IR_{anual,T-6+h\,|\,smoothed} \quad \text{for } h = 1, 2, 3, 4, 5, 6, \qquad (5)$$

where log $IR_{y,T}(h)$ is the forecast of the log yearly inflation rate at time T for h months ahead and log $IR_{anual,T-6+h\,|\,smoothed}$ is the smoothed annualized log monthly inflation rate. The advantage of this approach is that it is based on the annualized monthly inflation rate computed from the real data. It follows that it is able to catch breaks and other instabilities in the ”future” six months development of the yearly inflation rate, and can thus be efficient, especially in the unstable time periods. The drawback of this method is the fact, that the annualized monthly inflation rate is strongly seasonal and must be smoothed. As it was mentioned above, the HP filter can be used. The smoothing of the ends of the time series by two-sided filter (as is HP filter) is usually problematic and does not reflect reality. The solution is to forecast ”ex ante” the annualized monthly inflation rate, which gives the HP filter enough values to smooth more properly the end of the analyzed real time series. Afterwards, the smoothed forecasted values are removed. The same solution is used in the X13ARIMA seasonal adjustment method.

V. 5. The practical verification of the proposed method

The empirical verification of the proposed forecasting method is based on the recursive forecasting of the HICP yearly inflation rate. The forecasts with a horizon of 6 months start from the prediction threshold of September 2006, and repeat themselves with the prediction threshold of each subsequent month. The Hodrick-Prescott filter is used for smoothing the last six values of the actual annualized monthly inflation rate. Before that, however, it is necessary to calculate the annualized monthly inflation rate forecast for 12 months ahead, on the basis of the SARIMA models (until the prediction threshold April 2009 it is SARIMA(0,0,4)$(1,0,0)_{c,}$ and after that it is SARIMA(1,0,0)(1,0,1)). The accurate forecasts improve the quality of the smoothing of the time series ends considerably. The forecasts accuracy “ex post” is measured by the Mean Squared Errors, and by the Theil Inequality Coefficient. Its values lie between zero and one; zero indicates a perfect fit.

Fig. 5 shows some of the forecasts together with the real log yearly inflation rate time series. A period with significant breaks was deliberately chosen. It is clearly seen that the forecasts are able to capture instability, as well as fundamental changes in the behavior of the “future” development of the yearly inflation rate.

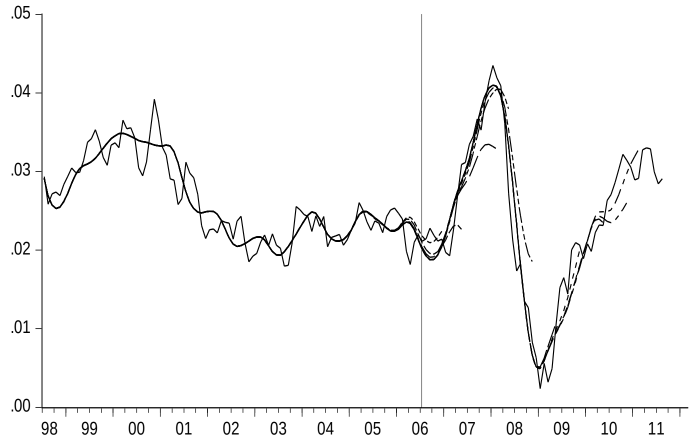

Fig. 5. The log$IR_{y,t}$, the smoothed log$IR_{annual,t}$, the log$IR_{y,T}(h)$ with the horizon of 6 months

Table 1 contains the Mean Squared Errors as well as the Theil Inequality Coefficients of recursive forecasts for 6 months. The values of the second measure vary, but they are very close to zero. It is interesting to compare the size of Theil Inequality Coefficients with the real values of the yearly inflation rate, which has been captured in Fig. 6. With decreasing values of the predicted time series, the Theil Inequality Coefficients have the tendency to grow, which means that the accuracy of the predictions decreases.

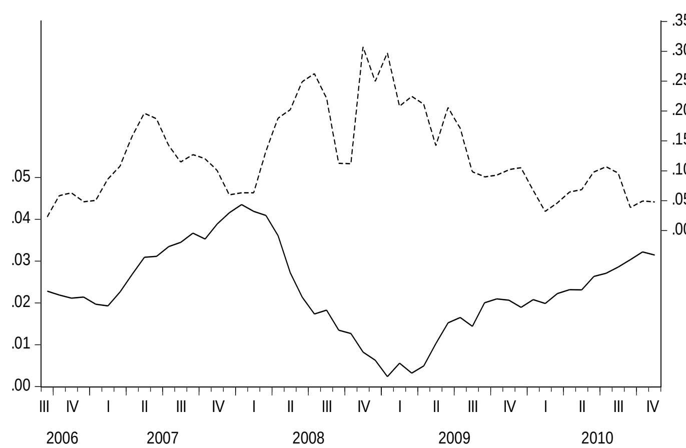

Fig. 6. The Theil Inequality Coefficients (dashed), the log$IR_{y,t}$

Table 1. The MSE and the Theil Inequality Coefficients of the

recursive forecasts

Date	MSE	Theil	Date	MSE	Theil
2006-09	0.0010	0.0229	2008-11	0.0071	0.3073
2006-10	0.0024	0.0581	2008-12	0.0040	0.2497
2006-11	0.0026	0.0630	2009-01	0.0041	0.2971
2006-12	0.0020	0.0480	2009-02	0.0028	0.2080
2007-01	0.0022	0.0502	2009-03	0.0043	0.2243
2007-02	0.0040	0.0863	2009-04	0.0039	0.2113
2007-03	0.0052	0.1078	2009-05	0.0036	0.1422
2007-04	0.0079	0.1580	2009-06	0.0050	0.2059
2007-05	0.0101	0.1960	2009-07	0.0049	0.1713
2007-06	0.0103	0.1867	2009-08	0.0033	0.0984
2007-07	0.0084	0.1424	2009-09	0.0032	0.0898
2007-08	0.0072	0.1146	2009-10	0.0034	0.0924
2007-09	0.0083	0.1271	2009-11	0.0039	0.1017
2007-10	0.0083	0.1199	2009-12	0.0047	0.1052
2007-11	0.0073	0.1001	2010-01	0.0030	0.0675
2007-12	0.0046	0.0599	2010-02	0.0014	0.0321
2008-01	0.0048	0.0632	2010-03	0.0021	0.0463
2008-02	0.0050	0.0632	2010-04	0.0030	0.0644
2008-03	0.0104	0.1323	2010-05	0.0033	0.0685
2008-04	0.0140	0.1880	2010-06	0.0048	0.0982
2008-05	0.0136	0.2021	2010-07	0.0055	0.1067
2008-06	0.0150	0.2492	2010-08	0.0052	0.0958
2008-07	0.0134	0.2627	2010-09	0.0022	0.0385
2008-08	0.0089	0.2218	2010-10	0.0029	0.0493
2008-09	0.0033	0.1124	2010-11	0.0029	0.0478
2008-10	0.0026	0.1117			

In this paper we argue that the principal property of the yearly inflation rate is its approximate six months time delay in comparison with the annualized monthly inflation rate. Unfortunately, this fact is not yet reflected in economic practice. We use it to suggest the new, nontraditional approach to yearly inflation rate forecasting. This method is verified for the case of the HICP yearly inflation rate. The recursive "ex post" forecasts are computed for the very unstable period. The accuracy of the "ex post" forecasts is measured by the Mean Squared Error, and the Theil Inequality Coefficients. It has been found that even in periods of great instability, the proposed method is very efficient and able to create relatively accurate forecasts, catching even the considerable breaks in the future development of the forecasted time series.

VI. Conclusion

In this paper we argue that the principal property of the yearly inflation rate is its approximate six months time delay in comparison with the annualized monthly inflation rate. Unfortunately, this fact is not yet reflected in economic practice. We use it to suggest the new, nontraditional approach to yearly inflation rate forecasting. This method is verified for the case of the HICP yearly inflation rate. The recursive "ex post" forecasts are computed for the very unstable period. The accuracy of the "ex post" forecasts is measured by the Mean Squared Error, and the Theil Inequality Coefficients. It has been found that even in periods of great instability, the proposed method is very efficient and able to create relatively accurate forecasts, catching even the considerable breaks in the future development of the forecasted time series.

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Josef Arlt graduated from the University of Economics, Prague in 1984, majoring in Economic Statistics. He currently works as professor in the Department of Statistics and Probability at the University of Economics, Prague and as vice-dean in the Faculty of Informatics and Statistics at the University of Economics, Prague. He focuses on economics, econometrics and economic and financial time series analysis.

Markéta Arltová graduated from the University of Economics, Prague in 1992, majoring in Economic Statistics. She currently works as a associate professor in the Department of Statistics and Probability at the University of Economics, Prague. She focuses on analyses of economic, financial and demographic time series.

Designing secure networks for substation automation and control systems

Niculescu Eliodor Sorin, Rusta Constantin, Mircea Paul Mihai, Ruieneanu Liviu and Daianu Adrian

Abstract— Development of the energy systems and utilities (water, gas) and the process information related to them but also their interconnection with other equipments and information systems led to increasing the risk and vulnerability; thus occurring the access possibility to the command /control systems and data for an unauthorized persons that may influence the operational safety.

It also results need to take measures to increase security systems by removing all data connections or linkages that are not necessary for the operative management of the energy system.

This paper focuses on describes a possible solution to increase safety for better management as well as to obtain more precise information (accurate) about events that occur while also reducing the vulnerability of the systems.

Keywords— Network security planning, process information system, risk, safety data, SCADA systems.

I. INTRODUCTION

INFORMATION systems security process is a relatively new IT technology, and was released as a result of the inherent diversification of communication in modern society based on efficiency and speed in decision making processes. E-mail services, web, data transfer, etc. is based on a sense of security often false, which can generate potential gains rapid access to information, but can cause major losses due to theft of data or insert false or misleading [1].

Command-control systems and automation in power systems are a special category of information process, which combined with the computer systems of the utilities (water, gas) are the backbone of technical civilization.

Power systems are a special category of industrial systems with high sensitivity and can go in case of errors / mistakes in the states of partial or total unavailability (the blackout) as having a strong impact on business and everyday life.

Moreover, if the decommissioning of the source system has an "intruder" external or external cause, the impact is even greater because the entire basic infrastructure is compromised, and could thus make "scenarios" different from any geographic points of the world.

If until few years ago these systems automation data network operated as "isolated" (self), new communications technologies have allowed their interconnection and implementation processes and telemanagement remote, which to some extent vulnerable security systems [3]. This integration of the local computer subsystems and motivation was to achieve high coverage networks (WAN – Wide Area Network) to: faster data acquisition, low propagation delay information to post-factum analysis centers, increasing the time response, optimization of decision making and maintaining a close link to the center to coordinate with various sublevels of subordination (Company / Branches / Centers / Substations / Process).

II. PROCESS INFORMATION SYSTEMS - BOUNDING ENERGY DOMAIN

A. *Definition. Features. Requirements*

Process Information Systems (PIS) is an information system as part of the collection, transmission, storage and processing is done using the elements or components of IT (Information Technology) [4], means that computers and modern communications, software specialized procedures and techniques plus trained personnel. In other words, PIS is that part of the information system, including acquisition, processing and automatic transmission of data and information within a macro information system [5].

Characteristics of information systems:

- there any system should have as a central database in real time (RTDB - Real Time Data Base), the stored data to be interrelated among themselves from internal and external sources;
- an information system must be authentic, accurate, and support presentation range from management level to another;
- a system must include a variety of mathematical models, technical, economic, eg, optimization models, simulation models, models of efficiency;

E. S. Niculescu, Romanian National Power Grid Company – Transelectrica Co., SCADA and Substation Control Systems Dept. Currently is PhD student at the University of Craiova, Faculty of Electrical Engineering sniculescu@pasys.ro;eli.sorin@gmail.com

C. Rusta, Romanian Hydro Power Company „Hidroelectrica Co.", SCADA and Industrial Systems Dept. (constantin.rusta@gmail.com).

P. M. Mircea, University of Craiova, Faculty of Electrical Engineering, Decebal Boulevard, no.107, Craiova, Romania; mmircea@elth.ucv.ro .

L. Ruieneanu is with the University of Craiova, Faculty of Electrical Engineering, Decebal Boulevard, no.107, Craiova, Romania: lruieneanu@elth.ucv.ro .

A. Daianu, Romanian Hydro Service Power Company „Hydroserv Co.", Automation and Protection Relay Dept. (daianuadrian@gmail.com).

- a system should be designed as a man-machine (HMI - Human Machine Interface) offering the possibility of an immediate and friendly interaction between user and system;
- a system must provide the highest possible degree of integration in two aspects: internal integration and external integration.

Computer system requirements:

To achieve systems that meet the required characteristics of systems is necessary to take into account the following requirements:

- a grounding system design to be made on grounds of economic efficiency;
- a direct participation in the design of management information system unit;
- ensuring a high technical level of the solutions adopted;
- a solution adopted in accordance with available resources and restrictions.

Structuring of information systems requirements in the overall design stages:

- one on each level of the structure must ensure the uniqueness criterion for decomposition of the system;
- a structure made up later to allow the entire system by aggregating separate modules.

B. SCADA Systems

It was tried to delimit the scope of the above systems and their implementation to investigate how the National Power Grid System reacts.

Thus, process control systems for power are known in literature as SCADA (Supervisory Control and Data Acquisition) systems. They are the "tools" based on the computers, which energy operators used to assist in controlling the operation of complex energy systems [2].

Base entire scaffold which contribute to the supervision, control and monitoring of electrical substation equipment and power networks is the control and data acquisition.

The functions of SCADA Systems

- supervising and control of equipment or parts of the facility and power networks.
- an alarm to "recognition" of the system with inadequate state supervision of equipment and networks;
- post factum analysis – maintain a running history of events in the surveillance;
- a graphical user interface (GUI - Graphical User Interface);
- a self-diagnostics – for continuous monitoring of their functional parameters;
- planning and tracking a maintenance process.

The architecture of control systems must comply with the requirements of open systems OSI - ISO (Open Systems Interconnection – International Standard Organization).

An open system provides opportunities that make applications such as:

- a system can be implemented from several suppliers of equipment;
- one can work with other applications made in open systems;
- to present a consistent style of interaction with the user;

The more open open-concept system that brings in SCADA system design is the ability to distribute processing functions

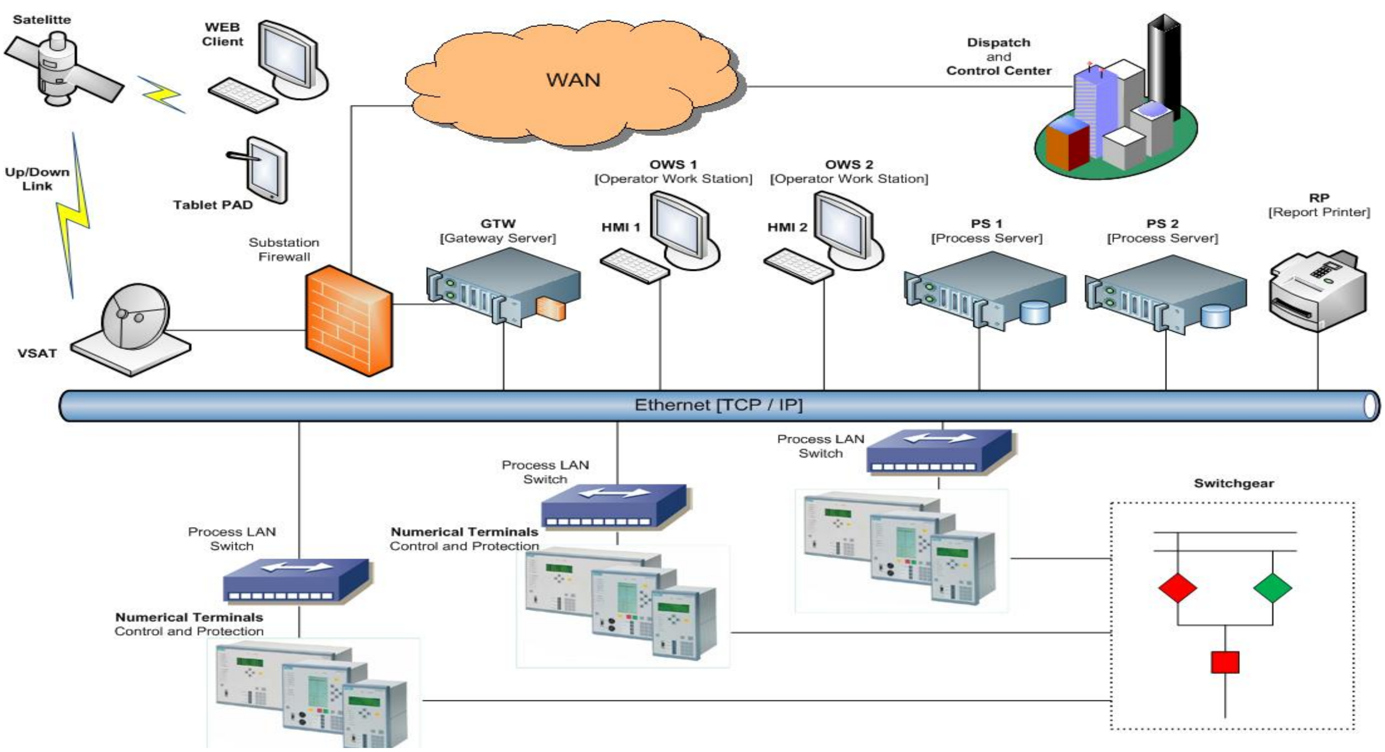

Fig.1 general architecture of a basic Substation Automation System in various knots. Each node is functionally independent of the hardware resource.

Dependence between nodes is variable, however the hardware must be provided as independent as possible, this way, and it can get the opportunity to expand further or replacement.

Also, the independence of processing nodes used to minimize transmission of messages and data network load.

Within the node redundancy increases availability and reduces the risk of loss and loss distribution functions for other nodes.

A characteristic of open systems is that nodes can be located at any distance, distributed architecture becomes a necessity, and used as a support for local data communication networks (LAN – Local Area Network) and remote (WAN – Wide Area Network) made using standard procedures and interfaces [7].

In Fig.1 is presented the general architecture of a distributed SCADA system, the key is to connect various components through communication networks.

C. The integration concept of distributed information systems

If in the early stages, information systems at power station were isolated entities, and their only external connection is made only with the dispatch center (the serial protocols IEC 60870-5-101, invulnerable to attacks) [9], the integration of these new policies structures of complex computer systems using competitive communication protocols (based on TCP / IP) led to an increase in default and vulnerability.

In order, to maximize technical and economic supervised process, the centralization of information and increase safety of National Power System were created regional information infrastructure (Control Center) which are able to download the complete information flow on all electric substations under the action of these centers.

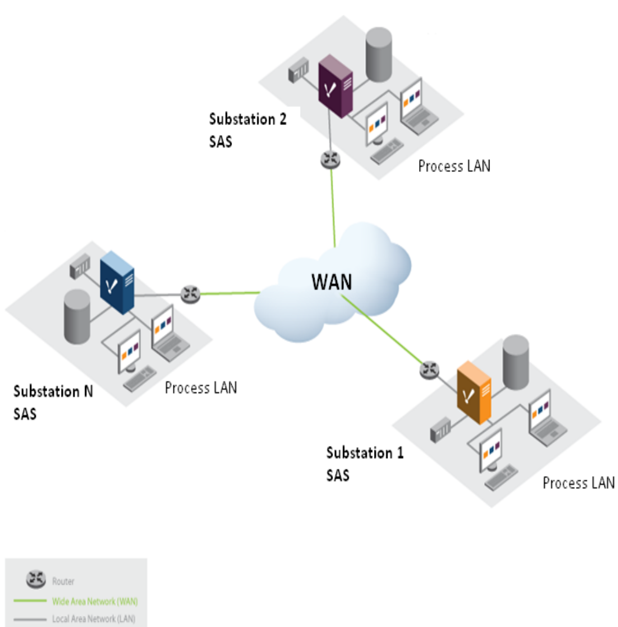

Fig. 2 *wide area SCADA concept*

Thus, developing the concept of Wide Area SCADA (Fig. 2) which requires a full integration of these sub-control protections (SAS), in the compact and complex computer entity capable of providing a remote management of all facilities automation without the need for continuous operational tour [6].

To achieve this goal, it is necessary the use of communication protocols capable of managing the entire amount of exchange of information between control centers and the process itself.

III. The SAS Security

A. Network Security Planning

In a computer network, there must be assurance that sensitive data is protected so that only authorized users have access to them [6].

The vulnerability of computer networks is manifested in two ways:

- modification or destruction of information (attack the physical integrity);
- a possibility of unauthorized use of information;

Providing "safety data" stored in a computer network involves procedures for handling data that can not lead to the accidental distribution of their measures and / or duplication of important data to be restored if necessary.

Having a secure computer network with access to data requires a user authentication procedure and / or differentiated authorization for certain resources.

Any network should be protected against intentional or accidental damage.

There are four major threats to the security of computer networks, as below:

- unauthorized access;
- electronic data alteration;
- data theft;
- on purpose or accidental damage.

Is the responsibility of the network administrator to ensure a secure, reliable and ready to face the dangers above?

It is believed that a computer system / computer network is safe(s) if all its operations are always carried out according to strictly defined rules, which results in a complete protection of entities, resources and operations.

The list of threats is the defining security requirements. Once they are known that the rules should be developed to control all network operations.

These operational rules are called *"security services"*, and implementation services are by security protocols [6].

To define a secure computer network should be developed as follows:

- a list of security requirements;
- rules for protection and security.

B. Defining security policies

In a computer network security model assumes the existence of three levels:

- a physical security;
- a logic of security levels;
- a secure connection.

Establish security policies and provide general orientation guidelines for network administrators and users in case of unforeseen circumstances.

The most important security policies are: prevention, authentication and training.

IV. Issues to be taken into account in the design process systems related networks

A. Identify all existing connections to the SCADA Systems

This entails a detailed analysis of network structure of the SCADA system for assessing risk and the need for all network connections. In this stage are assessed the following types of connections:

- Connecting to a SCADA computer network management of LAN, WAN (business networks);
- Connecting SCADA Systems to the Internet;
- Connecting to a SCADA Systems, the certain equipment including wireless connections via satellite;
- An existence of modems or other dial-up connections;
- An adjacent connection with partners, regulatory agencies, etc.

B. Disconnect from the SCADA systems all unnecessary connections

To ensure the highest degree of security of SCADA systems, recommended a "containment" of networks related to other adjacent networks or connections that are not related to the process.

Any connection to / with another network introduces security risks, especially in if it creates a path or connection to the Internet. Although direct interconnection with other networks / subnets can allow efficient and convenient information exchange, risk of insecure connections vulnerable to process network is large, the optimum is why the "isolation" of the SCADA network.

Can be used strategies such as using the "demilitarized zones" (DMZs – De Militarized Zones), and virtual sharing of computer related applications regarding managerial and process applications, but all of them, must be designed and implemented properly to avoid placing an additional risk by an incorrect configuration.

C. Evaluation and strengthening of securing all remaining connections to the SCADA system

This goal involves conducting penetration testing or vulnerability of all remaining links to the SCADA network to be able to assess the security of these connections [5].

In this respect, it is essential that every entry point to be used to process network firewalls and detection systems "Intruder" (IDS - Intrusion Detection Systems).

Physically, the firewall can be a simple PC, workstation, router or mainframe. From a logical standpoint, the firewall determines what information or services can be accessed from outside the network and who has the right to access these resources.

The firewall is located in the internal network makes the junction with the external network, called the checkpoint area.

The main functional components of a firewall:

- a packet filtering router;
- an application-level proxy gateway;
- a circuit-level gateway.

Packet filtering router is a network that transmits packets based on filtering rules implemented rules that are based on security policy.

If it is known the source or destination addresses, filtering rules on the router can accept or reject a packet depending on this information.

Data packets have a destination other than the IP address of those servers will not be allowed into the network.

Application-level control is achieved most often through a gate (gateway) or proxy server.

The gateway must be properly installed proxy code for every application that wants to pass the gate.

During the dialogue between a client and a server, the proxy server acts as the client and also becomes the target server or client.

For the original client, proxy server functions in a transparent but is able to monitor and filter out certain commands or information.

Proxy server is a dedicated server application running on the computer network that connects our world.

Because customers can access a proxy server as the client software must be modified to support proxy connection and proxy server log on.

D. Avoiding possible use of proprietary protocols in SCADA systems

Some SCADA systems use (purely commercial reasons) proprietary protocols for communication between the terminals “in the field" and servers; this is very risky because network security is often based solely on the security of these protocols obscure low.

In addition, the developer of such protocols can provide communication interfaces to other producers of some of its protocol specifications thereby increasing the vulnerability of the network indirectly through attacks backdoors.

E. Remove or disable unnecessary services

SCADA servers built on open operating systems are easily exposed to attacks via the default network services.

To reduce the risk of direct attack is recommended to remove or disable unused network services, this is particularly important when SCADA networks to interconnect with other

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networks.

An example of such a network service is "Remote maintenance", which should always be carried out only off and on the ground and only by authorized personnel in this regard.

It is also recommended that access these systems to management / administration to make only a single external point of access and only the system administrator based on the company's internal regulations.

V. Conclusion

IT security mechanisms described above is a possible solution to achieve the perspective LANs process allowing better management of facilities, a more precise and accurate information on the events run, decrease the vulnerability of computer systems, high reliability and technology tends to occupy all the industries.

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Location optimisation of trigeneration biomass power plant: the case of the city of Petrinja, Croatia

D. Dominković[1], B. Ćosić[1], N. Duić[1]

[1]University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture

Abstract**—**In this paper, optimization of the location of biomass trigeneration power plant was considered for three case studies in the city of Petrinja, Croatia. The system combined biomass cogeneration power plant, absorbers and the seasonal pit thermal energy storage. In order to find optimal location of power plants several factors influence merit of potential locations. When the biomass availability, capacity of the power plant or the number of power plants changes the optimal location also change. Case studies have shown that significant amount of yearly spending on fuel (biomass) can be avoided, if the optimal location has been chosen for the power plant location. Furthermore, economic assessment of choosing optimal and non-optimal location was performed. Moreover, it was shown that while choosing the optimal location of the power plant, economic figures such as net present value (NPV) can be satisfying for the potential investor in the trigeneration power plant even in residential area.

Keywords**—**absorption, location optimization, net present value, pit thermal energy storage, trigeneration

I. INTRODUCTION

Renewable energy sources have become common topic nowadays. Modelling renewable energy systems was performed by the vast number of authors in the past time. Quick review of papers dealing with trigeneration systems, optimization and thermal energy storages will be showed here. Reference [1] showed that the number of articles using optimization algorithms applied to renewable energy systems is growing exponentially in the last 20 years. Authors in [2] used a mixed integer optimization method for optimal design of a trigeneration power plant in a hospital complex. Authors in [3] suggested solutions for sizing a trigeneration plant in Mediterranean areas. However they didn’t carry out economic assessment. Authors in [4] have made a techno-economic assessment of biomass fuelled trigeneration system integrated with organic Rankine cycle. Although solutions were technically feasible, economic results for investors wouldn't be satisfying without subsidies, as the simple-payback time was 17 years. An energy and exergy analyses of a biomass trigeneration system using an organic Rankine cycle was done in [5]. They showed that significant improvement was obtained when trigeneration is used instead of only electrical power production. However, economic assessment hasn't been done. Authors in [6] have also modelled biomass fuelled trigeneration system in buildings. They showed that the specific investment in trigeneration system is rather high for the small biomass fuelled system. Performance comparison of three trigeneration systems using organic Rankine cycles have been carried in [7]. They showed that in their configurations biomass fuelled trigeneration system has the highest energy efficiency, i.e. 90%. Multicriteria synthesis of trigeneration systems considering economic and environmental aspects was optimized considering specific demands of a medium size hospital in [8]. Authors in [9] tackled the issue of cost allocation when the system is producing different products. On the opposite from the other papers, they have assessed trigeneration system in the residential-commercial sector featuring highly seasonal and daily variable demands, which will also be the case in this paper.

Other authors were dealing with integration of trigeneration systems and different thermal energy storages. In [10] authors combined a trigeneration system and compressed air thermal energy storage. However, they didn't assess large-scale trigeneration system. Integration of trigeneration system and thermal storage under demand uncertainties has been analysed in [11]. They used a hybrid system which produces thermal energy via both electricity and town gas.

Authors in [12] showed that the thermal networks are financially beneficial for areas with high densities and industrial complexes, while for low-density residential areas the economic advantages are not completely clear.

There are also a lot of papers dealing with optimization of power plant location. In [13] authors used mathematical model suggested by Balinski. They have built a model consisting of 17,012 variables which resulted in optimal power plant location for sizes of 10 MW and 15 MW [13]. The linear programming (LP) optimization method was used. They achieved economic feasibility, but dealing only with electricity production from the biomass power plant. Authors in [14] optimized biomass fuelled systems using Particle Swarm Optimization (PSO). They were using profitability index as objective function. They have evaluated three different technologies and in every case, the optimal location was different. They have also evaluated genetic algorithm (GA) against PSO, but the PSO obtained better solutions with a lower number of iterations. Authors in [15] developed a transport cost model consisting of distance fixed and distance dependent biomass transport costs. They have used Euclidian distance for calculations. Among other conclusions they have noted that considering transport costs, installing a smaller

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plant at three different locations would be less expensive than installing a single biomass plant. In [16] a mathematical model to optimize the supply chain of a forest biomass power plant was developed. The model considered supply, storage, production and ash management. The paper showed that the biomass purchase cost had the highest share in total cost. Thus, optimizing the biomass costs seem to be an obvious approach in reduction of overall costs.

The novel approach in this paper will be optimization of several factors in a large scale system, including power plant size, absorption unit size and the pit thermal energy storage size. Moreover, location of the power plant will be optimized in order to maximize Net Present Value (NPV). Moreover, the system considered will have to cover all of the heating and cooling energy demand in the city of Petrinja. The system will consist of the trigeneration power plant and seasonal pit thermal energy storage (PTES). The optimal location will be chosen depending upon the power plant size and the size of the distribution network system.

II. METHODOLOGY

A. *Problem definition*

Maximizing the profit is the key goal of most investors and all the other factors come afterwards. There are many factors influencing income side, as well as the expenditure side of the budget. The key element of the income side of the budget is feed-in tariff received per kWh of electricity produced. Other factors that contribute to the income side are revenue from sold heating and cooling energy. Thus, enlarging the power plant capacity will increase generation of energy rate, which will increase income if all the energy can be sold. On the other side, there are many factors which impact expenditure side such as operating and maintenance costs (both fixed and variable) of: biomass power plant, district heating and cooling network and seasonal storage. Depending on the chosen size of each of these parts of the system, operating and maintenance costs will differ. There are also many factors impacting investment costs. Generally, larger the parts of the system are, larger are the absolute investment costs. However, economy-of-scale can be quite significant when talking about relative investment, i.e. investment cost per kW of capacity. Thus, optimizing all of these factors is crucial in order to maximize profit for the investor.

Among the other factors, location of the biomass power plant is a significant factor that is contributing to the overall results. Choosing different location changes costs of the transportation of the biomass, as well as costs of distributing heating and cooling energy. Thus, optimizing these factors will be emphasized in this model.

B. *Model description*

The model consists of two major steps. In the first step, the model optimizes sizes of all parts of the system (power plant capacity, absorber unit capacity and seasonal storage capacity), taking into account constraints of the system. The system size is mostly constrained by the heat that can be consumed, and thus delivered, to the final consumers. Thus, this is a heat-driven model. Also, in order to be eligible for the feed-in-tariff, legislation of Croatia requests minimum yearly overall efficiency of the power plant of 50%. As a consequence, there is a finite amount of heating energy that does not need to be consumed by the end users. However, heating (or cooling) energy does not need to be consumed immediately after generation. Surplus of the heating energy production can be stored in the seasonal thermal energy storage and later used, when there will be shortage of the heating energy produced in the power plant. Also, considering the heating and cooling energy needs of the city modelled, the system has to cover all of the heating and cooling energy needs throughout the year on the hourly basis. It is assumed that all the electricity generated can be transferred to the grid due to guaranteed access of the renewable energy to the grid provided by legislation of Croatia.

Afterwards, in the second step the model optimizes the location of the biomass. In the first step biomass price, including transport is fixed and set to the 38 €/t. In the second step, transportation costs will be calculated taking into account the distance between the power plant and the locations of the forests. Price of the biomass at the forest road in Croatia, set by Hrvatske šume d.o.o., will be used for the biomass price. If there is lack of biomass for optimal power plant size, the model calculates additional costs of biomass that can be used from agricultural land that is not being used at the moment. However, on this land biomass has to be planted which increases costs of this type of biomass. For the purpose of this step, location will be divided into 361 quadrants, each with size of 1 x 1 km. Thus, the furthest quadrant will be distanced 12.5 km from the central point of the city considered. After this distance, it is assumed that heating and cooling energy losses in the distribution system are too large.

Optimization method used calculates the savings or losses comparing to the first step for the each quadrant. After positioning in the right quadrant the model calculates the distances of the forests taking into account available biomass. Furthermore, it calculates total costs from the nearest forests, which have sufficient amounts of biomass, including transportation costs from these forests. It also calculates the losses that are caused by increased distribution losses of heating and cooling energy, increasing the heating and cooling energy losses by 1% per kilometre, moving away from the centre of the city. Increased investment in the main pipe when moving away of the city centre is also taken into account. Finally, the model chooses the optimal location, i.e. location with the highest savings comparing to the first step. Moreover, the model van graphically shows changes in the savings or losses in each quadrant.

C. *Biomass power plant*

The size of the biomass power plant is calculated taking into account constraints of overall yearly efficiency that has to be satisfied in order to be eligible to receive the feed-in-tariff. Overall yearly efficiency, taking into account electricity produced and heating and cooling energy consumed by the end-users, has to be above 50%. Availability of the power plant is set to 90%. Thus, the model calculates the period with the lowest heating and cooling energy demand and shuts down the power plant for maintenance. In this period, heating and cooling energy demand is covered solely from the seasonal storage. Biomass moisture is considered to be constant throughout the year and is set to 30%.

D. *Seasonal thermal energy storage*

Pit thermal energy storage (PTES) was chosen for the seasonal heat storage mostly due to low investment costs and well-known technology for building large-scale storages of this type. Water as storage is a mature media, and taking into account its large specific heat capacity, proves to be valuable choice for the energy storage. PTES are the largest thermal energy storages being built according to [17]. Typical efficiency of such storage is between 80% and 95% depending on temperature level in the storage. Significant economy-of-scale is present in this kind of storage, but only up to volume of 50,000 m^3. After this size, economy-of-scale does not change significantly. Thus, building several storages can provide equal investment burden for the investor, but in the same time it facilitates maintenance and construction of these storages.

E. *Heating and cooling energy demand*

A degree hour is a method used for calculating yearly heating and cooling energy demand on an hourly resolution. Specific energy consumption per m^2 was set to 160 kWh/m^2 per annum, as insulation in Croatia is still not satisfying. As only single pipe was predicted, and the absorber units are centrally located, there is not a possibility of simultaneous flow of both heating and cooling energy in the same time. However, this shouldn't be a problem as there are no large industrial consumers which need to have constant heating energy supply.

F. *Absorbers*

Absorbers in the system are centrally located and thus, cooling energy is distributed via piping. They can be driven by both heat produced from the biomass power plant, or by heat taken from the pit seasonal thermal energy storage. Absorbers should function properly, as the predicted temperature of media in seasonal thermal energy storage is between 85 ^oC and 90 ^oC. Due to lower investment costs, absorbers got preference comparing to adsorbers.

G. *Location of the power plant*

There are several forests which can provide biomass. Only forests owned by state company Hrvatske Šume d.o.o. were taken into account in this model as they can provide stable supply with long-term contract. Coordinates from central point of each of the forests was used for calculations. For the city of Petrinja, in total 52 forests in reasonable distance provide biomass that can be used to fuel the biomass power plant. For the case study of Petrinja, coordinates of additional agricultural land that could be used for planting biomass were unknown, as there is lack of systemized data available. Thus, although the model can calculate with this additional land, for this case study it won't be used. After the optimal location has been chosen, results show names of forests that the biomass was taken from with associated amounts of biomass. For the transportation costs, price of 0.1 € / (km · t) has been used [18]. Nevertheless, *Haversine* formula has been used for calculation of distances between two points. *Haversine* formula calculates distances between two points on sphere. As distances in this model aren't large, difference between the real shape of the planet Earth and sphere is not significant and thus, this formula can be used.

III. OPTIMIZATION MODEL

Optimization variables

Four independent variables exist in this model:

L_{BP} - coordinates of optimal location of the biomass power plant (latitude, longitude)

P_{el} - electricity generating capacity of the biomass trigeneration power plant in kW_e. The heat capacity (P_{el}) is proportional to the electricity capacity, following assumed fixed heat-to-power ratio.

S_V - volume of the storage in m^3

P_A - capacity of the absorber unit(s) in kW

Objective function

Overall objective function is to maximize net present value. In the first step, the model calculates NPV using the fixed biomass price set to 38 €/t. In the second step model tries to improve NPV value by optimal positioning of the power plant in order to save some amount of funds that would be spent on transportation. Larger the savings are, better the improvement of NPV value is. NPV is calculated for the time of 14 years, as this is the time of guaranteed feed-in tariff in Croatia. The NPV function in the first step is:

$$\begin{aligned} NPV = &\left(I_h + I_c + I_{el} - E_{OM,Bf} - E_{OM,Bv} - E_{OM,DHCn} - E_{OM,S} - E_{fB}\right)\cdot D \\ &- Inv_B - Inv_A - Inv_{DHCN} - Inv_S \end{aligned} \quad (1)$$

where discount coefficient D is calculated as follows:

$$D = \frac{1}{\left(1+i\right)^t} \quad (2)$$

where i is the discount rate and t is the project lifetime.

In the second step savings (losses) are calculated as follows:

$$S = \left((T_A - T_R) - DHC_{YL}\right) \cdot D - I_{ADD} \quad (3)$$

Where S are total savings (if comparing to the first step losses occurs, the result is negative) comparing to the first step, T_A are assumed transportation costs in the first step and T_R are real calculated transportation costs of biomass. DHC_{YL} are yearly losses [€] that occurs because of higher distribution network losses due to larger distance between the power plant position and the consumers. I_{ADD} is additional investment cost in the main pipe due to larger distance between the power plant position and the consumers than in the first step.

Overall NPV is then calculated by adding savings (already discounted) to the NPV value from the first step:

$$NPV_O = NPV + S \quad (4)$$

where NPV_O is final net present value.

Income

Income consists of revenues from electricity, heating and cooling energy sales. As the power plant needs to satisfy all the need for heating and cooling energy, it can be assumed that all the heating and cooling energy need for the district considered is sold from this power plant. Income from the heat sales I_h equals:

$$I_h = h_P \sum_{j=1}^{8760} h_j \quad (5)$$

where h_P is the price of kWh of heat, h_j is the hourly value of heat demand (kWh) throughout the year.

I_c is the income from the sales of cooling energy:

$$I_c = C_P \sum_{j=1}^{8760} c_j \quad (6)$$

where C_P is the price of kWh of the cooling energy and c_j is the hourly value of the cooling demand (kWh) throughout the year.

I_{el} is the income from the sales of electricity:

$$I_{el} = E_P \sum_{j=1}^{8760} e_j - e_{pp} \quad (7)$$

where E_P is the price of kWh of electricity, e_j is the hourly value of electricity production (kWh) and e_{pp} is the power plant own electricity consumption throughout the year.

Expenditure

There are five expenditure items, fixed and variable operating and maintenance cost of the biomass power plant, operating costs of district heating and cooling network and thermal energy storage and cost of fuel, which is biomass in this case.

$E_{OM,Bv}$ is the expenditure on variable O&M:

$$E_{OM,Bv} = V \sum_{j=1}^{8760} e_j \quad (8)$$

where V is the variable cost of O&M (€/kWh).

$E_{OM,Bf}$ is the expenditure following fixed O&M cost:

$$E_{OM,Bf} = F \cdot P_{el} \quad (9)$$

where F is the fixed yearly O&M cost (€/kW).

$E_{OM,DHCn}$ is the O&M cost of district heating and cooling network:

$$E_{OM,DHCn} = Z \cdot N \quad (10)$$

where Z is the number of dwellings in district considered and N is cost of yearly network maintenance (€/dwelling).

$E_{OM,S}$ is the O&M cost of storage:

$$E_{OM,S} = U \cdot S_V \quad (11)$$

where U is the O&M price of the yearly storage maintenance (€/m^3).

E_{fB} is the expenditure on fuel (biomass):

$$E_{fB} = B \cdot \frac{1}{h_d} \cdot \frac{1}{\eta_{el}} \cdot \sum_{j=1}^{8760} e_j \quad (12)$$

where B is the price of biomass (€/t), h_d is the lower calorific value of biomass (kWh/t) and η_{el} is the electrical efficiency of the power plant.

In the second step, real transportation costs T_R has to be calculated in order to calculate savings (losses) comparing to the first step.

$$T_R = T_{coeff} \cdot \sum_{j=1}^{k} DIS_{f,k} \quad (13)$$

where T_{coeff} is transportation cost per kilometer per ton and DIS_f is the distance between the k-th forest and the power plant. Parameter k is the number of forests the biomass is taken from.

Investment

The overall investment consists of four parts, investment in the biomass power plant, in absorption chillers, in district heating and cooling network and in the pit thermal energy storage. Investment in the biomass power plant Inv_B is calculated as follows:

$$Inv_B = B_{inv} \cdot P_{el} \quad (14)$$

where B_{inv} is the price of investment per power plant capacity (€/kW$_{el}$).

Inv_A is the price of investment in absorption chillers:

$$Inv_A = A_{inv} \cdot C_{peak} \cdot \frac{1}{COP} \quad (15)$$

where A_{inv} is the price of investment per absorption capacity (€/kW), C_{peak} is the peak demand for cooling energy (kW) and COP is the coefficient of performance of the absorption units. As mentioned before, the model predicted that all the cooling energy needs to be satisfied from this power plant, thus the needed capacity of absorption units is equal to peak cooling demand divided by the coefficient of performance, which was set in this model to 0.7.

Investment in the district heating and cooling network Inv_{DHCN} is calculated as follows:

$$Inv_{DHCN} = N_{inv} \cdot Z \quad (16)$$

where N_{inv} is the investment per dwelling (€/dwelling). In this model N_{inv} was used from Ref. [19].

Investment in the pit thermal energy storage Inv_S :

$$Inv_S = S_{inv} \cdot S_V \tag{17}$$

where S_{inv} is the price of storage investment (€/m^3), which was implemented in this model from Ref. [17].

In the second step additional investment I_{ADD} can occur because power plant is located further away then assumed in the first step. Thus, this additional investment cost has to be calculated:

$$I_{ADD} = DIS_{add} \cdot S_{pipe} \tag{18}$$

where DIS_{add} is additional distance (km) of the power plant comparing to the first step, while S_{pipe} is the cost of the main pipe (€/km).

Constraints

1) *Constraints in the first step*

The heat demand in every hour *j* throughout the year needs to be covered, either by biomass power plant production, by heat stored in PTES, or by both sources of heat:

$$h_{B,j} + h_{S_V,j} \geq h_j \tag{19}$$

where $h_{B,j}$ is the hourly heat production in the biomass power plant and $h_{S_V,j}$ is the heat taken from PTES on an hourly basis.

Heat used in the absorption units needs to cover the cooling demand in every hour *j* throughout the year:

$$\left(h_{B,j} + h_{S_V,j}\right) \cdot \frac{1}{COP} \geq c_j \tag{20}$$

The sum of the heat production capacity of the biomass power plant and the heat from the storage that can be taken has to be larger or equal to peak heat demand:

$$P_{el} \cdot HTP + S_V \cdot \rho_w \cdot c_p \cdot \Delta T \cdot \frac{1}{3600} \cdot \eta_S \geq h_{peak} \tag{21}$$

where HTP is the heat-to-power ratio, ρ_w is the density of water (kg/m^3), c_p is the specific heat capacity of water (kJ/(kgK)), ΔT is the difference in temperature of stored water and the design temperature of the dwellings' heating systems (K), η_S is the efficiency of the PTES and h_{peak} is the peak heat demand (kW).

The cooling energy peak demand needs to be covered in the same manner as the heating energy peak demand:

$$P_{el} \cdot HTP \cdot COP + S_V \cdot \rho_w \cdot c_p \cdot \Delta T \cdot \frac{1}{3600} \cdot \eta_S \cdot COP \geq C_{peak} \tag{22}$$

Storage volume size has to be able to store all the heating energy which needs to be taken at certain time from the PTES:

$$h_{S_V,sum} \cdot 3600 \cdot \frac{1}{c_p} \cdot \frac{1}{\Delta T} \cdot \frac{1}{\rho} \cdot \frac{1}{\eta_S} \geq S_V \tag{23}$$

where $h_{S_V,sum}$ is the sum of heating energy which needs to be taken from the storage in the longest period of time where average biomass heat production rate is lower than heat demand (under the term “heat demand”, “cooling energy demand” is also assumed, which is the same in this model except COP coefficient which needs to be taken into account).

$$e + h \geq P_{el} \cdot \frac{1}{\eta_{el}} \cdot B_{av} \cdot 8760 \cdot \eta_X \tag{24}$$

where *e* and *h* present the produced electricity and heat demand during one year of power plant operation, η_{el} is the electrical efficiency of the power plant, B_{av} is the availability of the biomass power plant and η_X is the minimum overall efficiency power plant needs to have to be eligible to receive subsidy. Today, in Croatia η_X would be 0.50.

2) *Constraints in the second step*

In the second step, all the constraints are connected to the minimum/maximum distance from the central point of the city. The power plant has to be distanced minimum five kilometres from the central point of the city in order not to have heavy trucks carrying biomass through the city. Moreover, the furthest allowed distance of the power plant from the city centre will be set to 14 kilometres as it is assumed that losses after this distance will become too large.

$$\begin{gathered} DIS_H(PP_P - C_{CO}) \geq 5 \\ DIS_H(PP_P - C_{CO}) \leq 14 \end{gathered} \tag{25}$$

where $DIS_H(PP_P - C_{CO})$ is the distance between the power plant position and the central point of the city calculated by *Haversine* formula.

Optimization method

In the first step of the optimization model hybrid optimization was used. In order to increase the speed of calculation the model firstly drives Genetic Algorithm (GA), which is a useful tool for fast approaching to a global optimum. Comparing to the classical algorithms, where a single point is created at each step [20], genetic algorithm generates a population of points at each iteration and thus, approaches global optimum fast. However, near the global optimum GA converges rather slowly, so fmincon is a useful and fast optimization method, when an initial point near the global optimum is known. Thus, in the first step Genetic Algorithm and fmincon were used as optimization methods.

In the second step, the model searches for minimum costs of transportation subtracted by increased costs of distribution network investment. The model searches for minimum transportation costs from every quadrant in the 10 x 10 kilometres network. Thus, the quadrant with the lowest transportation costs subtracted by increased investment cost in the main pipe is the optimum solution, i.e. the largest savings compared to the first step are achieved. Optimization was programmed in Matlab©.

IV. CASE STUDY DESCRIPTION

The model was applied to the city of Petrinja, Croatia. It has a total population of 24,671, living in 8,736 households. Average distance between the household was set to 10m. Average yearly heating energy consumption is 160 kWh/m^2. Input data is provided in Table 1.

Table 1. List of the data used in the case study

	amount	*unit*
Power plant availability	0.9	
Biomass price	36	€/t
Biomass price at forest road	32	€/t
Lower calorific value (30 % moisture)	3,500	kWh/t
η power plant total	0.88	
η_{el}	0.29	
HTP ratio	2.034	
T_{coeff}	0.1	€/(km·t)
S_{pipe} **[21]**	56,700	€/km
B_{inv}	3,600	€/kW$_e$
A_{inv}	400	€/kW
N_{inv}	7,650	€/dwelling
S_{inv}	60	€/m^3
Plant own electricity consumption	6%	
Discount rate	7%	
Feed-in-tariff	0.156	€/kWh$_e$
COP	0.7	
Design temperature for heating	20	^{o}C
Design temperature for cooling	24	^{o}C
F	29	€/kW per annum
V	0.0039	€/kWh
N	75	€/dwelling per annum
U	0.1	€/m^3 per annum
h_P	0.0198	€/kWh
C_P	0.0198	€/kWh
Forestry residue	16%	

Three case studies were performed in order to evaluate the importance of optimization of location of biomass power plant.

The first step of the optimization, the step that chooses the optimal size of the power plant is unique for all case studies. However, different case studies for the second step of optimization will be developed in order to show importance of optimizing location of the biomass power plant. Yearly available biomass equals 132,890 m^3.

Case study I

In the case study I, construction of power plant with capacity of 5 MW$_e$ was assumed (in this case, optimal size of the power plant from the first step of the model will be neglected). This relatively small size of power plant, will show how significant are the differences by choosing the right location for the power plant when biomass supply is significantly larger than the need.

Case study II

In the case study II, complete optimization model will be done in order to fully evaluate the developed model. After the optimal size of the power plant will be calculated, the model will search for the optimal location of the power plant. Moreover, differences between the most favourable location and the least favourable location will be shown. The data from the Table 1 will be used in this case study.

Case study III

In the last case study, several smaller power plants will be assumed. Each of three power plants will have equal capacity. The capacity of the single power plant will be calculated after the optimal size of the power plant will be calculated in the first step of the model. After the first step, optimal size of the biomass power plant will be divided by three in order to have equal final capacity, but in three different power plants.

It is assumed here that power plants will be built one by one, so the first power plant will be optimized according to all available biomass, then the location of the second power plant will be chosen according to remaining biomass and then finally, the location of the third power plant will be chosen from remaining biomass.

In this way, building several smaller power plants, step by step, can reduce capital intensity of the whole investment in the starting point. Moreover, in this case study growth of the price of biomass for each power plant will be observed and evaluated.

V. RESULTS

A. *Case study I*

For the power plant with total capacity of 5 MW, using in calculation the data provided in Table 1., yearly biomass consumption is 37,540 tons. For this type of power plant, south-west position is the most appropriate one with average yearly cost of biomass of 34.91 €/t.

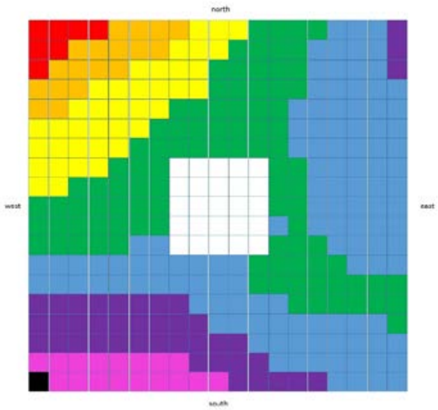

Fig 1. Biomass price in different quadrants (from higher to lower average price: red, orange, yellow, green, blue, purple and pink; the black quadrant represents the optimal solution; white quadrants are subject to constraints and these locations cannot be chosen)

It can be seen from the Fig 1. that potential locations for small biomass power plant are generally better in the south than the north. The best location (coordinates: 45.3523, 16.2199) is located in the south-west (black quadrant). Nevertheless, it can be observed that the cheapest biomass cost and thus, larger the savings are, moving from the north to the south. Yearly savings comparing the best position (south-west) and the worst position (north-west) equals 18,640 €. This saving represents 1.5% of yearly spending on the biomass. The result shows that savings on the small scale are not significant.

B. *Case study II*

In case study II complete model was used. The results from the first step of the model showed that optimal size of the power plant for the city of Petrinja is 21.6 MW. The optimal size of absorber(s) is 15.9 MW as it needs to cover the entire peak cooling energy consumption. The optimal pit thermal energy storage size is 32,765 m^3. The NPV value with the assumed parameters equals EUR 3,808,497.65. It should be noted here again that the assumed biomass price in the first step of the model was 36 € per ton.

Yearly biomass consumption is large and equals to 162,182 tons. In order to obtain this amount of biomass forestry residue should be around 28%.

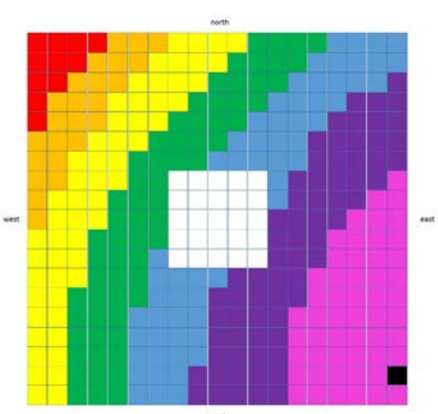

Fig 2. Biomass price in different quadrants

The lowest average biomass price equals 37.21 €/t. The optimal location is located in the south-east (coordinates: 45.3613, 16.3974). The most expensive average price equals 38.53 €/t which is a significant difference. It can be generally observed that average biomass prices reduce going from west to east and from north to the south. The yearly savings comparing the optimal location and the most expensive one is significant and equals 214,568 Euros. That is 3.6% of the yearly spending on the biomass. Comparing to the first part of the simulation, NPV is lower in both cases because assumed biomass price was set to 36 €/t which proves to be too low. NPV, when the optimal location is chosen, equals EUR 2,091,675, while on the least optimal location NPV equals EUR 218,777, which is a significant difference. These results show the significance of the right selection of the location, as the NPV value can soon become less favourable for the economic investment.

C. *Case study III*

In the third case study, three power plants, each with the size of 5 MW_e was chosen to be built in the area around the city of Petrinja. Result for the first power plant can be seen in the results of the case study I (see Figure 1.).

Optimal location of the second power plant (coordinates: 45.5143, 16.3974) with capacity of 5 MW_e can be seen in Figure 3.

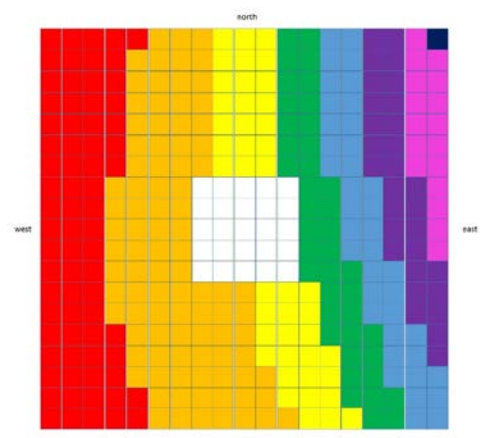

Fig 3. Biomass price in different quadrants

Compared to the first power plant with the capacity of 5 MW_e, the optimal location now is diametrically different. Optimal location for the second power plant is in the north-east, while the optimal location for the first power-plant was in the south-west. The average biomass price has also become more expensive and at the optimal location equals 35.99 €/t, while on the most expensive location equals 37.53 €/t. Thus, the yearly saving that can be achieved equals 57,830 EUR, i.e. 4.3% of yearly spending on the biomass.

The optimal location of the third power plant (coordinates: 45.3523, 16.3974) can be seen in Figure 4.

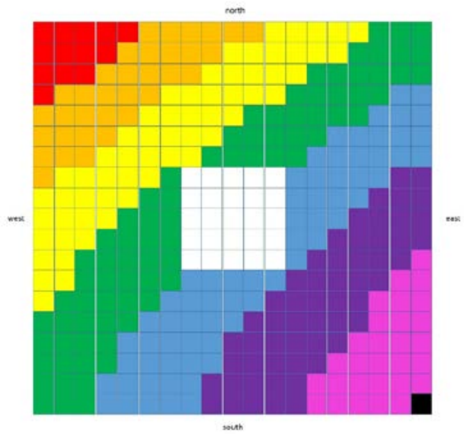

Fig 4. Biomass price in different quadrants

For the third power plant with capacity of 5 MW_e, the optimal location is located in the south-east. It can be observed that the average biomass price reduces gradually from the north-west to the south-east. The average biomass price on the optimal location equals 38.92 €/t, while on the most expensive location equals 40.53 €/t. Thus, the yearly saving on biomass by choosing the optimal location can reach 60,698 EUR, i.e. 4.2% of the yearly spending for the biomass.

It is good to look again at the optimal locations of the three biomass power plants, each with capacity of 5 MW_e. The first one was located in the south-west, the second one in the north-east and the third one in the south-east. It shows how the optimal location can be easily changed, if the biomass from the one location is reserved for some other purposes, and thus, not available for the power plant.

VI. CONCLUSIONS

In this paper, several case studies were performed in order to assess importance of choosing the optimal power plant location. Several conclusions can be made from this analysis:

- By increasing the power plant size, the saving in biomass costs increases significantly comparing to the smaller power plants
- Reserved biomass for other purposes and thus, unavailability for the current project changes the power plant optimal location dramatically
- Several smaller power plants will have quite different optimal locations than the one large scale power plant
- NPV value can significantly change by choosing non-optimal locations
- Choosing the optimal location of the trigeneration power plant can significantly improve the economic parameters and move the project towards economic profitability for the investor

ACKNOWLEDGEMNT

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Prospects for cost-effective integration of renewable energy sources

Liviu Ruieneanu, Mihai Paul Mircea, Marian Ciontu and Ion Gosea

Abstract**—** Increasing the quota of RES in the energy mix represents both a necessity and a challenge of our days, complicating the operational problems of the modern energy systems. In our paper we have analyzed various scenarios for a sustainable development of the energy system in terms of system flexibility and energy cost evolution caused by the integration of RES. Partial load operation, inappropriate operation regimes and fast load variations tend to reduce the lifespan of conventional power plants when operating in parallel with RES and, in the same time, to increase the costs of the main companies operating on the market.

Despite these obvious drawbacks we believe that it is still possible to maintain the energy price evolution within reasonable limits.

We have considered cogeneration, the use of multiple boilers per unit and CCS as methods to increase the flexibility of conventional coal power plants. For each of these methods we have estimated the evolution of the energy cost in order to evaluate the potential of each method.

Keywords**—**high flexibility conventional power plants, cogeneration; RES; CCS.

I. Introduction

THE intensive support policies have caused a rapid integration of RES sources in the energy mix (responsible for 25 % of the electrical energy generated today in Romania).

This fast evolution of the energy sector had also important drawbacks both in terms of energy costs and reliability. Due to their large costs, the energy storage units are almost inexistent and the support policies have a negative impact over the market self regulatory effect, as renewables have priority to the grid.

These particular conditions tend to gradually decrease the quota of the energy generated by the conventional power plants as new plants based on renewable energies become operational.

However the new EU targets for the RES development in the near future as well large scale promotion of energy efficiency will complicate even further the situation of the Romanian energy sector.

The operation under these new conditions will implicate new relations between the main actors of the energy market.

A possible evolution of the actual situation might necessitate an active support from the conventional steam and gas turbines power plants in the compensation of renewable energy sources. In this paper we have estimated the energy generation cost variation in the hypothesis of an increased renewables presence on the energy market.

For this purpose we have analysed the operation of a conventional coal power plant in parallel with a wind farm.

In the paper we have used the power plant efficiency, determined as:

$$\eta_P = \frac{E_{pl}}{Q_{eppl}} \tag{1}$$

Where:

Epl- Electrical energy generated by the power plant.

Qeppl- Primary energy of the fuel.

In a similar way it might also be defined an equivalent efficiency for the entire system (power plant and wind farm) as follows:

$$\eta_{sys} = \frac{E_s}{Q_{eppl}} = \eta_P + \frac{E_w}{Q_{eppl}} \tag{2}$$

Where:

Es- Electrical energy generated by the system;

Ew- Electrical energy generated by the wind farm;

In order to highlight the integration of the wind turbines all the calculation where made in relation with the quota of the electricity generated by the wind turbines:

$$f_r = \frac{E_w}{E_s} \tag{3}$$

L. Ruieneanu is with the University of Craiova, Faculty of Electrical Engineering, Decebal Boulevard, no.107, Craiova, Romania; e-mail: lruieneanu@elth.ucv.ro. +40728902505

M. P. Mircea is with the University of Craiova, Faculty of Electrical Engineering, Decebal Boulevard, no.107, Craiova, Romania; mmircea@elth.ucv.ro

M. Ciontu is with the University of Craiova, Faculty of Electrical Engineering, Decebal Boulevard, no.107, Craiova, Romania; mciontu elth.ucv.ro

I. Gosea is with the University of Craiova, Faculty of Electrical Engineering, Decebal Boulevard, no.107, Craiova, Romania; igosea elth.ucv.ro

II. PARALLEL OPERATION OF COAL POWER PLANT WITH BOTH BOILERS IN OPERATION

The parallel operation of coal power plants and RES is relatively difficult due to the slow response of the conventional plants.

This type of operation could be facilitated by the use of hydro power plants or energy storage systems that act as a buffer for the compensation of slow ramp rates of the coal plants (usually 4..5 MW/min).

At the parallel operation with a wind farm the overall cost for the energy generated by the conventional plant is also negatively influenced by the partial load operation both in terms of a decreased efficiency and of the redistribution of the fixed costs (such as annuities, personnel and maintenance) to a lower income (caused by the drop of the energy sales).

The analysed coal power plant operates in the vicinity of our town and has an installed power of 315 MW. The power plant has two 510 t/h Benson type boilers.

We have considered that in all the analysed cases the conventional plant operated in parallel with a wind farm.

In all the analysed cases we have considered for the wind farm an energy generation cost of 90€/MWh in accordance with the energy cost of various wind farms operating in Romania and at the EU level [3].

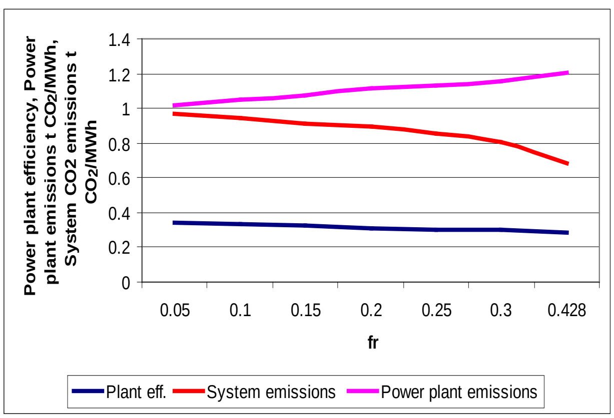

Fig. 1 The parallel operation of the power plant in parallel with a wind farm.

The graph (fig. 1) shows that the maximum power quota of the wind turbines (fr=0.42) was determined by the minimum operational power of the conventional power plant's group (180 MW). The quota of the wind turbines power will decrease with overall system power demand.

The graph also shows that the integration of the wind farm decreases the entire system CO_2 emissions, even if the emissions at the level of the conventional power plants are higher than before due to partial load operation.

In simple words this means that a CO_2 tax for the entire system conventional plant – wind farm will decrease the avoided CO_2 cost while a tax applied only for the conventional plant will increase it. For a correct calculation of the overall energy cost one has also to consider the indirect costs such as the reduction of the production, maintenance costs and other costs increases caused by the inappropriate operation regimes (especially for CHP plants).

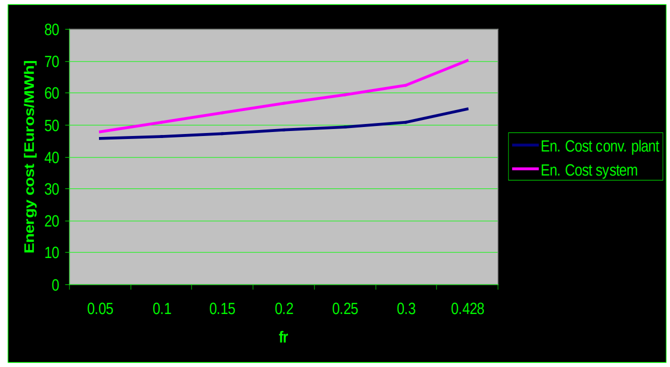

Fig. 2 Electrical energy cost for the conventional power plant and the conventional plant - wind farm system

For the conventional power the energy cost increases due to the partial higher coal specific consumption caused by the lower efficiency and an increased quota of the fixed expenditures such as personnel and maintenance costs in the overall energy cost. However the situation might be convenient for conventional plant since ,in Romania, the wind farm has grid priority (despite the higher energy price).

III. THE ADVANTAGE OF MULTIPLE BOILERS PER UNIT

By remaining with a single boiler in operation the conventional plant reaches its lowest possible operation point.

Fig. 3 shows that the operation in parallel with wind farm ensures very low CO_2 emissions.

The operation with only one boiler it's necessary only when the quota of the energy generated by the wind farm is higher than 42 %.

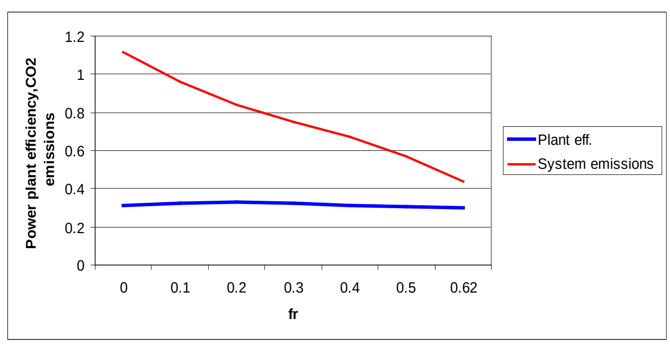

Fig 3 System emissions and the power plant operation efficiency.

The most important drawback of the method resides in the low ramp speed of the coal power plant.

If the other boiler is maintained in hot reserve the ramp speed is around 1,5 MW/min. In this case in order to reach the nominal unit power 315 MW (with both boilers) from the lowest operation power (118 MW), the power plant has to gradually increase its load for a 2 hour period.

The cost analysis depends largely of the influence of conventional plant fixed costs (such as personnel and maintenance costs) over the overall cost for energy generation.

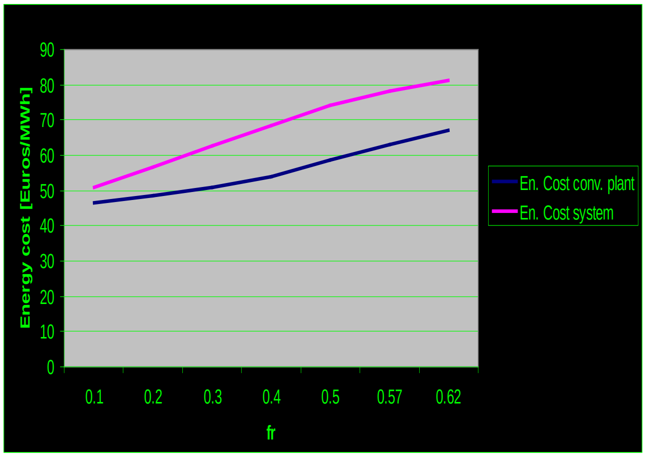

Fig. 4 Cost analysis for the two boiler unit.

IV. The use of CHP plants in PARALELL WITH THE WIND FARM

A few years back, the analysed power plant provided heat to a series of greenhouses situated in its vicinity. Due to the past operation as a combined heat and power plant there are 5 peak boilers still operational.

The use of steam extraction turbines in combined heat and power groups would allow a further increase of the electrical energy quota produced by renewable energy sources. The strict connection between the generated power and the heat output of a steam extraction turbine might be used to increase the flexibility of the power supply of the conventional power plants.

The condition is the use of oversized peak boilers that might provide the entire heat demand of the consumers (not only the peak load).

The use of oversized peak boilers is somehow common practice for many combined heat and plants, because in this way the plants might provide heat to the consumers when a malfunction occurs.

By increasing the quota of the heat produced by the peak boilers or by using exclusively its peak boilers, the plant increases its power by shifting from cogeneration to separate production of electricity and heat.

The superior efficiency of cogeneration combined with the increased quota of the wind farm leads to an important decrease of the CO_2 emissions (fig. 5).

The use of CHP plants in parallel with RES extends the power reserve of the system (CHP plant – wind farm). Due to cogeneration the lowest limit for the conventional plant power decreases from 180 MW to 132 MW. This allows an increase for the electrical energy quota of the RES to 0.57 (from 0.429 for the first case).

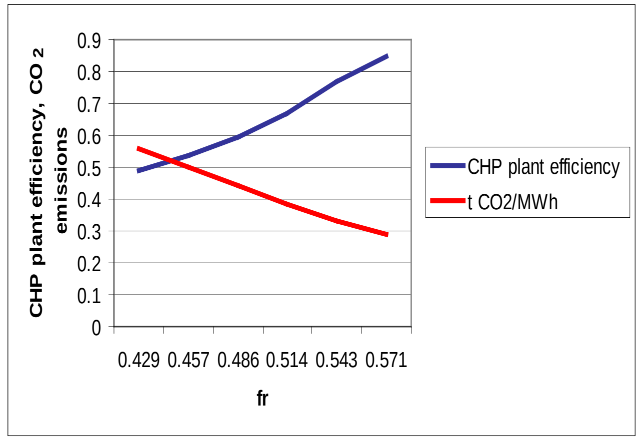

Fig. 5 Operating at the nominal thermal load

The flexibility of the steam extraction turbine CHP plant – RES system is largely determined by the momentary heat demand of the consumers. In this case it is possible to define an operation domain (for the maximum and minimum power of the conventional plant – RES system) and a **safe** operation domain for the conventional plant – RES system (that is the power domain where the conventional plant acts as a power back-up for the RES).

Table 1. Safe operation domain for the CHP plant – RES system vs. the thermal load

	System operation domain [MW]	**Safe operation domain [MW]**
100% heat demand	132.5-500	132.5 – 315
50 % heat demand	156- 473	156 – 315

The costs for the generation of the useful energy (electrical energy and heat, in this case) are smaller in this case, due to the operation of the conventional plant in cogeneration regime.

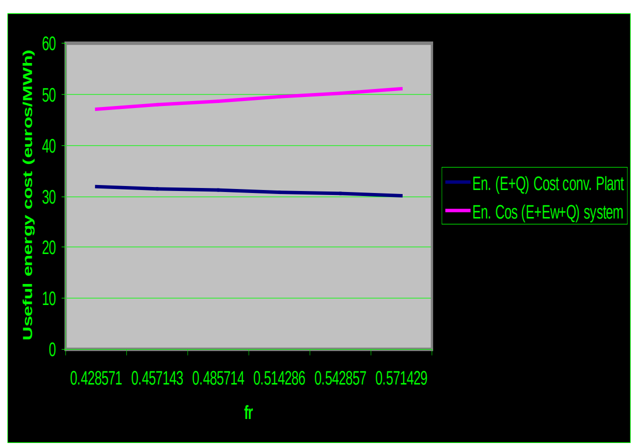

Fig. 6 Cost analysis for the operation of the CHP plant in parallel with the wind farm

V. The use of postcombustion CCS as method to increase the flexibility of a conventional power plants

Usually CCS is regarded as an alternative to the renewables in the attempt to decrease the CO_2 emissions. Here we shall try to point out that some post-combustion CCS methods have the potential to increase the flexibility of conventional plants thus contributing to the compensation of renewables.

The first Romanian CCS Demonstration Project will be developed for an existing 330 MW unit of the Turceni Power Plant in Oltenia, Romania.

For the CO_2 capturing systems, the plant engineers will adopt Alstom´s Chilled Ammonia post-combustion carbon capture technology.

We find this method to be particularly interesting for RES integration due to its specific high energy consumption. This high consumption allows an increased installed power for RES plants within a conventional power plant-RES system.

Our first estimations show that some CCS methods lead to an important decrease of the lower operation point of the power plant caused by the CCS system high consumption of energy. In fact for the steam turbine power plant analysed here, the operation of a Chilled Ammonia post-combustion CCS system will lower the minimum injected power to 40 % of the installed power (compared with 60 % without the CCS system).

In order to play an active role in the compensation of renewables we have considered the possibility of releasing the power plant emissions into the atmosphere when the safety of the power plant -wind farm system requires it. The system safe operation domain is dictated by the lower and upper limit for the power injected by the conventional coal power plant

Table 2. Safe operation domain for the coal power plant with a post-combustion CCS system operating in parallel with RES

	Safe operation domain [MW]
Coal power plant –wind farm system with the CCS system always in operation	126-221
Coal power plant –wind farm system with a discontinuous operation of the CCS system	126-315

In practical terms, the CCS system would be shut down only when the conventional plant has to inject more than 221 MW.

The period when the CCS system is not in operation might be decreased by a slight oversize of the wind farm increasing its self regulatory capacity.

The CO_2 emissions depend on the efficiency of the CCS system and could be considered neglegible when operatinf in parallel with a wind farm,

The use of the wind might compensate also the power drop caused by the CCS system.

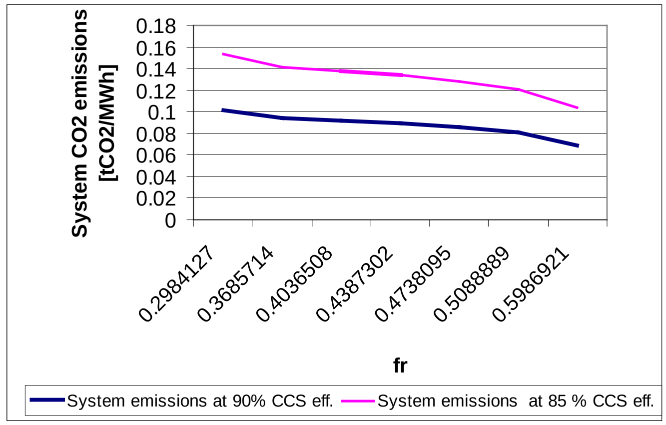

Fig. 7 System (power plant – wind farm) CO_2 emissions with a discontinuous operation of the CCS system

The efficiency of the power plant - wind farm system becomes equal to the previous power plant efficiency and might even overpass it if the wind farm is oversized.

The avoided CO_2 cost calculations show a slight increase from the previous case. However CCS could be used in parallel with other methods in order to achieve higher quotas for renewables in the energy mix (more than 60 %).

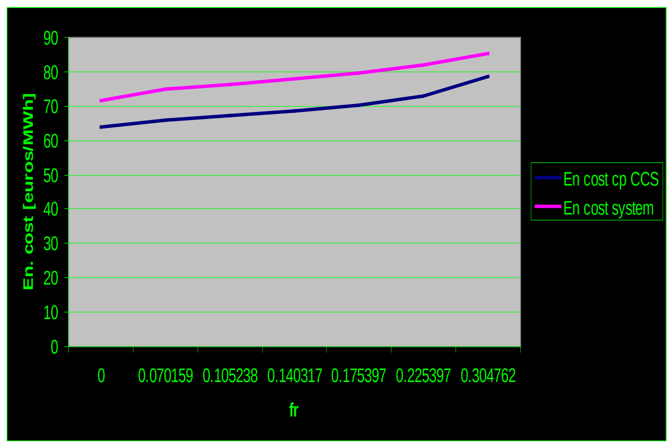

Fig. 8 Cost analysis for the use of post combustion CCS as a flexibility method

The graphs from fig. 8 show that the generated energy cost is very high in this case.

However we do believe that the power plants that use this post combustion CCS might contribute to the power reserves of an energy system. In this case conventional power plants would release the CO_2 in the atmosphere when other RES compensation solutions fail.

VI. Conclusion

Larger quotas for RES in the energy mix would necessitate new and innovative ways to reduce even further the lower operational limit of the conventional plants.

New gas turbine power plants have the advantage of high ramp speeds that facilitate the integration of RES decreasing in the

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same time the necessity for energy storage units at the level of the energy system.

However for the countries with important coal reserves, the development of flexible conventional steam turbines power plants and RES systems might be a more convenient, and even a safer alternative for fuel supply.

The use of coal power plants with multiple boilers per unit in parallel with RES has the advantage of a low energy cost beside the higher load flexibility. Cogeneration and even more trigeneration increase the fraction of the total power that might be generated by RES for a certain consumers demand.

The costs are also smaller. The superior efficiency of cogeneration decreases the negative financial impact of RES integration.

CCS might be regarded also as a method for increasing the flexibility of conventional power plants beside the reduction of CO_2 emissions. Even if the energy cost is slightly higher in this case, it might prove itself very useful for higher quotas of renewables in the energy mix.

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Identifying Family Businesses: The Surname Matching Approach

Ondřej Machek, Daniela Kolouchová, Jiří Hnilica

***Abstract*—**Family business has received considerable academic attention in the past decades. One of the most contentious issues is the very definition of family business, since the results of research studies with different definitions provide different results. Obtaining a comprehensive database of family businesses may be difficult when companies have no legal obligation to disclose if they are family firms or not. In this article, we present the surname matching approach to obtain a large sample of family firms. Besides the method, we also illustrate its use in the Czech Republic. Although employing arbitrary judgement, we believe that there exists no other way of obtaining a comprehensive database of family businesses when companies have no disclosing obligation.

***Keywords*—**Family business, database, surname matching, Czech Republic

I. Introduction

THE fact that for many the phrase "family business" connotes a small or medium-sized company with just a local significance does not reflect the powerful role that family-controlled enterprises play in the world economy. They also include companies like Walmart, Samsung, Tata Group, Estee Lauder and Porsche, and account for more the 30% of all companies with sales in excess of $1 billion [1]. In most countries, regardless of company size, family businesses account for a major share of business ([2] (United States), [3] (Spain), [4] (Chile), [5] (western Europe), [6] (Australia), [7] (Germany)). As such, family businesses make a significant contribution to employment, turnover, added value, investments and accumulated capital [8].

Therefore it is no wonder that interests of academicians have been attracted towards studying family businesses. However it is important to mention that family business as an academic discipline is relatively new. The first professional association, Family Firm Institute, was established in 1986. Family Business Review, the first scholarly publication devoted exclusively to exploration of the dynamics of family-controlled enterprise, was established in 1988 [9]. The importance of the topic is further highlighted by establishing "Centers for Family Business" at prestigious universities in the world (e.g. St. Gallen University; Center for Family Enterprises at Kelogg School of Management; Research Institute for Family Business at Wirtschaftsuniversität Wien; etc.)

While in many countries of the world, family businesses have received considerable academic attention, in post-communist European countries, the role of family businesses remains relatively undiscovered. Among these countries, we may cite Poland, Hungary, Slovakia, Romania, Bulgaria, or Croatia, among others.

While at the beginning of 1990´s we could hardly speak of any family businesses in these countries (with possibly an exception of those somewhat drawing upon the heritage of their predecessors who ran their own family businesses before the nationalization which occurred after the Second World War), then some 25 years later it is quite common that owners already have transferred their businesses to their heirs or have at least started considering it. From this perspective the reality of family businesses in post-communist countries including the Czech Republic resembles the situation in other countries around the world.

In the Czech Republic the role of family businesses has been particularly neglected. Some research has already been conducted ([10]-[14]), but it does not by far reflect the intensity devoted to this topic in the international academic literature.

One of the most contentious issues in family business studies is the very definition of family businesses, i.e. what actually constitutes a family firm. In the literature review, we present the most widely used approaches. Generally, family firms have no legal obligation to disclose whether they are family businesses or not. However, obtaining a database of firms based on a theoretical definition is often impossible since sometimes, qualitative aspects or unmeasurable statements are used in the existing definitions. Therefore, the possibilities of obtaining a comprehensive database of family firms are very limited.

One possible approach to obtain a sample of family firms is to use stratified random sampling. For instance, one may choose a sample of 1,500 random firms and then, using a questionnaire survey, filter firms which identify themselves as family firms or otherwise fulfil a requirement on family firms [15]. Such approach can be used to obtain a representative

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O. Machek is with the Faculty of Business Administration, University of Economics, Prague, Czech Republic (e-mail: ondrej.machek@vse.cz).

D. Kolouchová is with the Faculty of Business Administration, University of Economics, Prague, Czech Republic (e-mail: daniela.kolouchova@vse.cz).

J. Hnilica is with the Faculty of Business Administration, University of Economics, Prague, Czech Republic (e-mail: hnilica@vse.cz).

sample of family firms, but surely will not result in a comprehensive database of family firms.

In this article, we present the use of surname matching approach to identify family businesses. The successful use of surname matching in other sciences when investigating ethnicity [16], proportion of a group in a given population [17], triangulating identity of a target in genomics [18], or exploring a family history [19] reflects the potential of family names to be used to find relatives. We will show that it can also be used when identifying family firms.

II. Literature Review

The family business discipline has been establishing in multiple directions. In this section, we will present the main areas of interest of family business. First, we will discuss the issues of defining family businesses. Subsequently, we will present a brief overview of differences between family and non-family businesses in terms of performance and capital structure. Finally, we will discuss governance and management issues.

A. Defining family business

The very definition of family business is crucial because usually the research outcomes do compare family and non-family businesses from many perspectives. A number of possible definitions can be found in the past research.

Rosenblatt et al. [20] defined family business as a company where the majority of ownership or control rights are possessed by one firms and in which two or more family members are involved. Leach [21] defined family business as a company where family members possess at least 50% of ownership. Among other frequently cited definitions, we can cite the definition where a family owns 20% or more of voting rights [22]. We may also mention the definition of Klein [23] who used a special indicator, called SFI (substantial family influence), to measure the family involvement as a sum of shares of a family in management, ownership and supervisory boards.

In spite of the fact that there is no unanimous agreement upon it, it seems that each definition of family business explicitly or implicitly includes three dimensions [24]:

1. one or several families hold a significant part of the share capital;
2. family members retain significant control over the company, which depends on the distribution of capital and voting rights among nonfamily shareholders, with possible statutory or legal restrictions;
3. and family members hold top management and/or supervisory board positions.

Such criteria are also called “involvement” criteria [25] since they deal with the involvement of family in different areas of control over a company.

Other approaches involve the “essence” approach which include the “intention for succession”, self-identification as a family business, or behavioural aspects (“familiness”) as distinguishing factors of family firms. For instance, Chua et al. [26] defined family business as “a business governed and/or managed with the intention to shape and pursue the vision of the business held by a dominant coalition controlled by members of the same family or a small number of families in a manner that is potentially sustainable across generations of the family of families”. An alternative definition was presented by Habbershon and Williams [27] who proposed that “family firms should be distinguished by the presence of unique and synergistic resources and capabilities arising from family involvement and interactions between family members”. The difference between the two definitions is clear; Chua et al. [26] require the vision of continuing a business across multiple generation, while Habbershon and Williams [27] require the behaviour of companies to produce positive/negative synergistic outcomes.

Researchers (e.g. [28]) conclude that due to unique institutional legal contexts in countries across the globe it makes no sense to come up with a definition that could be universally applicable. Nevertheless each study must explicitly state what is understood under the family business because different definitions do lead to different findings [29].

The European definition of family business [30] is as follows:

- In the case of the non-listed firm, the majority of votes is in possession of the natural person(s) who established the firm, or in possession of the natural person(s) who has/have acquired the share capital of the firm, or in the possession of their spouses, parents, child or children’s direct heirs. Listed companies meet the definition of family enterprise if the person who established or acquired the firm (share capital) or their families or descendants possess 25 percent of the right to vote mandated by their share capital.
- The majority of votes may be indirect or direct.
- At least one representative of the family or kin is involved in the management or administration of the firm.

Note that this definition does not require multiple relatives from a family to officially participate in ownership or management.

The academic debate on whether “involvement” criteria are sufficient or they should be accompanied by “essence” criteria is still open and will deserve academic attention.

It is noteworthy that all definitions mentioned in this overview do not define what actually constitutes a family. Whether the family includes the nuclear family, extended family or segment of the extended family, is still not clear-cut [24]. To close the discussion, we will present the overview of De Massis et al. [24] of recurring criteria used to define a family business (see Table 1) in past studies (until 2012). Obviously, the “involvement” criteria have been by far more prevalent than other criteria.

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Table 1: Criteria used to define a family business

Definitional criterion	Frequency (%)
Ownership	79%
Management	53%
Directorship	28%
Self-identification	15%
Multiple generations	9%
Intra-family succession intention	7%

Source: Adopted from De Massis et al. [24].

B. Performance differences between family and non-family businesses

While a large number of empirical investigations find superior financial performance of family businesses compared to non-family ones (e.g. [22], [31], [1]), other authors, such as Dyer [32] and O'Boyle et al. [33] find no significant main effects. According to a recent study, there exists an economically weak, albeit statistically significant, superior performance compared to non-family firms [34]. A matched-pair investigation of Czech family and non-family businesses has been carried out with a sample of large and medium-sized companies [14] finding that family firms were performing better in terms of profitability (however, the analysis was not based on random sampling, so the results cannot be generalized, but they suggest that there exist differences between these two classes of companies).

The differences are often explained by a more effective management due to familial nature of businesses, with the following emphasized:

- Reduction of agency costs: The separation of ownership and control in companies may lead to agency costs. Since the interests of owners (principals) and hired managers (agents) are not the same, managers may act in order to maximize their own utilities instead of those who hired them [35]. This separation can be mitigated in family businesses as managers in family businesses (often family members or family "friends") act more like stewards ([28], [36]). However, other authors suggest that with family altruism and conflict between majority and minority shareholders, principal conflict can exist, offsetting advantages.
- Long-term orientation of the shareholders´ family: The intention of family business owners is usually to preserve the family inheritance for its transmission to following generations. This leads to better investment policies in comparison to non-family businesses ([37], [38]).
- Reduced levels of debt in balance sheets: Modern corporate finance considers a judicious amount of debt as a good thing because through financial leverage it may create value. On the other hand debt decreases room to manoeuvre if a setback occurs. Family firms tend to be more risk averse and as a result carry less debt ([1], [39]). Therefore they do not need to make big sacrifices to meet financing demands during recessions.

C. Goals and Objectives of Family Firms

It is generally assumed that firm-value maximization is not the only objective of family firms [40]. A number of authors, such as Stafford et al. [41], find evidence of family-centered goals. Such goals have been classified into economic and non-economic goals, such as wealth creation, maintaining socio-emotional wealth [42] and family harmony, as well as providing employment to family members. The management's choice between family-centered and other goals may be determined by family values [25]. It seems that family ownership itself is not the sole predictor of the adoption of family-centered goals [43]. However, the importance of economic and non-economic goals and their relation to performance remain a challenge for future researchers. The academic literature has been particularly silent on the goal formulation process in family firms [24].

D. Management and Corporate Governance

The most discussed topics in this area of research have been professionalization (such as employing non-family CEOs) and succession (transition of the firm to the next generation). Past literature has been focused on modeling the professionalization process and on the practices necessary to support the integration of non-family members into companies. However, this research topic remains emerging and fragmented [24]. The effect of professionalization on performance has also received academic attention but remains a relatively unexplored area.

Succession belongs to the critical points in the life-cycle of a family business. It is estimated that only one third of family and businesses survive into the second generation [44].

III. Methods

The surname matching approach is based on a repeated search for matches in family names of people involved in management/control and ownership of companies. It can be seen as one of the "involvement" criteria mentioned in section II.A. As such, it required a comprehensive database of all companies on which the search is applied.

Databases provided by public (government offices) or private (such as Creditinfo Group or Bisnode Group which operate in multiple European countries) institutions have become a classical source of financial data for research studies. Such institutions typically serve as providers of credit information and risk management solutions and gather data on all companies with registered identification number or any other kind of ID, such as Tax Identification Number (TIN) in most European countries. Besides financial data obtained from financial statements and annual reports, such companies also provide data on people in management, ownership and in supervisory boards. When it's possible to make queries on such databases, the surname matching can be applicable.

The first step in our surname matching approach is to filter all records where the following conditions are met:

1. Among owners there are at least two individuals with the same surname, or
2. within the supervisory board there are at least two individuals with the same surname, or
3. within the management board there are at least two individuals with the same surname.

The procedure will result in a rough set of firms which may or may not be true family firms.

The second step is to manually check all records for possible mistakes. Although it may be a time-consuming procedure, it can be simplified by verifying the matched surnames in management, ownership and supervisory boards. To see why this procedure is necessary, consider the following situations.

- There are only two people with the same surname, a husband and wife. The husband controls 90% of the company, the wife controls the remaining 10%. In this case, the family influence is not strong, so the company is unlikely to be a true family business.
- There are three people with the same surname (a man, his wife and his son) who jointly control and own the company. In this case, it's obvious that the company is a true family business.

The advantage of surname matching is the possibility of obtaining the exact shares of a family in management, ownership, and supervisory boards, if this information is available.

Among the possible disadvantages, we can consider that firms with the same extent of family involvement may not consider themselves family firms [29], so the "self-identification" and "intention for succession" can't be confirmed.

IV. Results and Discussion

We selected all Czech companies with registered tax identification number whose financial data are included in the Bisnode's Magnus database [45]. The criteria for inclusion were having more than 50 employees and a greater turnover than 30 mil. CZK. The sample of all such firms contained 10,285 companies.

After having applied the surname matching algorithm to this sample of firms, we obtained 3,349 companies marked as family firms. Out of these companies, we selected 2000 subjects with the largest headcount. Then, we carefully checked all records for possible mistakes in order to obtain a reliable sample of family firms with a considerable family influence. During this step, of course, some degree of arbitrary judgment was inevitable. The most frequent sources of mistakes or uncertainty were namesakes (accidental occurrence of the same last names, especially the most frequent Czech family names such as Novák or Svoboda, in which case the kinship cannot be confirmed) and marginal family influence (for instance, two relatives among tens of other non-related people in the supervisory board, in which case the company is clearly not a pure family business, or relatives in insignificant positions such as press officers).

We deleted 34.6% companies of the sample which means that in 65.4%, the matching by surnames was correct. The final sample contains 1,308 firms which can be objectively classified as family businesses. Such a sample is large enough to test performance gaps between family and non-family firms; in our meta-analysis [46] we found that the average sample size in past 78 most important studies was of 936 firms, while the median was of 465 firms.

To gain a better image on the efficiency of our surname matching procedure, we compared the database of 50 largest Czech family firms presented by Forbes in 2014 [47] with our database. The algorithm didn't detect 11 companies of this ranking, so 39 companies have been identified correctly. The most frequent reasons for these mistakes were the fact that the real owners could not be found (place of business abroad, especially in Cyprus).

Generally, when applying the surname matching approach, several issues should be taken into consideration:

- Naming customs in the country. For instance, family names of spouses in Slavic countries (Czech Republic, Poland, Russia, etc.) usually end in –ova;
- Relatives may own or control a company via an intermediary company (legal person). There may be intermediary companies which are located in tax havens (such as Cyprus) where the real owner will be hidden. In this case, we cannot confirm the family ties.
- The algorithm will not detect companies where relatives are not officially involved in ownership or management but contribute to a substantial part of the firm's success by various types of work, help and support.

V. Conclusion

Obtaining a comprehensive database of family firms is contentious since usually, family firms are not obliged to disclose whether they are family firms or not. Besides that, it is still not clear-cut what actually constitutes a family business and how to define it.

In this article, we presented the use of surname matching to detect family businesses. Although it is necessarily affected by errors such as accidental namesakes or impossibility to find the real owner, it allowed us to create a first larger database of family firms in the Czech Republic which is large enough to empirically test performance differences between family and non-family firms.

Such database can be used to collect further non-financial data, for instance, using phone interviews combined with on-line questionnaires with decision-makers (like CEOs) on goals and objectives, perceived opportunities and threats, succession issues, or professionalization.

The further research will be focused on building a greater database of family firms. Especially small firms must be included to the sample since their importance in the economy is crucial.

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Aggregation of Environmental Data

Bohuslav Sekerka, Ilona Obršálová, Petra Lešáková

Abstract—The paper deals with environmental data measuring and related problems. The main problem is undefined relation. On one hand, there are subjects which produce harmful substances or activities; on the other hand there are harmed subjects. The first subjects are known, those are the owners of the activities which cause damage while the other subjects are unknown. This leads to the fact that damage quantification and their value are practically not exactly measurable. It is, however, possible to work with assumptions and solve partial problems. The mathematical view sees it as defining scalar representatives of the comparative indicators such as prices. The paper draws attention to the fact that the literature often presents incorrect conception, e.g. the price level is defined by basic price index. The base has an assigned unit level. The indexes in general are, however, indicators of changes.

Key words—Aggregate indicator, damage measurability, environmental data, macro level

I. Introduction

THE undesirable activities are brought by the modern civilization. These activities might unfavourably influence the life on this planet and are connected to long-lasting and repeated creating of outputs on a large scale. It is not only the impacts of air and water pollution and landscape destruction but these activities are also related to damaging the natural resources such as tropical rain forest cutting which harms the circulation of water in all its forms.

The undesirable phenomena and activities are a result of human activities. They are usually not connected to the needs of people as such but to stockpiling of human-created tools such as money, financial capital, company profits and increasing of diversification among people.

To simplify, let us consider pollution caused by harmful substances emissions and let us answer such questions as:

What is pollution?
Who pollutes?
What is the rate of pollution bearing capacity?
What are the results of pollution?
What influence does the pollution have on the environment?
How much does it cost and what profits does it bring?

Modern technologies require processes which are connected to harmful substances emissions or other undesirable phenomena.

For decision tasks of these issues is necessary to create indicators. These indicators will have different levels of aggregation.

II. Selected Environmental Data and Attributes of Indicators

The data usually have three basic attributes:

- factual aspect of the indicator defining its meaning
- place or places the indicator relates to
- time of period which is described by the indicator

The meaning of the indicator must be defined clearly and unambiguously. It needs to reflect the particular occurrence or process complexly. It may not be in conflict with other indicators and cannot duplicate any other indicator.

The particular occurrence or process might be divided into parts while it is necessary that the parts are delimited clearly, must be disjunctive and their unification has to cover the full occurrence or process.

The place is defined by the area which the indicator is related to. This area might be e.g. a country, region as well as geographical area etc.

Time or Period

The indicator describes an entity which belongs to a certain time or time period. We mark the time stamp with a symbol, e.g. "t" or "s". The symbols defining time are usually attached to the indicator in the form of index.

A time period is a time interval <s, t) determined by two time stamps s and t where s<t. The time s is the beginning of the period while time t is the end. The length of a period is the difference between the end and the beginning, i.e. t-s.

Sometimes the interval <t-1,t) is called also as t. The fact whether we talk about time or interval is visible from the circumstances. Interval <t,t+dt) with a very short length of dt is call infinitesimal interval and dt is a infinitesimal magnitude.

A. Undesirable Phenomena and Activities

Let us use a simple example of heat production to demonstrate the complexness of the undesirable activity quantification.

It can be seen that heat production is connected to activities which depend on: necessary amount of heat, burnt substance, utilizing waste from burning, waste disposal, cost of equipment for burning, operational cost, cost related to damages from burning, cost for reducing damages, price of heat and yield from operations, price of emission damages, sustainability of activity, repeatability, etc.

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As for damages, it is necessary to follow the sequences of causes to quantifiable impacts, e.g. dispersion of selected pollutants and the impact on a particular group according to the selected character of damage (via dose – response).

Besides the obvious damages there are activities which produce future danger.

B. Some Economics Solutions in Terms of Environmental Economics

The economics of environment is a part of economics science which attempts to define the value of damaged environment, the cost to remove pollution and preserve nature and - more generally - puts emphasis on the need of an efficient policy to protect the environment. Certain production cost stand outside the production subject, therefore they are an externality; especially damages on environment are often cost that the producer does not have to cover. Negative externalities should be included to the economic calculations of all economic subjects; the cost of the nature should become a part of the cost of the producer. This leads to two questions:

- Is it possible to determine the cost of nature in all its form in a monetary form?
- How to internalize the cost of the nature to the internal cost of a production subject?

Utilizing Ownership Rights

Ronald Coase, a supporter of neoliberalism, suggests using the principle of ownership rights (for natural resources). There are two options:

- The producer disrupting or polluting the environment has the right to this behaviour (e.g. ownership) and it depends on the aggrieved to preventively compensate this potential polluter for the loss of profit by not using this right. E.g. a neighbour who is annoyed by noise from a workshop buys silence from the workshop owner and compensates him for not being able to make money.
- The other solution is derived from the assumption that the right for resource ownership (e.g. right for silence) is in the hands of the aggrieved. Therefore, the victims will be compensated for loss by the producer disrupting or polluting the environment.

In both cases, it is possible to express the cost monetarily.

This system cannot be used for the global pollution (acid rains, greenhouse effect, damaging of the ozone layer etc.) where it is difficult to find the victims as they are often not aware of being the victims (the problem of information availability and transparency on the market of polluting the environment), with difficult evaluation of the cost (how to investigate and put a price tag on increased risk of more frequent occurrence of cancer in regards to other risk factors?), and it is difficult to find the polluters (every person breathes out CO_2) and also the future generations are not able to negotiate about the compensation[1],[12].

Using Taxes - the Polluter Pays

This principle has been taken from the theoreticians of the welfare economics (A. C. Pigou, A. Marshall) who were the first to analyze externalities. The intervention of the state is mild in this case: the state will prescribe a tax to the polluter in the value of the damage and the polluter is thus motivated to invest into harmless material in order to avoid the tax. The government might also offer subsidies to those who invest to eliminate pollution. It is also difficult to determine the valued of the damages caused by global or long-term pollution.

Approval to Pollute

The state or a specialized agency sets a desirable level of acceptable pollution and provides a licence for the right to damage the environment within an intensity limited by the level which should be reached. Some of these rights might be sold on the market: those who pollute less might sell not used rights to those who pollute more, therefore, the purchase price becomes an internal cost item for the buyer. This system is relatively effective for local pollution but meets obstacles how to set a desirable level of global pollution and distribute the pollution right among countries in a fair way.

Irreversibility and Damages Which Cannot Be Assessed by Market

The price of some damages cannot be estimated as they will take effect only in a long term; their correction has not started yet and therefore, the cost cannot be defined. If these potential costs are not taken into account in the economic calculations, it may happen once, when they can be evaluated, they are irreversible. There is also another problem: how to put a price tag on non-market resources (e.g. plant and animal species which humankind does not use but destroys them)?

Actualization Rate

Eliminating pollution today - and so fight against damages in the future - creates the problem of actualization: it is necessary to compare two values which do not correspond in time (assuming their monetary evaluation has been solved).

It cannot be said that the economic theory has or does not have a reliable solution to fight ecological problems. This statement is used to console both, those who believe in market mechanism as well as those who doubt and suggest various moratoriums, regulations or even bans on activities which contribute to global pollution.

Monitoring of arising externalities is necessary with regards to the originator (polluter pays principle). To fulfil this basic principle is not trivial and the way from detecting emissions and pollutant dispersion to identifying the impacts, their natural valuation and finally monetary valuation is extremely complicated. The result is connected not only with high cost for the analysis itself but also with many uncertainties:

- Emission analysis itself (flow of the pollutants to the environment). The uncertainty here is relatively low, especially for basic polluting substances as many types of emissions are continuously or at least periodically measured based on the air protection law. Considering the influence of polluted air and origin of pollutants it is necessary to take into account very different local ratio of the polluting sources. For state of pollution it is necessary to expect significant deviations from the reality according to areas and at estimates of the basic background concentration.

- Behaviour and destiny of the pollutant in the environment - dispersion (transformation) of pollutants. The mechanism of the impact of atmospheric reactions to the state of the atmosphere is extremely complex and not fully explained yet.

- Dose - response function. The most frequent materials are epidemiological studies. For health evaluation as the most important segment of damages, reactions to some substances are not known yet. The function is usually assumed as linear due to missing LV (Limit Value) and the current concentration for other than basic polluting substances. Different outcomes of the influence may be expected for different ways of defining pollutant concentration. In contrary to our practice, emphasis has been recently put on ozone for impact on harvest, for nitrogen oxides the fertilizing function is assumed also for secondary compounds. Our local conditions also consider other agricultural crops as sensitive than in e.g. comparable conditions in Europe [5],[6]. Used methods for calculating damages in agricultural production, above all forests, in the Czech Republic form a standalone problem. So far the area of burden accumulation and especially problem of synergic impact of more pollutants has been researched very little. This latency of impact might be very significant e.g. for toxicological impacts.

- Economic valuation. Economic valuation is very significant for decision making; it reflects the scarcity and uses market prices, if they are known, readiness to pay, national economic accounting and the principle of external effect internalisation. The techniques used for evaluation in economic terms [14] may be divided into two groups - those where functional relation between pollutant dose and environmental response (damage function) can be found and those where a different solution needs to be found. Results of damage impact calculations derived from knowing natural damage have been published in the literature [3],[4],[12]. Most frequently these were damages from running energetic facilities, especially damages from air pollution and its impact on health of population and production (agriculture, forestry etc.). There are also newer methodical procedures based on population behaviour. This may be in form of direct methods: method of political referendum or contingent valuation method or indirect approaches: method of individual substitution, method of travel cost and method of hedonic price.

The problem of damage estimate also includes a link to the sustainable development principles [6],[10],[11]. These principles take the form of proposing not only narrowly defined utility value (either direct or indirect) but also existential value (given by the existence of the nature itself) and option value (ensuring the value of the nature for the future) in its wider conception about using all types of resources.

Damage may be also defined in cost necessary to remedy or prevent the damage. This alternative solution of the calculation based on the cost (real cost of the damage will not be found) may have various form: cost of avoiding the source of burden, cost of damage remedy, cost to prevent the damage, targeted prohibitive cost, defensive cost etc.

The text above was supposed to outline possible methods for quantification of activities and occurrences which concern humankind as a whole [2]. It is the problem of emission quantification, pollution and its impacts. In the end, we shall outline a few comments concerning this problem.

It has shown that the weak spot is monitoring the undesirable phenomena on one hand and publishing needed data in classification and structures which will have needed explicitness. The methodology of collection and processing such data is at its beginning [13].

III. EXAMPLE OF DATA AGGREGATION: VALUE, PRICE, QUANTITY

A. *The Whale and Its Parts*

Indicators are defined by attributes. The attributes include above all the meaning of the indicator, place and time.

The indicator is expressed by quantitative or qualitative characteristics.

If it relates to the whole, the indicator is specified as overall, aggregate etc. If it relates to a part of the certain whole, it is called partial, individual etc. Quantitative indicators have a dimension related to the meaning of the indicator. The dimension may be unit of currency, quantity etc.[7],[15], [16]. From the dimension character it is possible to determine if these partial (individual) indicators may be added together [9], [8].

B. *Value, Quantity and Unit Value*

Value and Quantity

Let us consider a whole which consists of n partial disjoint parts i, the unification of which gives the whole.

For each part i let us consider an indicator h_i. Let us assume that variables h_i are addable i.e. they have the same dimensions. We will call them values.

For each part let us assume variables $q_{i,}$ which represent the number (quantity) of objects in the part i. The dimensions of these can be different, therefore, their sum may not make sense. These variables will be called quantity.

We will state

$$H = \sum_{i=1}^{n} h_i \tag{1}$$

We have obtained for each part two variables: value and quantity.

Unit Value

For the needs of further presentation we will set variables for each i

$$p_i = \frac{h_i}{q_i}. \tag{2}$$

The variables represent the value of item i for the unit of quantity for part i

If the value is expressed in monetary units, these variables represent prices. Generally, it may not be so, therefore, we will use term unit value.

For any h_i and positive q_i it can be said:

$$h_i = \frac{h_i}{q_i} q_i . \tag{3}$$

therefore, for any i holds true

$$h_i = p_i \ q_i. \tag{4}$$

variables h_i will form vector h

variables q_i will form vector q

Both of these vectors have *n* coordinates which correspond to the considered items. By aggregating the sum we will determine the total value in period t which will be marked as *H*. It holds true that

$$H = \sum_{i=1}^{n} h_i = \sum_{i=1}^{n} p_i \, q_i \quad . \tag{5}$$

A question arises whether it is possible to set numbers P and Q which correspond to vectors p and q so that following holds true

$$H = P \ Q \, . \tag{6}$$

Numbers P and Q will be called representatives of vectors p and q.

C. *Changes of Data and Their Impact*

From the above written relations results

$$dH = \sum_{i=1}^{n} dh_i = \sum_{i=1}^{n} \frac{dh_i}{h_i} h_i = \sum_{i=1}^{n} d(p_i \, q_i) = \sum_{i=1}^{n} (q_i \, dp_i \, + p_i \, dq_i) \tag{7}$$

$$\frac{dH}{H} = \sum_{i=1}^{n} \frac{dh_i}{H} = \sum_{i=1}^{n} \frac{dh_i}{h_i} \frac{h_i}{H} = \sum_{i=1}^{n} \frac{dh_i}{h_i} w_i = \sum_{i=1}^{n} \frac{d(p_i, q_i)}{p_i \ q_i} \ w_i \tag{8}$$

where

$$w_i = \frac{h_i}{H}. \tag{9}$$

This relative change of the total value is equal to weighted sum of relative changes of the values for individual parts. This leads to

$$\frac{dH}{H} = \sum_{i=1}^{n} \frac{p_i \, dq_i + q_i \, dp_i}{p_i \ q_i} \ w_i = \sum_{i=1}^{n} \left(\frac{dq_i}{q_i} + \frac{dp_i}{p_i} \right) w_i \tag{10}$$

Therefore, infinitesimal growth of value is equal to sum of weighted infinitesimal changes of unit value and quantity.

In order to express infinitesimal growth we will assume dependency of the variables on parameter t which will be assigned as an index to considered variables. Therefore, we will write

$$H_{t+dt} = H_t + dH_t \tag{11}$$

$$\frac{H_{t+dt}}{H_t} = 1 + \frac{dH_t}{H_t} \tag{12}$$

It arises from here that the index reduced by a unit represents relative change of variable H.

$$\ln \frac{H_{t+dt}}{H_t} = \ln H_{t+dt} - \ln H_t = \sum_{i=1}^{n} w_i (\ln q_{it+dt} - \ln q_{it}) + \sum_{i=1}^{n} w_i \, (\ln p_{it+dt} - \ln p_{it}) \tag{13}$$

$$\ln \frac{H_{t+dt}}{H_t} = \ln H_{t+dt} - \ln H_t = dln \, H_t \tag{14}$$

From which arises

$$\sum_{i=1}^{n} w_i \left(\ln \frac{q_{it+dt}}{q_{it}} + \ln \frac{p_{it+dt}}{p_{it}} \right) = \sum_{i=1}^{n} w_i \, \ln \frac{q_{it+dt}}{q_{it}} \, \frac{p_{it+dt}}{p_{it}} \tag{15}$$

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Let us mark

$$Q_t = q_{1t}^{w_1} q_{2t}^{w_2} \dots q_{nt}^{w_n} \tag{16}$$

$$P_t = p_{1t}^{w_1} p_{2t}^{w_2} \dots p_{n}^{w_{nt}} \tag{17}$$

$$\ln H_{t+dt} - \ln H_t = (\ln Q_{t+dt} - \ln Q_t) + (\ln P_{t+dt} - \ln P_t) \tag{18}$$

$$\ln \frac{H_{t+dt}}{H_t} = \ln \frac{Q_{t+dt}}{Q_t} + \ln \frac{P_{t+dt}}{P_t} = \ln \frac{Q_{t+dt}}{Q_t} \frac{P_{t+dt}}{P_t} . \tag{19}$$

Which emerges into

$$\frac{H_{t+dt}}{H_t} = \frac{Q_{t+dt}}{Q_t} \frac{P_{t+dt}}{P_t} \tag{20}$$

Variable P_t may be considered as aggregate variable of units values, i.e. as level of unit value and variable Q_t may be considered as aggregate variable of value.

D. *Determining of Levels for Unit Values and Quantities*

In this paragraph we will consider continuous time and infinitesimal time interval <t, t+dt).

This assumption leads to relations

$$dH_t = \frac{dH_t}{dt} dt \tag{21}$$

$$dp_{it} = \frac{dp_{it}}{dt} dt \tag{22}$$

$$dq_{it} = \frac{dq_{it}}{dt} dt \tag{23}$$

Variables

$$\frac{dH_t}{dt}, \quad \frac{dp_{it}}{dt}, \quad \frac{dq_{it}}{dt} \tag{24}$$

represent derivations of corresponding variables. These derivations represent intensity of changes of the respective variables.

A question arises whether it is possible to define a scalar representative of vector p_t which would represent level of unit value P_t and a scalar representative of vector q_t which would represent level of e Q_t so that holds true

$$H_t = P_t Q_t. \tag{25}$$

It is clear that P_t and Q_t do not have to be set in one way only. To prove this it is possible to consider any positive number and multiply one of the variables by this number and divide the other variable by this number.

We will stem from intensity defined by relation

$$\frac{d}{dt} H_t = \frac{d}{dt} \sum_{i=1}^{n} p_{it} q_{it} = \sum_{i=1}^{n} \frac{d}{dt} p_{it} q_{it} = \sum_{i=1}^{n} \left(p_{it} \frac{dq_{it}}{dt} + q_{it} \frac{dp_{it}}{dt} \right) \tag{26}$$

By deriving of the hypothetical relation

$$H_t = P_t Q_t. \tag{27}$$

by t, we will get

$$\frac{d}{dt} H_t = P_t \frac{dQ_t}{dt} + Q_t \frac{dP_t}{dt}. \tag{28}$$

It is natural that following holds true:

- if all derivations of coordinates of vector q_t are zero, also derivation of function Q_t is zero and coordinates of vector q_t are constants independent on t.

- if all derivations of coordinates of vector p_t are zero, also derivation of function P_t is zero and coordinates of vector p_t are constants independent on t.

This means that in the first case we will get

$$\sum_{i=1}^{n} q_{it} \frac{dp_{it}}{dt} = Q_t \frac{dP_t}{dt} \tag{29}$$

in the second case we get relation

$$\sum_{i=1}^{n} p_{it} \frac{dq_{it}}{dt} = P_t \frac{dQ_t}{dt} \tag{30}$$

if we divide mentioned relations

$$H_t = (q_t, p_t) = \sum_{i=1}^{n} q_{it}\, p_{it} = Q_t\, P_t \tag{31}$$

we get Divizov's differential equations

$$\frac{\sum_{i=1}^{n} q_{it} \frac{dp_{it}}{dt}}{\sum_{i=1}^{n} q_{it}\, p_{it}} = \frac{\frac{dP_t}{dt}}{P_t} \qquad \frac{\sum_{i=1}^{n} p_{it} \frac{dq_{it}}{dt}}{\sum_{i=1}^{n} q_{it}\, p_{it}} = \frac{\frac{dQ_t}{dt}}{Q_t} \tag{32}$$

The first equation corresponds to constant q_{it} and variable p_{it} , the second equation corresponds to constant p_{it} and variable q_{it} . These equations cannot be valid at the same time as in such case analyzing of changes in unit values and quantity would be unsubstantial. The solution of the equations leads to values P_t and Q_t. However, these values are not unequivocal.

By processing these equations we get

$$\sum_{i=1}^{n} w_{it} \frac{dp_{it}}{p_{it}} = \frac{dP_t}{P_t} \qquad \sum_{i=1}^{n} w_{it} \frac{dq_{it}}{q_{it}} = \frac{dQ_t}{Q_t} \tag{33}$$

where

$$w_{it} = \frac{p_{it}\, q_{it}}{\sum_{k=1}^{n} q_{kt}\, p_{kt}} \tag{34}$$

If weights w_{it} are constant in time, we can write

$$\sum_{i=1}^{n} w_i \frac{dp_{it}}{p_{it}} = \frac{dP_t}{P_t} \qquad \sum_{i=1}^{n} w_i \frac{dq_{it}}{q_{it}} = \frac{dQ_t}{Q_t}. \tag{35}$$

which leads to

$$\sum_{i=1}^{n} w_i \, d\ln p_{it} = d\ln P_t \qquad \sum_{i=1}^{n} w_i \, d\ln q_{it} = d\ln Q_t \tag{36}$$

By integration and setting integration constants $\ln K_P$ a $\ln K_Q$ we get

$$\sum_{i=1}^{n} \ln p_{it}^{w_i} + \ln K_P = \ln P_t \qquad \sum_{i=1}^{n} \ln q_{it}^{w_i} + \ln K_Q = \ln Q_t \tag{37}$$

after processing and delogarithming, we get relations for level of unit value which is a scalar representative of the unit values level

$$P_t = K_P\, p_{1t}^{w_1}\, p_{2t}^{w_2} \ldots p_{nt}^{w_n}. \tag{38}$$

for level of quantity which is a scalar representative of the quantity level

$$Q_t = K_Q\, q_{1t}^{w_1}\, q_{2t}^{w_2} \ldots q_{nt}^{w_n} \tag{39}$$

So we have got relations for sought price levels.

$$K_Q\, K_P = 1. \tag{40}$$

IV. CONCLUSION

If gradually filled with data, the presented suggestion might become a suitable tool for aggregation of a huge amount of primary information which needs to be processed for decision making on higher levels of management. The first results will be presented on the macro-level.

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Prof. Ing. Bohuslav Sekerka, CSc. is professor of the Financial Mathematics at the Institute of Economics.
Assoc.Prof. Ing. Ilona Obršálová, CSc. is engaged in the field of Environmental Economics at the Institute of Administratiove and Social Sciences.
Ing. Petra Lešáková is PhD. student at the Institute of Administratiove and Social Sciences.
All are employed at the University of Pardubice, Faculty of Economics and Administration.
http://www.upce.cz/english/fea/index.html

Modelling examples of sustainable electric power equipment

Cornelia A. Bulucea, Doru A. Nicola, Marc A. Rosen, Nikos E. Mastorakis, and Carmen A. Bulucea

Abstract— Enhancements are made to the concept that technical systems processes involving energy conversion, and particularly electric power equipment, need to be linked to environment engineering, since biological ecosystems generally are not free of anthropogenic influences. The study addresses some aspects, illustrating energy conversion processes during the operation of power transformers and induction motors, as modeling examples of sustainable electric equipment. Based on the model equations, this paper presents the structural diagrams method, as a modeling method of three-phase electric transformer and induction motor in dynamic regimes, according to an ecosystem pattern. The overall objective is to enhance thinking such that anthropogenic activities are viewed in concert with the entire system on Earth.

Keywords—Electric power equipment, electromagnetic torque, exergy, induction motor, power transformer, structural diagram, sustainability dynamics

I. INTRODUCTION

ELECTRICAL power is used all over the world, and standards of life and development of civilization is often interpreted in correlation with the use of electricity [1-3]. Nonetheless, concerns and questions have been raised regarding, how to achieve a sustainable industrial metabolism. Integrating technical and ecological aspects represents a significant challenge to humanity within the present industrial world. In line with this idea, sustainability concepts can help improve understanding of the efficiencies of electric power equipment and systems and guide improvement efforts [3-10].

Traditionally, the basic concepts of energy, exergy and embodied energy are founded in the fields of physics and engineering, although they have environmental and economical significance as well. These concepts can be explained, interpreted and applied in a more universal manner, due to their multidisciplinary traits [4-13].

Taking a holistic view, this study focuses on highlighting that industrial ecology permits an alternate view of anthropogenic applications, related both to technical and environmental reference systems. Modelling of an electric power transformer (in the use phase), and of an induction motor (operating within an electrically driven system) according to an industrial ecosystem pattern enhances thinking that anthropogenic activities can and should be viewed in concert with the entire system on Earth.

II. POWER TRANSFORMER MODELLING THROUGH STRUCTURAL DIAGRAM METHOD

Three-phase transformers are widely used since three phase power is the widespread way to produce, transmit and use electrical energy [2,14]. A three-phase transformer transfers electric power from the three-phase primary winding through an inductively coupled three-phase secondary winding, changing values of three-phase RMS voltage and current. Most commonly, the transformers windings are wound around a ferromagnetic core [2].

Over the last few decades, international legislation have required environmental impact assessment be carried out for all phases of transformer life [14-15], according to Life Cycle Assessment tool, which includes the production phase, use phase and end-of-life phase. Modelling of all these transformer life stages might offer solutions for further improvement potential, focusing on technologies that reduce the electricity losses during the use phase, and on alternative materials for reducing human health and environmental impacts [13-15].

The operation principle of a three phase transformer follows. Varying currents flowing in the primary winding (due to the varying phase voltages u_A, u_B and u_C) create a varying magnetic flux in the transformer core, and thus a varying magnetic field through the secondary winding [2,14]. This varying magnetic field induces a varying electromotive force in the secondary winding. If a three-phase electric load is connected to the secondary winding, electrical energy is transferred from the primary circuit through the transformer to the load. Since u_a, u_b and u_c are the secondary phase voltage, the load three-phase currents system i_a, i_b and i_c will be at the same time the transformer secondary winding currents system. Note that these

Cornelia A. Bulucea is with the University of Craiova, Faculty of Electrical Engineering, Craiova 200440, Romania (e-mail: abulucea@gmail.com).
Doru A. Nicola is with the University of Craiova, Faculty of Electrical Engineering, Craiova 200440, Romania (e-mail: dorunicola@gmail.com).
Marc A. Rosen is with the University of Ontario Institute of Technology, Faculty of Engineering and Applied Science, CANADA (email: marc.rosen@uoit.ca).
Nikos E. Mastorakis is with the Technical University of Sofia, Industrial Engineering Department, Sofia, Bulgaria & Military Institutions of University Education (ASEI), Hellenic Naval Academy, Piraeus 18539, Greece (e-mail: mastorakis4567@gmail.com).
Carmen A. Bulucea is with the University of Medicine and Pharmacy of Craiova, Craiova 200349, Romania (e-mail: carmen.bulucea@gmail.com).

currents represent the feedback (or inverse reaction) between the electric load and the power transformer. In line with this idea, the three-phase transformer representation as an industrial ecosystem is depicted in Fig. 1.

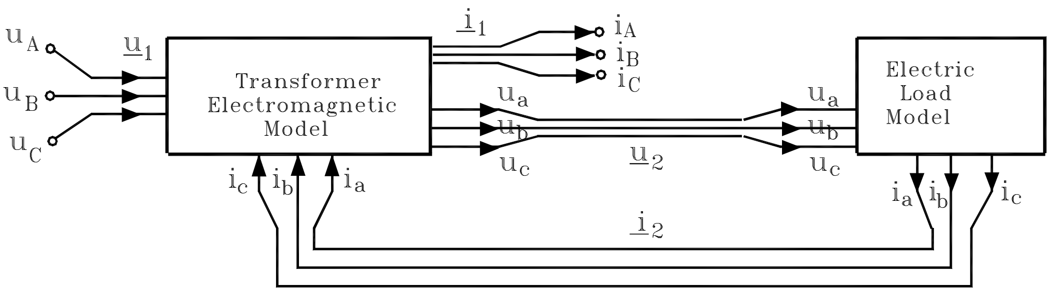

Fig. 1 Three-phase transformer representation

Since efficiency standards can be expressed in terms of electrical efficiency depending on load characteristics, in an attempt to improve the power transformer efficiency, the structural diagram method is presented below for analyzing the three-phase transformer operation in the life use phase.

The classic models, meaning the equivalent electric schemes and the phasor diagrams of power transformer, could be considered only in a permanent regime operation, when all the state quantities have a sinusoidal variation in time. In dynamic regimes, they lose their validity and other models should be developed [2].

As a principle, with electrical transformer modelling one can understand the use of conventional representations (geometric constructions, electrical circuits, structural diagrams etc.) to describe the behavior (or for the simulation) of various operation states or regimes [2,14].

Physically, dynamic regimes of electric transformers are characterized by the variation in time of "electromagnetic status", meaning the currents and fluxes.

Qualitatively, the dynamic phenomena of an electromagnetic nature in the electric transformers are fast are develop with small time-constants (usually, between 1 and 100 ms).

Mathematically, the processes dynamics of electric transformers are described by differential equations which, in most cases, are nonlinear. Based on the mathematical model equations, we present the structural diagrams method in this paper, as a modeling method of electric transformers for use in phase dynamic regimes. One benefit of this approach is derived from the easy conversion of structural diagrams in Matlab-Simulink implementations [2,14].

Basically, a structural diagram [2] represents the graphical image of the differential equations corresponding to the mathematical model of the dynamic regime of the physical system taken into account. Hence, real or complex variables are represented by lines with arrows and graphical symbols are associated with the mathematical operations effected on the variables.

In this context, a number of "arrangements" are described in which mathematical equations (equations of voltages and fluxes) of the three-phase electric transformer can be represented directly by structural diagrams. Since in the structural diagrams, the variables are always represented by lines with arrows, the load current $\underline{i}_2$ (which are flowing through the secondary winding) represent the feedback reaction between the power transformer and the electric load (connected at the secondary winding terminals).

For a three-phase transformer, electrically and magnetically symmetric, one could obtain the equations corresponding to the mathematical pattern, written with phase quantities space phasors in fixed coordinates, according to the following system:

$$\begin{aligned}
&\underline{u}_1 = R_1 \cdot \underline{i}_1 + \frac{d\underline{\psi}_1}{dt} \\
&-\underline{u}'_2 = R'_2 \cdot \underline{i}'_2 + \frac{d\underline{\psi}'_2}{dt} \\
&\underline{\psi}_1 = L_{\sigma 1} \cdot \underline{i}_1 + \underline{\psi}_{u1} \\
&\underline{\psi}'_2 = L'_{\sigma 2} \cdot \underline{i}'_2 + \underline{\psi}_{u1} \\
&\underline{i}_1 + \underline{i}'_2 = \underline{i}_{1\mu} \\
&\underline{i}'_2 = \frac{w_2}{w_1} \cdot \underline{i}_2 \\
&\underline{u}_2 = (-\underline{u}'_2) \cdot (-\frac{w_2}{w_1})
\end{aligned} \qquad (1)$$

where $\underline{u}_1$ = primary voltage; $\underline{i}_1$ = primary current; $\underline{u}_2$ = secondary voltage; $\underline{i}_2$ = secondary current; $\underline{\psi}_1$ = primary magnetic flux; $\underline{\psi}_2$ = secondary magnetic flux; $\underline{\psi}_{\upsilon 1}$ = main (useful) magnetic flux; $i_{1\mu}$ = magnetizing current; R_1 = primary phase resistance; R_2 = secondary phase resistance; $L_{1\sigma}$ = primary leakage inductance; and $L_{2\sigma}$ = secondary leakage inductance.

In order to be used for the structural diagrams building, the equations in (1) are written as follows:

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$$
\begin{aligned}
&\underline{\psi}_1 = \int_0^t (\underline{u}_1 - R_1 \cdot \underline{i}_1) \cdot dt + \underline{\psi}_1(0) \\
&\underline{i}'_2 = \frac{w_2}{w_1} \cdot \underline{i}_2 \\
&\underline{i}_1 = \frac{\underline{\psi}_1 - \underline{\psi}_{u1}}{L_{\sigma 1}} \\
&\underline{i}_1 + \underline{i}'_2 = \underline{i}_{1\mu} \\
&\underline{\psi}'_2 = \underline{\psi}_{u1} + L'_{\sigma 2} \cdot \underline{i}'_2 \\
&-\underline{u}'_2 = R'_2 \cdot \underline{i}'_2 + \frac{d\underline{\psi}'_2}{dt} \\
&\underline{u}_2 = (-\underline{u}'_2) \cdot (-\frac{w_2}{w_1})
\end{aligned}
\qquad (2)
$$

Note that system (2) needs to be completed with the magnetization curve $\phi_u = f(i_{1\mu})$ of the transformer ferromagnetic core. The magnetization characteristic of any magnetic circuit made by ferromagnetic material contains information about the main flux saturation degree. Even under the assumption of negligible magnetic hysteresis phenomenon, when the space phasors $\underline{\psi}_{u1}$ and $\underline{i}_{1\mu}$ have a sin phase variation, one can develop two patterns: linear and non-linear.

One can obtain a linear model under the assumption that the ferromagnetic core magnetization characteristic $\phi_u = f(i_{1\mu})$ can be approximated by a straight line. Hence, for the case of a linear model, the transformer ferromagnetic core is considered as non-saturated, and one can apply the principle of effects super-position, taking into consideration the main cyclical inductance of the transformer primary. Consequently, the structural diagram of linear electromagnetic pattern of three-phase transformer is depicted as in Fig. 2.

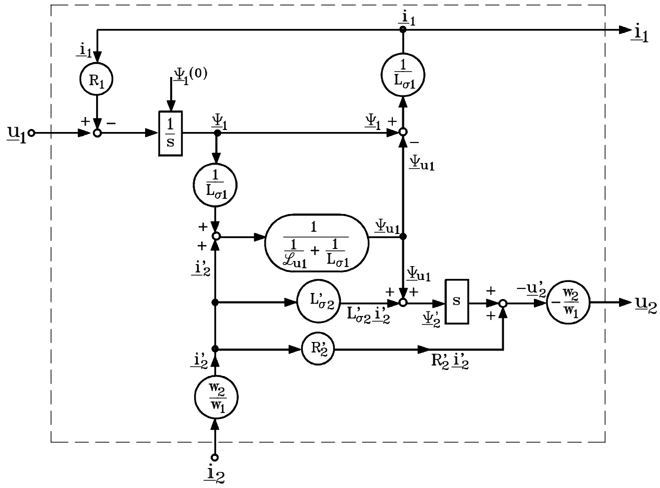

Fig. 2 Structural diagram with space phasors of three-phase transformer linear model

The three-phase transformer non-linear model takes into consideration the non-linear dependence between the main fascicular magnetic flux and the magnetizing current. On a broader front, the magnetizing characteristic of the transformer ferromagnetic core has a non-linear trait. Actually, the magnetizing curve $\phi_u = f(i_{1\mu})$ is obtained by testing points and in the literature one can find it in tabular form.

For each value of the useful fascicular flux ϕ_u, the main magnetic flux ψ_{u1} (through the surface delimited by all turns w_1 of primary phase winding) is given by $\psi_{u1} = w_1 \cdot \phi_u$. Moreover, neglecting the losses in the transformer ferromagnetic core, the total useful flux space phasor $\underline{\psi}_{u1}$ and the magnetizing current space phasor $\underline{i}_{1\mu} = \underline{i}_1 + \underline{i}'_2$ are collinear. So they can be mathematically translated by the following relation:

$$\frac{\underline{\psi}_{u1}}{|\underline{\psi}_{u1}|} = \frac{\underline{i}_{1\mu}}{|\underline{i}_{1\mu}|} \quad \Rightarrow \quad \underline{\psi}_{u1} = |\underline{\psi}_{u1}| \cdot \frac{\underline{i}_{1\mu}}{|\underline{i}_{1\mu}|} \qquad (3)$$

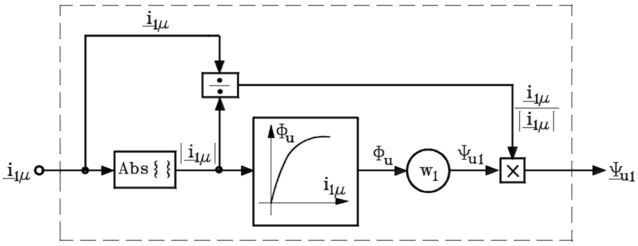

Fig. 3 Structural diagram with space phasors of magnetization circuit

Consequently, if the calculation block of the absolute value of a complex quantity it is noted by "*Abs { }*", then for the non-linear magnetization branch-circuit (with $\underline{i}_{1\mu}$= incoming quantity and $\underline{\psi}_{u1}$= outgoing quantity) one could conceive and represent a structural subsystem, exactly as in Fig. 3.

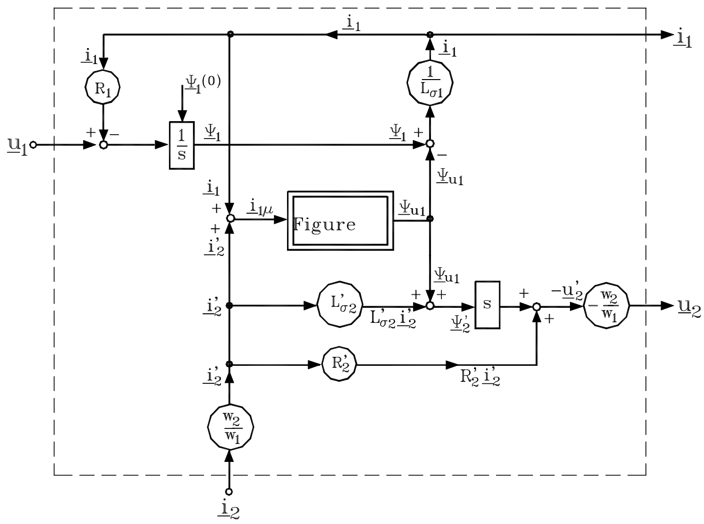

Fig. 4 Structural diagram with space phasors of three-phase transformer non-linear model

Further, for the non-linear pattern of the three-phase transformer one could represent the structural diagram with the variables represented by the space phasors, as in Fig. 4, where the magnetization circuit structural subsystem is represented as the "Figure" rectangle.

In order to highlight the interactions and feedback loops of this industrial ecosystem, representations corresponding to the space phasors $\underline{u}_1$, $\underline{i}_1$, $\underline{u}_2$ and $\underline{i}_2$, could be coupled at the incoming and outgoing, respectively, in all structural diagrams built for the three-phase transformers. Obviously, the representations are made with space phasors of the phase quantities. Since this is a common feature of all modelling diagrams of three-phase transformers, one should emphasize that structural diagrams are beginning with input variables and ending with output variables of complex quantity type.

III. MODELLING OF ELECTROMAGNETIC TORQUE DEVELOPED BY INDUCTION MOTOR

Within the framework of industrial ecology, the exergy concept, which is a measure of energy quality, can be used to enhance understanding and help improve the efficiencies of electric power equipment which convert energy [1,10,16-17].

In physics and engineering, work is a specific form of action, and exergy is defined based on work, i.e. ordered motion, or ability to perform work [1,10,16-17]. While energy is a measure of quantity only, exergy is a measure of quantity and quality or usefulness.

Since exergy is a measure of the potential of a system to do work, the electromagnetic torque M developed by an induction motor can be interpreted as the driving force of useful work, i.e. the electric motor output exergy [16-17].

Utilization of an induction motor with a rotor squirrel cage in electrically driven systems became possible solely in the conditions of a three-phase supply system with controlled variable frequency and r.m.s. voltages or currents, namely a machine-side converter [16-24]. This research extends earlier work by the authors [1-3, 16-18,24].

A. Induction Motor Operating at Variable Frequency and Controlled Flux

The operation at variable frequency with controlled flux is preceded for induction motors in drive systems with vectorial control [18-23]. The vectorial regulation and control method is based on space phasor theory, taking into consideration the control of both the flux and the induction machine electromagnetic torque M. In principle, the stator current space phasor is decomposed into two perpendicular components (a flux component and a torque component) which are separately controlled. One could analyze the permanent harmonics regime of variable frequency operation with controlled stator flux, controlled useful flux or controlled rotor flux. As an example, we present the operation with controlled stator flux [3,18].

The following relations can be derived for the stator current components [18]:

$$I_{sx} = \frac{\psi_s}{L_s} + \frac{1-\sigma}{\sigma L_s}\frac{\psi_s}{\frac{R_{r'}}{\omega_r \sigma L_{r'}} + \frac{\omega_r \sigma L_{r'}}{R_{r'}}}\frac{\omega_r \sigma L_{r'}}{R_{r'}}$$
$$I_{sy} = \frac{1-\sigma}{\sigma L_s}\frac{\psi_s}{\frac{R_{r'}}{\omega_r \sigma L_{r'}} + \frac{\omega_r \sigma L_{r'}}{R_{r'}}} \qquad (4)$$

The absolute value of the stator current can be determined with the formula $I_s = (I_{sx}^2 + I_{sy}^2)^{1/2}$.

Within an ecological framework, the electromagnetic torque M is related to the system output exergy. We can express M in complex coordinates axes system (oriented on $\underline{\psi}_s$) as

$$M = 3p \cdot Im\{\underline{I}_s \cdot \underline{\psi}_s^*\} = = 3p \cdot Im\{(I_{sx} + jI_{sy}) \cdot \psi_s\} = = 3p \cdot \psi_s \cdot I_{sy} \qquad (5)$$

Substituting I_{sy} from (4), the torque relation becomes

$$M = 3p \cdot \frac{1-\sigma}{\sigma L_s} \cdot \frac{\psi_s^2}{\frac{R_{r'}}{\omega_r \sigma L_{r'}} + \frac{\omega_r \sigma L_{r'}}{R_{r'}}} \qquad (6)$$

If the stator flux ψ_s is constant, the electromagnetic torque magnitude depends on the rotor current pulsation ω_r but not the stator supply frequency f_s. The torque curve $M=f(\omega_r)$ at ψ_s=const. is not linearly dependent on ω_r, having two symmetrical extremes:

$$\frac{\partial M}{\partial \omega_r} = 0\ ;\ \omega_{rk\psi_s} = \pm \frac{R_{r'}}{\sigma \cdot L_{r'}}\ ;$$
$$M_{k\psi_s} = M(\omega_{rk\psi_s}) = \pm \frac{3p}{2} \cdot \frac{1-\sigma}{\sigma \cdot L_s} \cdot \psi_s^2 \qquad (7)$$

The dependence of $M=f(\omega_r)$ at ψ_s=const. is shown in Fig. 5. In a steady-state regime, a system stable operation (with $\partial M/\partial \omega_r > 0$) is performed only on the ascendant zone of the characteristic $M=f(\omega_r)$ in Fig. 5 and corresponds at small rotor pulsations to the condition $|\omega_r| \leq \omega_{rk\psi s}$. The mechanical characteristics family M=f(n) of the induction motor operating at ψ_s=const., for different stator frequencies f_s, are shown in Fig. 6.

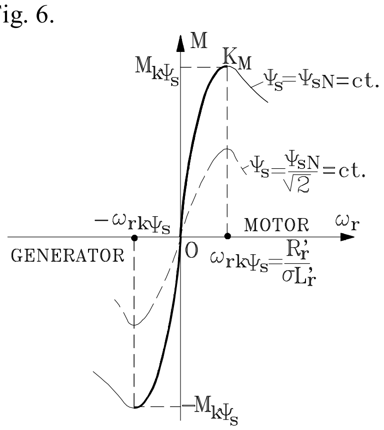

Fig. 5 Torque characteristic $M=f(\omega_r)$ at controlled stator flux

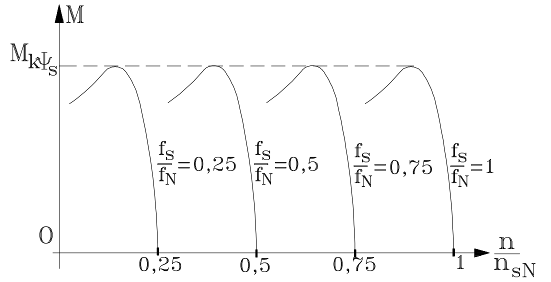

Fig. 6 Mechanical characteristics M=f(n) at ψ_s=const. for different frequency f_s values ($f_s \leq f_N$)

The constant stator flux magnitude ψ_s for any stator frequency f_s and torque M (respectively, any rotor pulsation ω_r) imposes an exact control of either the supply voltage U_s or the supply current I_s. We see again an analogy between this electrical system and an ecosystem. An appropriate technical system control must be achieved for reducing exergy destruction when the equilibrium point passes from one stable state (represented by the operation point on a certain mechanical characteristic) to another stable state (on another mechanical characteristic). This observation implies the system control needs to be assessed next.

One could notice in the permanent harmonic regime among the fluxes $\underline{\Psi}_s$, $\underline{\Psi}_u$, $\underline{\Psi}'_r$ and the currents $\underline{I}_s$, $\underline{I}'_r$ of any unsaturated induction machine, electric and magnetic symmetry. Hence the following operating relations apply:

$$\begin{aligned} &\underline{\psi}_s = L_{s\sigma}\cdot\underline{I}_s + \underline{\psi}_u \\ &\underline{\psi}_s = \sigma\cdot L_s\cdot\underline{I}_s + \frac{L_u}{L_{r'}}\cdot\underline{\psi}'_r \\ &\underline{\psi}'_r = \underline{\psi}_u + L'_{r\sigma}\cdot\underline{I}'_r \\ &0 = R'_r + j\,\omega_r\cdot\underline{\psi}'_r \end{aligned} \tag{8}$$

Accordingly, shown in Fig. 7 are the fluxes and currents phasor diagram of induction machine operating in motor regime. In the complex reference system, with real axis (+1) along the direction of phasor $\underline{\Psi}'_r$ (with $\underline{\Psi}'_r=\Psi'_r+j\cdot 0$; $\underline{I}_s=I_{sx}+j\cdot I_{sy}$ and $\underline{I}'_r=0-j\cdot I'_r$), from the geometry of the rectangular triangles OAA' and OBB' (see Fig. 7) one could write:

$$\begin{aligned} &\psi_s^2 = [\frac{L_u}{L_{r'}}\cdot\psi'_r + \sigma\cdot L_s\cdot I_{sx}]^2 + (\sigma\cdot L_s\cdot I_{sy})^2 \\ &\psi_u^2 = \psi'^{\,2}_r + (L'_{r\sigma}\cdot I'_r)^2 \end{aligned} \tag{9}$$

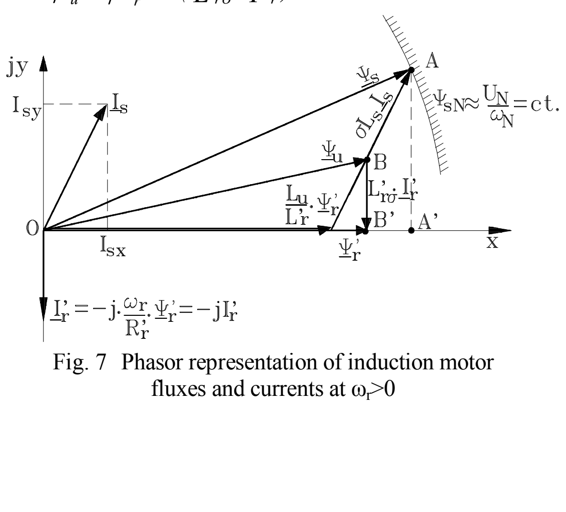

Fig. 7 Phasor representation of induction motor fluxes and currents at ω_r>0

Furthermore, taking into consideration the components I_{sx} and I_{sy} , as well as the rotor current I'_r in accordance with the following relations:

$$I_{sx} = \frac{\psi'_r}{L_u}\,;\, I_{sy} = \frac{\psi'_r}{L_u}\cdot\frac{L'_r}{R'_r}\cdot\omega_r\,;\, I'_r = \frac{\omega_r}{R'_r}\cdot\psi'_r \tag{10}$$

and after mathematical calculations, the expressions of fluxes Ψ_u and Ψ'_r can be determined:

$$\begin{aligned} &\psi_u(\omega_r) = \psi_s\cdot\frac{L_u}{L_s}\cdot\sqrt{\frac{1+(\frac{L'_{r\sigma}}{R'_r}\cdot\omega_r)^2}{1+(\frac{\sigma\cdot L'_r}{R'_r}\cdot\omega_r)^2}} \\ &\psi'_r(\omega_r) = \psi_s\cdot\frac{L_u}{L_s}\cdot\frac{1}{\sqrt{1+(\frac{\sigma\cdot L'_r}{R'_r}\cdot\omega_r)^2}} \end{aligned} \tag{11}$$

Note that the fluxes Ψ_u and Ψ'_r depend on Ψ_s, as well on machine parameters and on ω_r. But any induction machine designed to be supplied with phase voltage U_N at stator frequency f_N (ω_N = $2\pi\cdot f_N$) will have the stator flux Ψ_s approximately constant, with the magnitude Ψ_{sN}, where:

$$\psi_{sN} \approx \frac{U_N}{\omega_N} = ct. \tag{12}$$

Hence, at the operation with constant stator flux (Ψ_s = Ψ_{sN} = ct.), the reference levels of the fluxes Ψ_u=ct. and Ψ'_r = ct., respectively should set to such values so that, over the entire variation range of rotor pulsation ω_r, the stator flux Ψ_s will not exceed the established limit value. Therefore, in Fig. 8 there are represented the dependence $\Psi_s=\Psi_{sN}$=ct. in accordance with (12), Ψ_u = $f_1(\omega_r)$ and Ψ'_r = $f_2(\omega_r)$ according to (11) for the maximum variation range of ω_r ($|\omega_r| \leq R'_r/L'_{r\sigma}$ when induction machine has stable operation at Ψ_u=ct.).

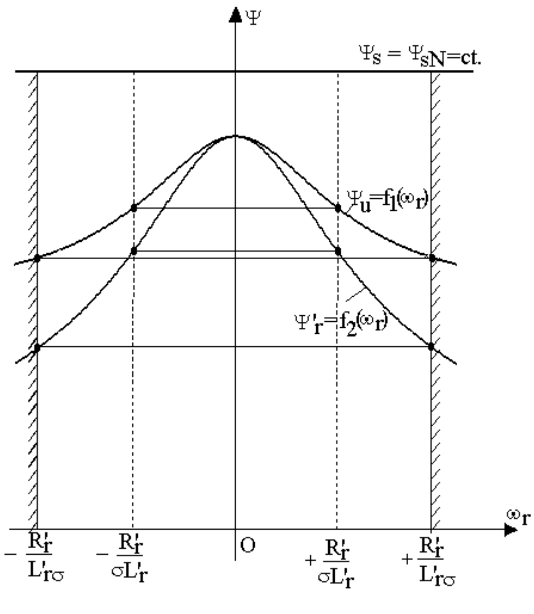

Fig. 8 Dependence of induction machine fluxes Ψ_s, Ψ_u and Ψ'_r on ω_r

Based on the curves of Fig. 8 and the mentioned relations the constant flux levels are determined:

$$\psi_s = \psi_{sN} = ct. \tag{13}$$

$$\psi_u = f_1\left(\pm\frac{R'_r}{L'_{r\sigma}}\right) = \psi_s \cdot \frac{L_u}{L_s} \cdot \frac{\sqrt{2}}{\sqrt{1+\left(\frac{\sigma L'_r}{L'_{r\sigma}}\right)^2}} = ct.$$

$$\psi'_r = f_2\left(\pm\frac{R'_r}{L'_{r\sigma}}\right) = \psi_s \cdot \frac{L_u}{L_s} \cdot \frac{1}{\sqrt{1+\left(\frac{\sigma L'_r}{L'_{r\sigma}}\right)^2}} = ct. \quad \left(\psi'_r = \frac{\psi_u}{\sqrt{2}}\right)$$

For these constant values of fluxes Ψ_s, Ψ_u and Ψ'_r, an exergetic analysis imposes the electromagnetic torque characteristics $M = f(\omega_r)$ and stator current characteristics $I_s = f(\omega_r)$ are compared on the stable operation intervals.

A1) Electromagnetic Torques Comparison at Ψ_s = ct., Ψ_u=ct. and Ψ'_r = ct.

For the three subsequent cases, the electromagnetic torque M has the following expressions:

a) When stator flux is constant Ψ_s = ct.:

$$M = \frac{2 \cdot M_{k\psi_s}}{\frac{\sigma \cdot L'_r \cdot \omega_r}{R_{r'}} + \frac{R_{r'}}{\sigma \cdot L'_r \cdot \omega_r}} \tag{14}$$

$$M_{k\psi_s} = \frac{3p}{2} \cdot \frac{1-\sigma}{\sigma \cdot L_s} \cdot \psi_s^2$$

b) When useful flux is constant Ψ_u = ct.:

$$M = \frac{2 \cdot M_{k\psi_u}}{\frac{L'_{r\sigma} \cdot \omega_r}{R'_r} + \frac{R'_r}{L'_{r\sigma} \cdot \omega_r}} \tag{15}$$

$$M_{k\psi_u} = \frac{3p}{2} \cdot \frac{1}{L'_{r\sigma}} \cdot \psi_u^2$$

c) When rotor flux is constant Ψ'_r = ct.:

$$M = 3p \cdot \frac{\omega_r}{R'_r} \cdot \psi'^{\,2}_r \tag{16}$$

Moreover, according to the constant flux levels (13), between the maximum torques $M_{k\Psi s}$ and $M_{k\Psi u}$ the following recurrence relationship can be demonstrated:

$$\frac{M_{k\psi_s}}{M_{k\psi_u}} = \frac{1}{2} \cdot \left(\frac{\sigma \cdot L'_r}{L'_{r\sigma}} + \frac{L'_{r\sigma}}{\sigma \cdot L'_r}\right) \tag{17}$$

Also, since the electromagnetic torque is interpreted as output exergy, based on the observation $\Psi'_r = \Psi_u/\sqrt{2}$ = ct., at Ψ'_r = ct. a relationship for the electromagnetic torque M could be useful within the exergetic analysis:

$$M = M_{k\psi_u} \cdot \frac{L'_{r\sigma}}{R'_r} \cdot \omega_r \tag{18}$$

Graphically, curves of the induction machine electromagnetic torque $M/M_{k\Psi s} = f(\omega_r)$ at Ψ_s = ct., Ψ_u = ct., and Ψ'_r = ct., respectively, are presented in Fig. 9.

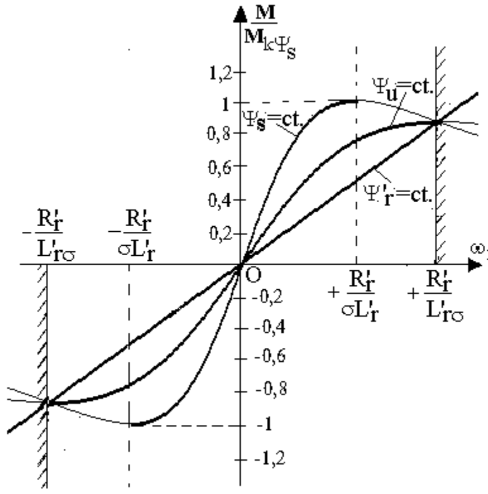

Fig. 9 Curves of $M/M_{k\Psi s}=f(\omega_r)$ at constant flux

A2) Stator Currents Comparison at Ψ_s = ct., Ψ_u = ct. and Ψ'_r = ct.

According to relationship (13) for the constant flux levels, the stator current I_s expressions become as follows:

a) When stator flux is constant Ψ_s = ct.:

$$I_s = \frac{\psi_s}{L_s} \cdot \sqrt{\frac{1+\left(\frac{L'_r}{R'_r} \cdot \omega_r\right)^2}{1+\left(\frac{\sigma \cdot L'_r}{R'_r} \cdot \omega_r\right)^2}} \tag{19}$$

b) When useful flux is constant Ψ_u = ct.:

$$I_s = \frac{\psi_s}{L_s} \cdot \frac{\sqrt{2}}{\sqrt{1+\left(\frac{\sigma \cdot L'_r}{L'_{r\sigma}}\right)^2}} \cdot \sqrt{\frac{1+\left(\frac{L'_r}{R'_r} \cdot \omega_r\right)^2}{1+\left(\frac{L'_{r\sigma}}{R'_r} \cdot \omega_r\right)^2}} \tag{20}$$

c) When rotor flux is constant Ψ'_r = ct.:

$$I_s = \frac{\psi_s}{L_s} \cdot \frac{1}{\sqrt{1+\left(\frac{\sigma \cdot L'_r}{L'_{r\sigma}}\right)^2}} \cdot \sqrt{1+\left(\frac{L'_r}{R'_r} \cdot \omega_r\right)^2} \tag{21}$$

Graphically, Fig. 10 represents the characteristics of stator current I_s at Ψ_s = ct., Ψ_u = ct., and Ψ'_r = ct., respectively.

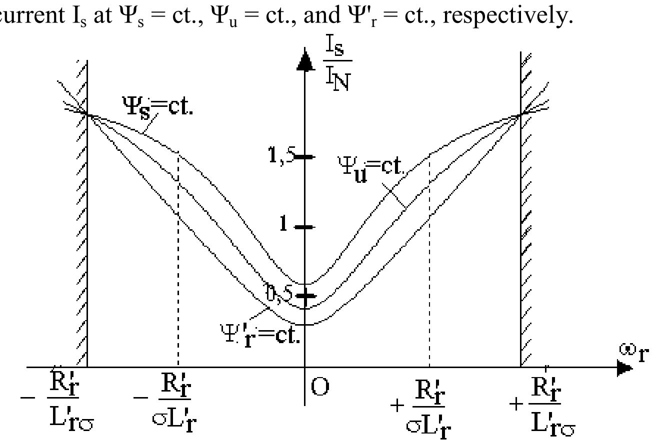

Fig. 10 Characteristics of $I_s/I_N=f(\omega_r)$ at constant flux

A3) *Discussion of Torques*

The greatest magnitudes of electromagnetic torque are obtained in operating at Ψ_s=ct. Moreover, with the usual approximations $\sigma\cdot L'_r=L_{s\sigma}+L'_{r\sigma}$ and $L'_{r\sigma}$_$L_{s\sigma}$, the maximum torque relationship is obtained in the form:

$$M_{k\psi_u} \approx \frac{4}{5} \cdot M_{k\psi_s} \tag{22}$$

This emphasizes that the maximum electromagnetic torque in operating at Ψ_u = ct. is approximately with 20% smaller than the maximum torque in operating at Ψ_s = ct. The ratio of the critical rotor pulsations $\omega_{rk\Psi s}$ and $\omega_{rk\Psi u}$ is:

$$\frac{\omega_{rk\psi_s}}{\omega_{rk\psi_u}} = \frac{L'_{r\sigma}}{\sigma \cdot L'_r} \approx \frac{1}{2} \tag{23}$$

This means that an "inferior" maximum torque $M_{k\Psi u}$ is developed at the rotor pulsation with a double value that of the rotor pulsation corresponding to $M_{k\Psi s}$ ($\omega_{rk\Psi u} = 2\cdot\omega_{rk\Psi s}$).

Moreover, at the imposed electromagnetic torque, the smallest value of rotor pulsation is obtained in operation with Ψ_s = ct.

From Fig. 10 similar conclusions are emphasized with regard to the stator currents. Actually, the smallest values of stator currents I_s are obtained in operation with Ψ'_r = ct.

The analysis of induction machine operation with constant flux highlights that only at Ψ'_r = ct. the induction machine mechanical characteristics not have extremum points; they are straight lines. These linear characteristics are preferable for the applications which demand high sustainability dynamics in induction machine operation.

B. Modelling of Induction Motor Operating at Variable Frequency and Controlled Flux through Structural Diagram Method

In order to be used with high energy and exergy efficiency in an electrically driven system, modelling is carried out for the induction motor using a structural diagram.

As a complex electromechanical system, the induction motor can be conceptually decomposed into electromagnetic and mechanical subsystems. Between these functional parts, the electromagnetic torque M and the rotor mechanical speed Ω_m interact as internal variables. The induction motor electromagnetic part can be described by the following equations [16-18,24]:

$$\begin{aligned} &\frac{d\underline{\psi}_s}{dt} = \underline{u}_s - R_s \cdot \underline{i}_s \\ &\frac{d\underline{\psi}_{r'}}{dt} = j \cdot p \cdot \Omega_m \cdot \underline{\psi}_{r'} - R_{r'} \cdot i_{r'} \\ &\underline{i}_s = \frac{\underline{\psi}_s - \frac{L_u}{L_{r'}} \cdot \underline{\psi}_{r'}}{\sigma L_s}; \quad \underline{i}_{r'} = \frac{\underline{\psi}_{r'} - \frac{L_u}{L_s} \cdot \underline{\psi}_s}{\sigma L_{r'}} \\ &M = \frac{3}{2} \cdot p \cdot Im\{\underline{i}_s \cdot \underline{\psi}_s^*\} \end{aligned} \tag{24}$$

Here, $\underline{u}_s$ denotes the stator voltage vector; $\underline{i}_s$ the stator current vector; $\underline{i}_r$' the rotor current vector; $\underline{\Psi}_s$ the stator flux vector; $\underline{\Psi}_r$' the rotor flux vector; L_u the magnetizing inductance; L_s the stator inductance; L_r' the rotor inductance; p the number of pole pairs; R_s the stator resistance; R_r' the rotor resistance and $\sigma = 1 - \frac{L_u^2}{L_s \cdot L'_r}$ the motor leakage coefficient.

Using equation (24), the structural diagram and the mask block of the induction motor electromagnetic subsystem are depicted in Fig. 11.

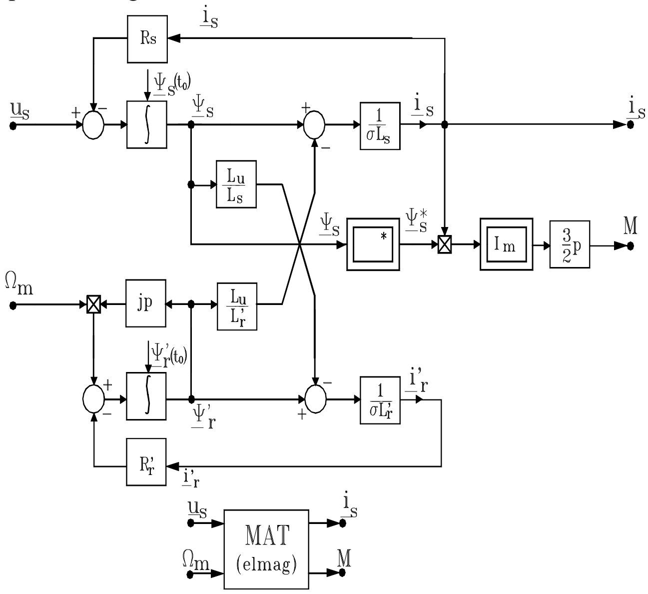

Fig. 11 Structural diagram and mask block for induction machine electromagnetic subsystem

The structural diagram of the electromagnetic subsystem can be coupled both with the structural diagram of the machine-side converter through the input variable $\underline{u}_s$ and output variable $\underline{i}_s$ and with the structural diagram of the mechanical subsystem via the input quantity Ω_m and the output quantity M.

IV. CONCLUSION

The benefits of using sustainability concepts and mathematical modeling to understand the efficiency of electric power equipment which use or convert electrical energy have been demonstrated.

By modelling the electric power transformer and the induction motor in dynamic regimes according to an industrial ecosystem pattern, one could provide a holistic view of the interactions and symbiosis interrelationships among technical equipment operation and ecological processes.

The main environment impact related to the operation phase of a power transformer and an induction motor, respectively, is caused by the electricity losses of the electric equipment under specific load conditions. By implementing sustainability dynamics in mathematical modeling (through structural diagram method) the increase of energy and exergy efficiency of electric power equipment has been demonstrated. The structural diagram method illustrates, according to the model of an industrial ecosystem, the interactions and the feedback loops among the different variables that describe the three-phase power transformer and induction motor operation. By modeling the electric power equipment dynamic regimes according to an industrial ecosystem pattern, one can attempt to reduce or minimize the environmental impacts and optimize the efficiency of energy use.

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STATISTICAL-FINANCIAL ANALYSIS OF CAPITAL STRUCTURE IN THE SERVICE BUSINESS

Radojko Lukić, Ph. D., University of Belgrade, Faculty of Economics
Nenad Lalić,Ph. D.,University of East Sarajevo,Faculty of Education
Srdjan Lalić,Ph. D.,University of East Sarajevo, Faculty of Business Economics
Nataša Tešić, MSc, University of East Sarajevo, Faculty of Business Economics
Dragan Milovanović MSc, University of Banja Luka, Faculty of Economics

Abstract**—**In order to efficiently manage capital structure (i.e., optimization) to achieve the target performance of the company, it is imperative to know its determinants. General and specific determinants exist for each company, depending on various factors such as the very nature of its business, as in the case of commercial chains. This paper investigates the determinants of capital structure in the service busines, ie. in trading companies, as in the matter of Serbia. In that context, special consideration is given to the internal determinants of the capital structure of trade in Serbia for the 2008-2013 period. Recognizing positive and negative effects and significant determinants is important for the optimization of capital structure, in order to achieve the overall target performance of future trade in Serbia.

Keywords**—**determinants, theory of capital structure, financial leverage, performance, trade in Serbia.

I. Introduction

As widely understood, specific determinants of trading companies' capital structures are numerous. Typical examples include: opportunistic growth (asset growth, sales growth), profitability, asset structure, business risk, tax shield, liquidity, and analysis of capital structure and techniques (Abdout et al. 2012). Other factors—primarily external nature—are surely influential on the capital structure of trading companies, such as industry-specific determinants (industrial leverage, industrial growth) and macroeconomic determinants (inflation, GDP growth, capital flows, tax shield) (Köksal, 2014; Kühnhausen, 2014). Regardless of the variety of internal and external factors affecting the capital structure of trading companies, this paper analyzes the subject of specific determinants of the capital structure of a company, to optimize its function and thereby improve overall trade performance in Serbia. This paper aims to thoroughly investigate the determinants of capital structure in Serbia's commercial sector. Knowing the intensity of their effect, whether positive or negative, is highly important for trade managers. Their determining of optimal capital structure (via effective financial decision-making) is used to achieve target performance at both the individual trading companies, and trade in general. This, among other things, manifests the scientific and professional contribution of this paper.

This work was supported in part by the U.S. Department of Commerce under Grant BS123456 (sponsor and financial support acknowledgment goes here). Paper titles should be written in uppercase and lowercase letters, not all uppercase. Avoid writing long formulas with subscripts in the title; short formulas that identify the elements are fine (e.g., "Nd–Fe–B"). Do not write "(Invited)" in the title. Full names of authors are preferred in the author field, but are not required. Put a space between authors' initials.

F. A. Author is with the National Institute of Standards and Technology, Boulder, CO 80305 USA (corresponding author to provide phone: 303-555-5555; fax: 303-555-5555; e-mail: author@ boulder.nist.gov).

S. B. Author, Jr., was with Rice University, Houston, TX 77005 USA. He is now with the Department of Physics, Colorado State University, Fort Collins, CO 80523 USA (e-mail: author@lamar. colostate.edu).

T. C. Author is with the Electrical Engineering Department, University of Colorado, Boulder, CO 80309 USA, on leave from the National Research Institute for Metals, Tsukuba, Japan (e-mail: author@nrim.go.jp).

II. Literature overview

Rich is the literature devoted to general theoretical and practical analysis of capital structure factors, or to the impact of financial leverage on company performance (liquidity and profitability) (Köksal, 2014; De Luca, 2014). Due to its importance, special attention is increasingly, and in recent time, being paid to the analysis of specific determinants of capital structure and the impact of financial leverage on company performance in certain economic sectors, including trade. Nonetheless, very few specialized, particularly comprehensive works exist on the subject of specifics determinants of capital structure, as well as the impact of financial leverage on the performance of trading companies (wholesale and/or retail). This issue only partially tackles the context of principle research specifics and the importance of financial strategies for trading companies (Van der Wijst, 1993; Gill et al. 2009; Evans, 2005; Little et al. 2011; Kamath, 2013; Li et al. 2014; Lee, 2014; Moatti et al. 2014; Chevalier, 1995; McGloldrick, 2002; Levy, 2007; Berman, 2010; Yu, 2014). In recent times, regarding comprehensive written works on the topic of specificity factors and the effects of capital

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structure on trading/commercial companies, the works of the following authors are particularly famous (Chevalier, 1995; Gleason, 2000; Gill, 2009; Abdou, 2012; Ajanthan, 2013; Anhin, 2014; Hilgen, 2014; Kaya, 2014; Lee, 2014).

According to our knowledge in Serbia, as well as in the world, virtually no comprehensive work exists which is devoted to the research of specific factors of capital structure and the impact of financial leverage, such as measures of financial risk, on the performance of trading companies in Serbia. This issue is only partially addressed in the works of the following authors (Lovreta, 2011; Lukić, 2011, 2012, 2013a b, 2014a b c d). Gaps are filled in, to an extent, by this paper, which by its content and methods of treating issues aims to provide an adequate basis for a more efficient management of financial leverage, in accordance with the theory of capital structure, and overall financial position as a function of future performance improvements of trading companies in Serbia. In this, among all else, lays its scientific expertise.

III. Hypothesis, Research Methodology, and Empirical Data

Given the importance and complexity of the issues treated in this paper, we will test the following hypotheses using appropriate methodology based on original empirical data for trade in Serbia during the 2008-2013 period. The hypotheses are: H1 - a positive relationship exists between leverage raids and growth; H2 - a positive relationship exists between leverage raids and size; H3 - a negative relationship exists between leverage raids and profitability; H4 - a positive relationship exists between leverage raids and asset structure; H5 - a negative relationship exists between leverage raids and business risk; H6 - a negative relationship exists between leverage raids and amortization raids (expressed as a percentage of sales); H7 - a negative relationship exists between leverage raids and liquidity; H8 - there is significant impact on leverage raids by profitability, physical assets, size, and growth.

Research methodology, consequential of the aim and defined hypotheses, is based on the ratio analysis and the application of statistical analysis. Also applied, to the extent necessary according to research, is a comparative analysis of the theory of capital structure, as well as exploring the rich literature of general problems treated.

For the purpose of research for this paper, original empirical data for trade in Serbia during the 2008-2013 period was used; data was obtained from the Serbian Business Registers Agency. The sample includes (for each analyzed year) a large number of trading companies which are required under applicable law to submit annual financial reports to the Business Registers Agency (illustration: number of involved trading companies in 2013 is 33341).

IV. Theoretical Basis and Specific Dimensions of Capital Structure in Trade

Generally speaking, under the notion of capital structure, financial leverage implies the relationship between others' and own sources of funding (i.e., participation in the debt financing of specifics types of assets (business) of the company). Financing operations of the company by borrowing certainly has advantages and disadvantages.

The advantages of borrowing, as opposed to raising funds by issuing shares, include tax reliefs and stimulating managers to acquire greater discipline when making investment decisions. Disadvantages include increased expected bankruptcy costs, reduced flexibility of gaining additional financing in the future, and conflict between the shareholder and lender. Generally, if the marginal utility exceeds the marginal cost, the company must borrow. In all other cases, the company should use the issuance of its own shares (Damodaran, 2007).

Analysis of the impact of financial leverage on the performance of the trade company in this paper is based on, in principle, the theory of capital structure (Brealey, 2007; Van Horne, 2007; Abdou et al., 2012; Kühnhausen, 2014). Two major theories of capital structure are the Trade-off theory and the Pecking-Order theory.

Regarding the Trade-off theory, whose main contributors are Modigliani and Miller (1958, 1963), the following factors are influential, regarding the formation of capital structure: tax shield, the market value of the company, and the cost of capital.

On the formation of capital structure, in addition to the mentioned factors, the following are also influential, according to Jensen and Meckling (1976) and Myers (1977): cost of bankruptcy and financial trouble and agency costs, respectively.

Regarding the Pecking-Order theory, advocated by Myers and Majluf (1984), perception of the order of financing is as follows: internal financing, debt, and issuance of shares. In trading companies, it is determined empirically that the Pecking-Order theory is more frequently applied. This is in keeping with the character of the business, treated as special, highly significant determinants of capital structure (Degryse, 2012).

The capital structure significantly affects the financial performance of the company. The negative relationship between capital structure and financial performance indicates that agency problems lead to the fact of using more loans than necessary in the capital structure, which produces poorer performance (Gleason, 2000). All companies, including trade companies, strive for optimal capital structure in order to achieve profit and other target goals. In principle, the optimal capital structure is realized in maximizing the value of the company with a minimization of the cost of capital. This is in accordance with the theory of static compromise, which is now the prevailing theory of capital structure. Table 1 shows the different effects of some principal internal determinants on the leverage, considering the Pecking-Order theory and Trade-off theory.

Table 1. Theories of capital structure and the relationship between leverage and internal determinants

Determinant	Theory	
	Pecking-Order theory	Trade-off theory
Profitability	Negative	Positive
Size	Negative	Positive
Growth	Positive	Negative
Assets (reaches towards)	Positive	Positive

Source: Ajanthan, 2013

V. General characteristics of capital structure of trade in Serbia

Before we turn to the analysis of the determinants of capital structure of trade in Serbia, we will shortly look at their general characteristics. Table 9 and Figure 1 show the ratio of own funds and interest coverage ratio for the economy as a whole and by selective economic sectors, including trade, in 2012 and 2013.

	Ratio of own funds		Interest coverage ratio	
	2013	2012	2013	2012
Companies — total	36.6	37.3	1.21	0.39
Agriculture, forestry, and fishing	46.5	42.3	3.46	1.69
Manufacturing	23.3	24.5	0.18	1.14
Construction	35.3	36.0	-0.22	-2.31
Wholesale and retail	*22.8*	*22.2*	*2.34*	*1.30*
Financial and insurance activities	47.5	51.8	-4.30	-4.66

Note: The ratio of own funds/resources - share of equity in total capital, whose extent is dictated by the needs of financing fixed assets and the effects of financial leverage. Interest coverage ratio - the ratio of net results and the interest paid from one side, as well as the other.

Source: The Serbian Business Registers Agency

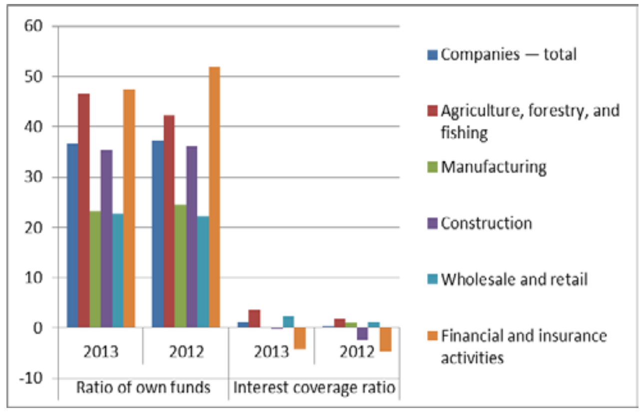

Figure 1. Ratio of own funds and interest coverage ratio for the economy as a whole and by selective economic sectors, including trade, in 2012 and 2013.

Source: Prepared according to data from Table 2.

The data in Table 2 clearly shows that in 2013, the lowest share in the total capital of their own went towards trade in relation to the economy as a whole, as well as other observed sectors. In other words, it is highly indebted. This is indicated by the interest coverage ratio. This appropriately reflects on its overall performance.

VI. Calculating dependent and independent variables

Table 3 shows the calculation of dependent and independent variables used in this work in general, and in particular, the statistical analysis of the determinants of capital structure of trade in Serbia.

Table 3. Calculating the dependent and independent variables

Variable	Formula
Dependent variable	
Y Ratio of debt (leverage)	Total liabilities / total assets
Independent variable	
X_1 Current liquidity	Current assets / current liabilities
X_2 Accelerated liquidity	Current assets - Inventories / Current liabilities
X_3 Yield of operating income	Net profit / Operating revenues
X_4 Return on assets	Net income / Total assets
X_5 Asset growth	Total Assets (t) - Total Assets (t - 1) / Total Assets (t - 1)
X_6 Asset structure	Fixed assets / Total assets
X_7 Company growth – percent change in operating income	Operating income (t) - Operating income (t - 1) / Operating income (t - 1)
X_8 Company size	Log 10 –operating income

X_9 Business risk	Standard deviation of annual net profit for 6 years / Average annual net profit for 6 years
X_{10} Gross operating surplus – amortization (in percentages) of operating income	Gross operating surplus –amortization / Operating income
X_{11} Asset turnover	Operating income / Assets
X_{12} Return on equity capital	Operating income / Equity capital

Note: Calculations based on author's research through literature

Methodologically speaking, financial leverage can be expressed in many ways. Typical methods include: short-term leverage = short-term debt / total assets; long-term leverage = long-term debt / total assets; total leverage = total debt / total assets.

In the context of the strategic profit model, based on the DuPont analysis, financial leverage is displayed as: financial leverage = total assets / total shareholders' equity. This method of expressing financial leverage is exclusively adopted by trading companies, within the strategic profit model, which is widely used as an instrument of financial leverage.

Table 4 and Figure 2 include summarized baseline variables, determined as shown in Table 3, for the purpose of statistical analysis of the determinants of capital structure of trade in Serbia for the 2008-2013 period. The given variables also indicate the general performance characteristics of trade in Serbia. Thus, for example, financial indebtedness in the reporting period increased annually, except for 2012. It is high in relation to trade in countries with developed market economies and "industrial standards". Liquidity is also satisfactory in comparison to golden banking rules (2 : 1), particularly in 2013. Profitability explored through the prism of return on operating revenues is unsatisfactory (i.e., in the reporting period, it declined annually due to low purchasing power of buyers/consumers). Low purchasing power, combined with high unemployment and other unfavourable general conditions of production, is significantly reflected in other measures of performance, in the negative sense.

	2008	2009	2010	2011	2012	2013
Financial leverage	*0,616*	*0,631*	*0,708*	*0,686*	*0,622*	*0,683*
Current liquidity	1,037	1,004	1,003	1,006	1,017	0,995
Accelerated liquidity	0,682	0,677	0,669	0,662	0,661	0,661
Yield of operating income	3,59	3,30	3,23	3,40	3,09	3,10
Return on assets	4,04	3,36	3,87	4,25	3,94	3,72
Asset growth	14,10	5,03	-5,73	3,47	9,30	1,93
Asset structure	46,75	45,74	35,37	33,02	33,05	33,02
Company growth - percent change in operating income	19,29	-5,13	11,23	7,73	11,47	-4,05
Company size	9,373	9,350	9,397	9,429	9,429	9,476
Business risk	0,992	0,866	0,942	1,070	1,084	1,044
Gross operating surplus - amortization (in percentages) of operating income	6,029	5,467	5,570	4,474	5,175	5,020
Asset turnover	1,125	1,016	1,199	1,249	1,273	1,222
Return on equity capital	10,66	9,23	13,53	13,78	13,15	12,02

Note: Author's calculations

Source: Business Registers Agency and Statistical Yearbook of Serbia

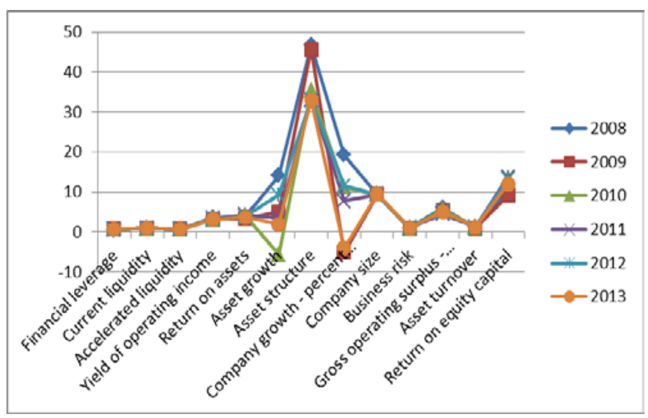

Figure 2. Determinants of capital structure of trade in Serbia
Source: Generated using data from Table 4.

VII. Statistical Analysis of Determinants of Capital Structure of Trade in Serbia

Table 5 shows the descriptive statistics of analyzed performance indicators (i.e., determinants of capital structure of trade in Serbia during the 2008-2013 period).

Table 5. Descriptive Statistics (analyzed determinants of capital structure on trade in Serbia)

	N	Minimum	Maximum	Mean	Std. Deviation
Financial leverage	6	,62	,71	,6577	,03924
Current liquidity	6	1,00	1,04	1,0103	,01485
Accelerated liquidity	6	,66	,68	,6687	,00905
Yield of operating income	6	3,09	3,59	3,2850	,19066
Return on assets	6	3,36	4,25	3,8633	,30349
Asset growth	6	-5,73	14,10	4,6833	6,74682
Asset structure	6	33,02	46,75	37,8250	6,59252
Company growth - percent change in operating income	6	-5,13	19,29	6,7567	9,57429
Company size	6	9,35	9,48	9,4090	,04519
Business risk	6	,87	1,08	,9997	,08399
Gross operating surplus - amortization (in percentages) of operating income	6	4,47	6,03	5,2892	,53063
Asset turnover	6	1,02	1,27	1,1807	,09534
Return on equity capital	6	9,23	13,78	12,0617	1,80432
Valid N (listwise)	6				

Note: Author’s calculations aided by statistical program SPSS

In the given period, as demonstrated by the results of descriptive statistics, average values of some indicators include: financial leverage 0.65; current liquidity 1.01; yield of business income 3.28; company growth — percent change in business income 6.75; company size 9.40. Their values, in principle, are worse than they are in countries with developed market ecnomies and “industrial standards”. This was influenced by unfavourable general conditions of production, high banking costs, unfavourable exchange rates, and low purchasing power of the population as a consumer.

Table 6 shows the correlational analysis of determinants on the capital structure of trade in Serbia.

Table 6.Correlational relationship between determinants and financial leverage on trade in Serbia.

	Financial leverage Pearson Correlation	Sig. (2-tailed)	N
Financial leverage	1		6
Current liquidity	-,707	,116	6
Accelerated liquidity	-,491	,323	6
Return on business income	-,277	,596	6
Return on assets	,185	,726	6
Asset growth	-,902*	,014	6
Asset structure	-,614	,195	6
Company growth - percent change in operating income	-,210	,690	6
Company size	,453	,366	6
Business risk	,066	,901	6
Gross operating surplus - amortization (in percentages) of operating income	-,454	,366	6
Equity turnover	,392	,443	6
Return on equity capital	,612	,197	6

*. Correlation is significant at the 0.05 level (2-tailed).

Note: Author’s calculations aided by statistical program SPSS

As shown by the results of the correlation analysis, there is variation regarding the impact of individual analyzed determinants on the financial leverage of trade in Serbia. Some have positive impacts, while others have negative impacts. Significant, negative impacts on financial leverage are caused by determinants including current liquidity and the growth and structure of assets. Yield of equity capital is a positive determinant. Other determinants—positive or negative, less or more—minimally impact financial leverage. Based on the correlation coefficient of asset growth and structure, the increasing use of modern technology in trades in Serbia has a significant impact on financial leverage, as seen in countries with developed market economies. It will significantly improve the overall performance of trade in Serbia, in the future (Shin, 2014). The situation is similar to the application of the concept of sustainable development (Phillips, 2010).

Based on the correlation analysis, consequently the nature of the relationship between leverage and determinants, it can be concluded that certain tested hypotheses are confirmed (H2, H3, H7), while others are rejected (H1, H4, H5, H6).

With the regression analysis (i.e., linear regression equation), the impact of each individual, analyzed determinant on the capital structure of trade in Serbia is investigated. This is expressed in the general formula:

$$Yit = \alpha i + \beta Xit + \mu it ,$$

where: Yit = independent variable, i = unit (1,2,3 ... N), t = time (1,2,3 ... T); αi = coefficient (dependent variable of each unit); β = coefficient (independent variable); Xit = independent variable; µit = error.

Table 7 shows the descriptive statistics of selective determinants of capital structure of trade in Serbia.

Table 7. Descriptive Statistics (selective determinants of capital structure of trade in Serbia)

	Mean	Std. Deviation	N
Financial leverage	,6577	,03924	6
Current liquidity	1,0103	,01485	6
Yield of operating income	3,2850	,19066	6
Company size - percent change in operating income	6,7567	9,57429	6
Company size	9,4090	,04519	6

Note: Author's calculations aided by statistical program SPSS

Displayed average values of selective determinants of capital structure for trades in Serbia are, as mentioned, lower compared to the same values of trade in countries with a developed market economy and "industrial standards". This was certainly a contribution of poorer general economic conditions.

Table 8 shows the correlation matrix of selective determinants of capital structure for trades in Serbia.

Table 8. Correlation matrix of selective determinants of capital structure for trades in Serbia

		Financial leverage	Current liquidity	Yield of operating income	Company growth - percent change in operating income	Company size
Pearson Correlation	Financial leverage	1,000	-,707	-,277	-,210	,453
	Current liquidity	-,707	1,000	,669	,801	-,441
	Yield of operating income	-,277	,669	1,000	,503	-,585
	Company growth - percent change in operating income	-,210	,801	,503	1,000	-,191
	Company size	,453	-,441	-,585	-,191	1,000
Sig. (1-tailed)	Financial leverage	.	,058	,298	,345	,183
	Current liquidity	,058	.	,073	,028	,191
	Yield of operating income	,298	,073	.	,155	,111
	Company growth - percent change in operating income	,345	,028	,155	.	,358
	Company size	,183	,191	,111	,358	.
N	Financial leverage	6	6	6	6	6
	Current liquidity	6	6	6	6	6
	Yield of operating income	6	6	6	6	6

	Company growth - percent change in operating income	6	6	6	6	6
	Company size	6	6	6	6	6

Note: Author's calculations aided by statistical program SPSS

Results of the correlation analysis show that current liquidity has a significantly negative impact on financial leverage of trade in Serbia. Operating income yield and company growth — percent change in business income negatively, yet slightly, affects financial leverage. Company size positively and moderately impacts financial leverage.

Table 9., the results of the regression model for selective determinants of capital structure of trades in Serbia are shown.

Table 9. Results of the regression model for selective determinants of capital structure of trades in Serbia

	Dependent Variable: Financial leverage			
Independent Variable	Unstandardized Coefficients	Std. Error	t	Sig.
(Constant)	3,628	2,473	1,467	,381
Current liquidity	-4,610	,990	-4,656	,135
Yield of operating income	,103	,057	1,803	,322
Company growth - percent change in business income	,004	,001	2,981	,206
Company size	,141	,208	,675	,622
Weighted statistics				
R Square	,966			
Adjusted R Square	,829			
F	,829			
Sig.	,274			
Durbin-Watson	2,200			

Note: Author's calculations aided by statistical program SPSS

The regression model results demonstrate that individual selective determinants do not significantly impact the capital structure of trade in Serbia (Sig. > 0.05). They collectively, as evidenced by the multiple regression coefficient, agree that the coefficient of determination significantly affects (of 83%) the capital structure of trade in Serbia. In view of these results, the conclusion of the regression model is to confirm the eighth hypothesis, H8. In the given regression model, there is no autocorrelation of independent residuals (Durbin-Watson test is within standard test limits). In addition to tested determinants that have influence of the capital structure of trade in Serbia, there are other determinants.

VIII. Conclusion

Based on the above empirical research (i.e., trade in Serbia), this conclusion serves to summarize the important general and obtained statistical results. This particularly suggests that the shown average value of all (including selective) analyzed determinants of capital structure of trade in Serbia is lower than the same value of trade in countries with developed market economies and "industrial standards". This was certainly a contribution of poorer general economic conditions.

Logically, the influence of certain analyzed determinants on the financial leverage of trade in Serbia varies. Some results are positive, while others are negative. Significant, negative impacts on financial leverage arise from determinants such as current liquidity and the growth and structure of assets. Positive determinants include yield of equity capital. Other determinants, whether positive or negative, minimally or moderately impact financial leverage. Judging by the correlation coefficient of asset growth and structure, the increasing application of modern technologies in trade, in Serbia, results in a significant impact on financial leverage.

Attained results of the regression model show that individual selective determinants—including current liquidity, yield of operating income, company growth, and company size—insignificantly impact capital structure of trade in Serbia (Sig. > 0.05). Collectively, however, they significantly affect the capital structure of trade in Serbia, as evidenced by the multiple regression coefficient and the agreed determination coefficient. In the shown regression model (i.e., trade in Serbia), there is no autocorrelation of independent residuals (Durbin-Watson test is within standard test limits). On the capital structure of trade in Serbia, additional pre-analyzed and other determinants have a significant impact, as shown by the value of the respective test.

For the future of trade in Serbia, in the context of analysis and improving performance in a broader sense, focused attention should be given to sustainable growth models, modelled on the countries with developed market economies (Phillips, 2010). They are among the important factors of cost reduction, thereby increasing profits, thus should become increasingly applied in trades in Serbia, in the future.

Generally speaking, there is great significance for modern technology as a performance improvement technique of commercial chains (Shin, 2014). Its use in Serbia is currently unsatisfactory, in comparison to countries with developed market economies, but there are hopes for increased use in the future. This will satisfactorily affect the positive effects of financial leverage on the performance of commercial chains in Serbia.

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An Overview of Direct Digital Manufacturing

N.Rajesh Jesudoss Hynes and J.Angela Jennifa Sujana

***Abstract*—** The main goal of Rapid Manufacturing is to produce fully dense and net shaped metal parts in a single step for next decade. Direct Metal Laser Fabrication (DMLF) processes can generate nearly full density and near net shaped metal parts from CAD data without using any traditional methods or secondary operations. Metal powders are completely melted without retaining much porosity in these processes. Laser based processes such as Selective laser sintering, Direct Metal Laser Sintering and Laser Engineered Net Shaping are gaining much importance in the present manufacturing scenario and are going to dominate all other techniques in the coming future. In this paper Direct Metal Laser Fabrication are described, compared and discussed with applications.

***Keywords*—** STL Format, Selective laser sintering, Direct Metal Laser Sintering and Laser Engineered Net Shaping

I. Introduction

Building physical objects directly from computerized designs without going through time-consuming steps such as process planning and tool manufacturing was merely science fiction till the induction of Rapid Prototyping (RP) technology in late 1990s. The initial set of RP processes were largely confined to non-metallic materials. However integration of RP processes with secondary processes like silicon rubber molding, epoxy tooling and investment casting, provides an attractive avenue for quick translation RP parts into regular engineering materials in an indirect way. These indirect processes, referred to as Rapid Tooling, help the engineers in slashing the time taken for tool manufacture, especially in case of complex geometries [1,2]. Thus RP processes, both direct and indirect types, have changed the way products are designed and manufactured. While RP helps in compressing the product development cycle, RT shortens the product life cycle Together they help the organizations in retaining their competitive edge over their competitors. Just as "stone age", "bronze age" etc. are milestones in evolution of human civilization, "slice age" heralded by RP augurs a new paradigm for the manufacturing industry.

Engineers are no longer satisfied with the manufacture of prototypes using RP; they want to produce functional parts through the same concept Such RP technologies have made small but steady progress in terms of producing the components and tools in metallic materials such as steels, bronze etc. Efforts to prototype the parts out of Titanium, Aluminum, Nickel alloys etc., have resulted either in near net shape parts or in processes that can refurbish the worn out components [3,4]. Since the manufacturing domain of aerospace, nuclear, defense and marine systems demands lighter, stronger and high temperature resistant materials there is a strong need to adapt RM technologies for these superior set of engineering materials.[18,19]

High power laser based metal fabrication techniques are most popular of Rapid Manufacturing processes. Several laser based metal fabrication technologies have been developed and commercialized, and some systems are still under development [6]. Some of the commercialized laser based metal fabrication technologies are based on metal sintering technology such as Selective Laser Sintering (SLS) and Direct Metal Laser Sintering (DMLS) and Directed Material Deposition such as Laser Engineered Net Shaping (LENS)[1].

N.Rajesh Jesudoss Hynes is with Mechanical Engineering Department of Mepco Schlenk Engineering College, Virudhunagar, Tamil Nadu, India (phone:09865248527,e-mail: findhynes@yahoo.co.in).

J.Angela Jennifa Sujana is with Mepco Schlenk Engineering College, Virudhunagar, Tamil Nadu, India (phone: 9865248527;e-mail: ang_jenefa@mepcoeng.ac.in).

II. Process Description

A. CAD Model Creation by Software

First, the object to be built is modeled using a Computer-Aided Design (CAD) software package. Solid modelers, such as Pro/ENGINEER, tend to represent 3-D objects more accurately than wire-frame modelers such as AutoCAD, and will therefore yield better results. The designer can use a pre-existing CAD file or may wish to create one expressly for prototyping purposes. This process is identical for all of the RP build techniques.

B. Conversion to STL Format

The various CAD packages use a number of different algorithms to represent solid objects. To establish consistency, the STL (stereolithography, the first RP technique) format has been adopted as the standard of the rapid prototyping industry. The second step, therefore, is to convert the CAD file into STL format. This format represents a three-dimensional surface as an assembly of planar triangles, "like the facets of a cut jewel." 6 The file contains the coordinates of the vertices and the direction of the outward normal of each triangle. Because STL files use planar elements, they cannot represent curved surfaces exactly. Increasing the number of triangles improves the approximation, but at the cost of bigger file size. Large, complicated files require more time to pre-process and build, so the designer must balance accuracy with manageability to produce a useful STL file. Since the .stl format is universal, this process is identical for all of the RP build techniques [20].

C. Slice the STL File

In the third step, a pre-processing program prepares the STL file to be built. Several programs are available, and most allow the user to adjust the size, location and orientation of the model. Build orientation is important for several reasons. First, properties of rapid prototypes vary from one coordinate direction to another. For example, prototypes are usually weaker and less accurate in the z (vertical) direction than in the x-y plane. In addition, part orientation partially determines the amount of time required to build the model. Placing the shortest dimension in the z direction reduces the number of layers, thereby shortening build time. The pre-processing software slices the STL model into a number of layers from 0.01 mm to 0.7 mm thick, depending on the build technique. The program may also generate an auxiliary structure to support the model during the build. Supports are useful for delicate features such as overhangs, internal cavities, and thin-walled sections. Each PR machine manufacturer supplies their own proprietary pre-processing software.

D. Layer by Layer Construction

The fourth step is the actual construction of the part. Using one of several techniques (described in the next section) RP machines build one layer at a time from polymers, paper, or powdered metal. Most machines are fairly autonomous, needing little human intervention.

E. Clean and Finish

The final step is post-processing. This involves removing the prototype from the machine and detaching any supports. Some photosensitive materials need to be fully cured before use. Prototypes may also require minor cleaning and surface treatment. Sanding, sealing, and/or painting the model will improve its appearance and durability.

III. DIFFICULTIES IN APPLYING RAPID MANUFACTURING

Of course, not all conditions are perfect for RM. Even if the process were cost effective from a capital investment point of view, it may not be possible to build parts for the following reasons.

A. Materials

There are still a limited number of materials available for RM. This is partly just because not all materials have been tested and developed for this purpose. However there are also some materials that don’t match the requirements for processing using some RP technologies. Cost of materials is an important factor and materials have to be developed to match very stringent processing requirements [28]. As RM grows and resulting costs come down, it is anticipated that the range of materials will increase significantly.

B. Process repeatability

The accuracy of RP technologies is not as good as many other comparable manufacturing approaches. However, even within a certain acceptable accuracy range, one can expect poor repeatability from most RP machines. This is because the machines are designed for flexibility of use rather than for high part tolerance and good process control. For example, laser beam diameters will change from region to region; temperature fluctuations will also result in varying part densities and strengths. However, again this is because the technology has not fully matured to suit RM requirements. If Boeing does request Rivi technologies to supply over 200 000 parts per month then it would be worthwhile developing the technology to suit the required part range with better process control [28].

C. Cost

Since RP represents only a small portion of the manufacturing industry, machine costs are currently at a premium. Machines are built without any real form of automation and the costs reflect this. Again, RM has the potential for exponential growth of this technology and one can expect machine costs to come down accordingly.

D. Size:

Many parts cannot be built using RP technology because of their sheer size. Parts may be broken up into components, but this starts to detract away from some of the benefits relating to design. Most examples of RM involve relatively small parts that can be made cost-effectively if they are combined using a batch manufacture approach. The Phonak hearing aids are very expensive if we just look at the size of the components. High added value is therefore a very critical justification for choosing RM.

E. Post processing

Most parts using RP technology require significant amounts of manual post processing. This can include removal of support structures as well as cleaning up the parts and applying coatings. Every additional operation adds complexity and cost so post processing should be kept to a minimum. As machine accuracy, process repeatability and material properties improve, the amount of post processing ought to reduce.

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F. Logistics

Many applications for Rivi will involve customization of the parts to suit individual users. As the number of parts being handled by a particular company increases, so the need to keep track of them becomes more difficult. Being digital data, it is relatively easy to incorporate identification methods into the components themselves. However, handling, packaging, etc. can still be quite time-consuming.

IV. Laser Rapid Manufacturing Techniques

High power laser based metal fabrication techniques are most popular of Rapid Manufacturing processes. Several laser based metal fabrication technologies have been developed and commercialized, and some systems are still under development. Some of the commercialized laser based metal fabrication technologies are based on metal sintering technology such as Selective Laser Sintering (SLS) and Direct Metal Laser Sintering (DMLS) and Directed Material Deposition such as Laser Engineered Net Shaping (LENS).

A. Selective laser sintering

Selective Laser Sintering (SLS) is one of the most popular Rapid Manufacturing techniques. In SLS, a laser beam selectively fuses or sinters powder materials, nylon, elastomer etc. Selective Laser Sintering (SLS) can provide your manufacturing business with a leading edge by producing rapid plastic or metal prototypes that closely match their molded counterparts.

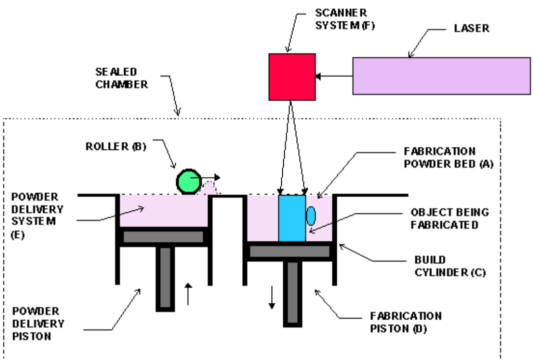

Fig.1 Selective laser sintering

In SLS (Fig.1), a laser beam is traced over the surface of a tightly compacted powder made of thermoplastic material. The powder is spread by a roller over the surface of a build cylinder. A piston moves down one object layer thickness to accommodate the layer of powder. The powder supply system is similar in function to the build cylinder. It also comprises a cylinder and piston. In this case, the piston moves upward incrementally to supply powder for the process. Heat from the laser melts the powder where it strikes under guidance of the scanner system. The CO2 laser used provides a concentrated infrared heating beam. The entire fabrication chamber is sealed and maintained at a temperature just below the melting point of the plastic powder. Thus, heat from the laser need only elevate the temperature slightly to cause sintering, greatly speeding the process. A nitrogen atmosphere is also maintained in the fabrication chamber which prevents the possibility of explosion in the handling of large quantities of powder [15,16].

After the object is fully formed, the piston is raised to elevate the object. Excess powder is simply brushed away and final manual finishing may be carried out. That's not the complete story, though. It may take a considerable time before the part cools down enough to be removed from the machine. Large parts with thin sections may require as much as two days of cooling time.

No supports are required with this method since overhangs and undercuts are supported by the solid powder bed. This saves some finishing time compared to stereolithography. However, surface finishes are not as good and this may increase the time. No final curing is required as in stereolithography, but since the objects are sintered they are porous. Depending on the application, it may be necessary to infiltrate the object with another material to improve mechanical characteristics. Much progress has been made over the years in improving surface finish and porosity. The method has also been extended to provide direct fabrication of metal and ceramic objects and tools [27].

B. Direct Metal Laser Sintering

Direct Metal Laser Sintering (DMLS) is a revolutionary technology that produces otherwise 'impossible-to-make' end-use metal parts directly from your 3D CAD data, whilst negating the investment in time and money of conventional tooling. The parts produced are comparable to a good investment cast part and the mechanical properties are comparable to those of a cast or machined component. The DMLS process is not restrictive in its application and the components produced can be used in place of almost any conventionally manufactured part, whether they would normally be machined or cast. The advantage of the process is that the more complex or feature rich the component, the more economical the process becomes.

DMLS is an 'additive' technology that works by fusing together very fine layers of metal powder using a focused laser beam. A support structure is required to hold the parts in position during building and this is anchored onto a steel platform. The supports and components are built with a layer thickness ranging from 20 to 60 microns depending on the material used. Each layer is scanned with the laser fusing the powder to layer below and forming the new build layer, the base is lowered one layer, a fresh layer of powder is deposited, and the next layer is scanned. A powerful 200W Yb-fibre laser is precisely controlled in the X and Y co-ordinates allowing for exceptional tolerances to be held (<+/-0.1mm).

The latest technology takes advantage of a ‘dual-spot’ laser allowing feature sizes as small as 0.4mm to be built. With a machine build envelope of 250mm x 250mm x 215mm (including platform), many medium to small parts and inserts are able to be constructed in hours and days versus days and weeks using traditional processes. Once started, the machine builds unattended, 24 hours a day. Parts and inserts that come out of the machine are 99.99% dense and require no post-sintering or other infiltration process. They typically will go through a series of ‘post processing’ steps including support removal, shot peening and polishing.

The principal advantage of making production parts directly using DMLS is that there is no tooling required, and only a modest amount of machining and finishing. 98% of the powder not used to make the part is recycled and so the process is economical and environmentally friendly. One notable feature of DMLS is that it is possible to create a part that has both external and internal complexity in one go. Not only does this mean that you can create highly functional parts, but you can potentially combine what would have been several parts into one, saving manufacture cost, reducing assembly time and increasing reliability.

C. *Laser Engineered Net Shaping*

Laser Powder Forming (LPF) technologies such as Laser Engineered Net Shaping and others are gaining in importance. The strength of these technologies lies in their ability to fabricate fully-dense metal parts with good metallurgical properties at reasonable speeds. The methods are also sometimes referred to by the general term, *laser fusing*.

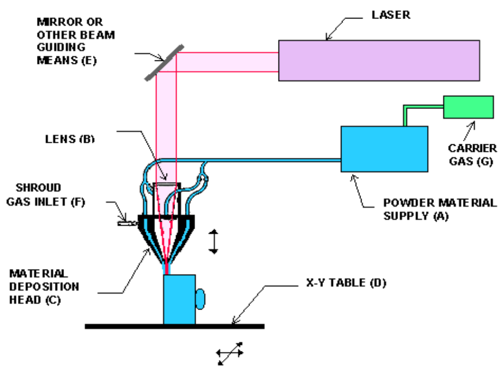

Fig.2 Laser Engineered Net Shaping(LENS)

A high power laser (Fig.2) is used to melt metal powder supplied coaxially to the focus of the laser beam through a deposition head. The laser beam typically travels through the center of the head and is focused to a small spot by one or more lenses. The X-Y table is moved in raster fashion to fabricate each layer of the object. Typically the head is moved up vertically as each layer is completed. The laser beam may be delivered to the work by any convenient means. A simple right angle mirror is shown, but fiber optics could also be used. Metal powders (A) are delivered and distributed around the circumference of the head either by gravity, or by using an inert, pressurized carrier gas. Even in cases where it’s not required for feeding, an inert shroud gas (F) is typically used to shield the melt pool from atmospheric oxygen for better control of properties, and to promote layer to layer adhesion by providing better surface wetting.

A variety of materials can be used such as stainless steel, Inconel, copper, aluminum etc. Of particular interest are reactive materials such as titanium. Most systems use powder feedstock, but there has also been work done with material provided as fine wires. In this case the material is fed off-axis to the beam. Materials composition can be changed dynamically and continuously, leading to objects with properties that might be mutually exclusive using classical fabrication methods. The building area is usually contained within a chamber both to isolate the process from the ambient surroundings and to shield the operators from possible exposure to fine powders and the laser beam. The laser power used varies greatly, from a few hundred watts to 20KW or more, depending on the particular material, feed-rate and other parameters.

Objects fabricated are near net shape, but generally will require finish machining. They are fully-dense with good grain structure, and have properties similar to, or even better than the intrinsic materials. Laser powder forming has fewer material limitations than SLS, doesn't require secondary firing operations as some of those processes do, and can also be used to repair parts as well as fabricate them. Parts can be labeled directly using DMLS, building a number or other identifier directly into the part, an important attribute for traceability. Because DMLS parts do not require tooling to make them, it saves on the tooling cost and WIP inventory. One can even have small design variations for every single part and the DMLS process will treat them all in the same way. In effect, DMLS enables ‘Mass Customization’.

V. DISCUSSION OF SIGNIFICANT PARAMETERS

A. *Material Variety*

In SLS, only material used is a stainless steel/bronze matrix, which is not a common engineering alloy. In DMLS, however, a number of steel and bronze based materials could be used. Besides, a variety of materials can be used such as stainless steel, inconel, copper, aluminium and titanium alloys could be processed. Furthermore, material composition can be changed dynamically and continuously. This also provides embedded structured metal parts, because completely different types of materials could be used at different locations or layers in a process. This property also provides to produce multi-material structured parts. Only

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required areas can be produced with high quality material and at the rest of the part any other appropriate material can be used. For instance, only molding area can be produced with required material and the rest of the tool insert can be produced with any other material. It is obvious that this will reduce the cost of the tool insert.

B. Surface Quality

It is obvious that surface quality is dependent upon what type of material and powder characteristics is used, layer thickness and line spacing at the X-Y direction. Good surface quality could be achieved with SLS and DMLS processes, but to get better surface in LENS process is preferred because very high power laser is used in LENS process [27].

C. Density

Parts produced by SLS system are needed to be infiltrated to have fully density. Power of the laser used in SLS process does not enough for sintering metal powder particles in contrast with as in DMLS process. In SLS process, only binder material is sintered to bond metal particles together when laser processing. After the SLS operation is completed, resulting parts have to be fired to completely sinter of metal particles and infiltrated with bronze material to have fully density state.

On the other side, parts produced with DMLS are fully dense because either the power of the laser used in DMLS process is higher than SLS process or velocity of the laser is lower in DMLS in contrast with SLS. So, steel powder material is completely melted and sintered without requiring any furnace sintering process.

In LENS process, parts are produced at fully dense state with good metallurgical and thermal properties. They have good grain structure, and have properties similar to, or even better than the intrinsic materials [27].

D. Dimensional Accuracy

One of the most important problems of the rapid prototyping systems for tooling applications is dimensional accuracy because of shrinkage. Shrinkage condition is also dependent on material as well as laser power and sintering conditions. So, it is obvious that shrinkage occurs in all laser assisted fabrication techniques because solidification occurs. Separately, plastic binder in the metal powders is removed to make hard the part by firing in a furnace in SLS. Consequently, this additional firing operation causes the more loss of the dimensional accuracy because of shrinkage [8].

E. Support Structure

Support is needed for overhang and undercut areas. There is no need additional support structure generation for SLS and DMLS processes because unsintered excess material acts as support structure. In these processes, powder material is spread by roller mechanism over top of the layer, and just cross section of belonging layer is sintered, rest is removed after the whole part is complete.

Additional support, structure is required for LENS process because powder material is deposited coaxially and simultaneously with laser beam. Metal powder which has lower melting than base material is used as support structure. However, after the whole part is completed, removing of the support structure is difficult because both of the material is metal based material.

F. Repairing Operations

Laser assisted material deposition systems could be used to repair damaged equipments. It is not possible to apply repairing operations with pre-deposited systems as in SLS and DMLS systems. Powder material should be deposited with a roller and it is not possible to achieve with these systems because roller will crash to the higher level of the part while spreading the material at the level of the damaged region of equipment. Only coaxial powder deposition systems like LENS could achieve these types of operations. LENS process is especially considered for repairing operations.

G. Finishing Operations

SLS process requires more additional processes than DMLS process which are secondary sintering in a furnace to bond metal particle together and bronze infiltration to have full density. Only shot-peening operation is may be needed in DMLS process. Secondary finish machining operation is needed in LENS process because parts produced with LENS process are near net shape.

On the other hand, removing excess processes for SLS and DMLS but it is difficult for LENS process because additional support structure is required for overhang areas an this support structure is made of metal material.

H. 5 axis capability

It is z axis operations in SLS and DMLS processes because of pre-deposited powder material limitations. However, tilting and leading motions could be generated in LENS process Meanwhile, leading and tilting motions may eliminate - the required support structure in LENS process when making the overhang features.

VI. APPLICATIONS

A. LENS

The LENS system uses the energy from a high-power laser to build up structures one layer at a time directly from powdered metals. The resulting fully functional 3-dimensional components have mechanical properties that are equivalent or superior to forged materials. LENS solutions can be used throughout the entire product lifecycle for applications ranging from Materials Research to Functional Prototyping to Volume Manufacturing [23]. An additional benefit is its unique ability to add material to existing components for Service and Repair applications. A LENS system serves as a powerful product development tool that facilitates basic materials research, design feasibility studies and functional prototyping. LENS offers unique flexibility in the geometries and material range it supports, enabling the use of innovative design concepts such as hollow and internal structures, and functional material gradients that incorporate mechanical property transitions within a single part [25].

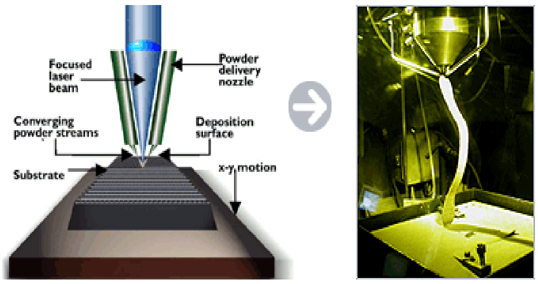

Fig.3 Advanced Product Development by LENS

Once a geometry and material or material combination has been identified, LENS can rapidly produce a 3-dimensional prototype with excellent mechanical properties that not only give the designer a view of form and fit, but also enable full functional and structural analysis. The tool-less process is driven directly from CAD data, so a prototype of a new design or a design iteration can be produced in a matter of hours, providing significant time compression advantages.

B. SLS

Over the years the selective laser sintering (SLS) process has evolved into a common option for the creation of end-use production parts. The large assortment of different plastics and metals have made it quicker and less costly to use selective laser sintering (SLS) as opposed to other methods of manufacturing such as tooling. Selective laser sintering (SLS) is especially attractive when a design is complex or customized and the total part production requirements are low. Finally, the selective laser sintering (SLS) technology is well suited for use in rapid tooling. Rapid tooling, or RT, is generally different from conventional tooling in the following key areas.

Rapid tooling is generally produced faster than conventional tooling, taking off as much as 80-90% of the time it takes to create first parts. This is where the speed of selective laser sintering (SLS) comes into play as parts can be created in days as opposed to weeks. Rapid tooling is typically delivered at a lower cost compared to conventional tooling – as much as 90-95% less. Tolerances for rapid tooling are usually not as accurate as conventional tooling but selective laser sintering (SLS) allows for customization of specs to meet customer needs. Rapid tooling life is considerably less than a conventional tool [18].

In spite of these differences, for many applications, rapid tooling using the selective laser sintering (SLS) process is ideal for first run parts or short run prototype production until conventional tooling methods can be obtained. Selective laser sintering (SLS) is an avenue that cuts a products time to market down considerably and, since the process can be customized, allows for design changes to be made without having to create a new tool. Harvest Technologies has multiple options for selective laser sintering (SLS) rapid tooling, as well as others, so please allow us to consult with you on the best choice for your requirements.

C. DMLS

DMLS is fast becoming a recognized manufacturing method for the fast, accurate production of one-off prototype components or for the economical manufacture of small series parts for testing purposes, or as final products for use in many different environments. The process generates hard wearing but intricate components, opening up opportunities to all industries, including Aerospace, Automotive, Electronic and Medical, and for generating Tooling Inserts. Certain materials give the parts rigidity and weight, thereby making it attractive to the aerospace and automotive sectors for vigorous testing and use in a wind tunnel. The strength of the process makes it attractive to the medical sector, and the high levels of finishing produces parts that are sterile and hygienic.

With the introduction of DMLS to the medical industry, the manufacture of patient specific instrumentation and implants has become cost- and time- effective. The DMLS process enables surgical and medical devices to be manufactured directly from the CAD design, without having to endure the cost elements of conventional manufacturing techniques. The reduction in lead-times that this technology offers opens up new opportunities for custom devices to be designed and manufactured for trauma patients. Rather than using standard products, they can have the right tools and instruments to meet their specific requirements.

The DMLS process holds tremendous potential for Formula 1 and Aerospace applications [3]. Not only can it produce complex and structurally challenging parts in various materials, but it can also offer lead-times unachievable by other methods. DMLS enables production of very strong but lightweight parts by building them hollow or with an intelligent internal structure. Complex parts can also be produced that couldn't be made any other way. For example, you can combine a number of parts into a single one, making it lighter and potentially improving the functionality and strength. DMLS can currently create parts in Cobalt Chrome, Stainless Steel and Maraging Steel. At the moment, the Cobalt Chrome Super alloy is probably the most attractive one for these markets, as it offers very high strength and hardness, and can withstand high operating temperatures (up to 1100°C). The material could be used to produce accurate, complex exhaust manifold forms for example, and other options may include gearbox parts, suspension parts or complex fixings.

Fig.4 Engine exhausts in Cobalt Chrome

Fig.5 Turbine blade in Cobalt Chrome using DMLS

Fig.6 Propeller prototype for wind tunnel testing in Bronze

Fig.7 Aerospace blades built using DMLS in Cobalt Chrome

French company LEGRAND [24] was keen to test the improved DMLS technology to produce more efficient inserts in a shorter time. One of the products was a wall socket in ABS with a very high volume production (> 1 million parts a year). Two inserts; core and cavity; (Fig 8.) were designed around that part as shown.

Fig 8 (L) Core (R) Cavity

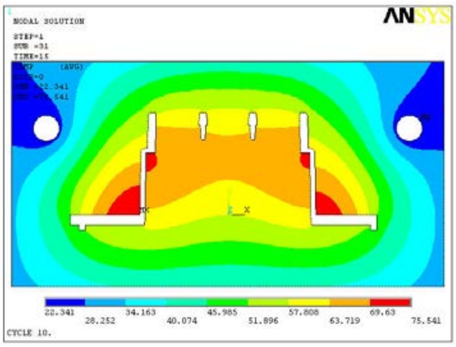

Fig 9 - Conventional mould temperature distribution [12]

In order to optimize the design of the cooling channel, the first step was to analyze the performance of the existing mould in terms of thermal performance. The simulation showed an uneven mould temperature distribution with a fairly high hot spot (around 75°C), which means that the quality of the part will not be optimum. (see Fig 9.)

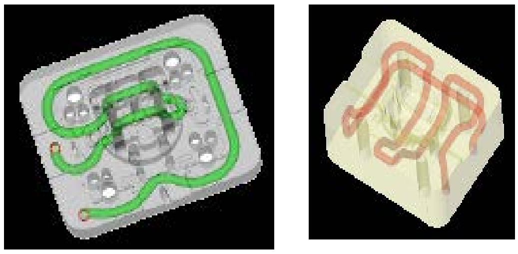

Fig 10 Conformal cooling design

The second step was to redesign the cooling channel to get a more uniform mould temperature distribution. With the inserts being produced layer by layer, there is nearly no limitation in the cooling channel design (see Fig 10.). A new thermal simulation has shown that this time the mould temperature was more uniform and that the hot spot was lower (around 53°C), which will lead to a shorter cycle time and a better part quality due to a more uniform part temperature (see Fig 11).

A fully instrumented mould was produced using the DMLS inserts. A first set of inserts was built on an EOS M270 machine using the EOS DSH20 steel powder in 70h and fitted in the bolster in around 50h. (A second set of inserts was built recently using the new MS1 tool steel powder in 35h). The cost and lead-time of the mould were reduced by about 30%. Finally, during the injection moulding trial, the simulation results were confirmed in terms of mould temperature and cycle time.

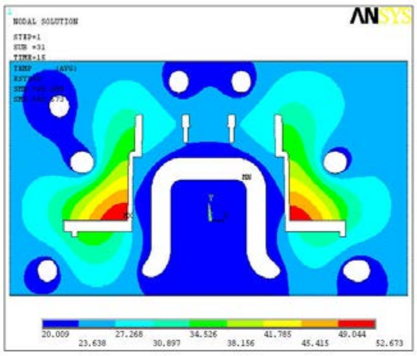

Fig 11 - DMLS mould temperature distribution [12]

This study has shown that by using the DMLS technology it is possible to significantly reduce the cost and the lead time of a plastic injection moulding tool (results dependent of part geometry). The introduction of conformal cooling will lead to higher productivity and better part quality [12]. Finally, it is very important to do a full thermal simulation with various conformal cooling configurations to guaranty the optimum results in terms of productivity.

VII. Conclusion

Software based high power laser based metal fabrication techniques are most popular of Rapid Manufacturing processes. Several laser based metal fabrication technologies have been developed and commercialized, and some systems are still under development. Some of the commercialized laser based metal fabrication technologies are based on metal sintering technology such as Selective Laser Sintering (SLS) and Direct Metal Laser Sintering (DMLS) and Directed Material Deposition such as Laser Engineered Net Shaping (LENS).

It can be seen that some systems have advantages over the others when comparing of some parameters of Direct Metal Laser Fabrication systems. Compared systems are just currently commercialized systems and it is obvious that there are a lot of under research systems which are cool similar to these systems. It appears that further developments on SLS and DMLS processes are limited compared with LENS process. Only accuracy and material variety developments could be made in SLS and DMLS systems. It should be noted that processing steps should be decreased in SLS process. For instance, secondary sintering and infiltration steps are important disadvantages for the manufacturing sectors that paying attention on time and cost for production.

LENS process can be seen as future's technology among Rapid Prototyping and Manufacturing Technologies from the points of view such as material variety, multi-material structured part, fuljy dense in one step, repairing operations, 5 axis capabilities even ifl of them are not completely fruitful for now. Nevertheless, some parameters such as surface quality, eliminating secondary finishing operation and

support structure problem have to be overcome to be succeeded.

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Automatic Metal Surface Inspection in Steel Rolling Mills

J.Angela Jennifa Sujana and N.Rajesh Jesudoss Hynes

Abstract *- In Steel rolling mills the surface quality of strip is currently controlled mainly by human on-line visual inspection before cutting the strip into variable length sheets for delivery. Human inspectors classify the defects according to their cause and origin because the inspection results are used as feedback to correct the manufacturing process. Automatic metal surface inspection in automation is being investigated for two decades, but there is no general approach available for recognition of defects automatically. Different tasks involved in this challenge are, image acquisition, segmentation of anomalies, anomaly measurement, feature extraction and decision making for classification of defects. The present work focuses on segmentation, i.e. isolating the suspected anomalies in the image. Though, Watershed Transformation, which is a well-established tool for segmentation of images, it produces excessive over-segmentation without any reference to texture changes. Hence, texture characterization is done at each pixel to produce texture gradient using Non Decimated Complex Wavelet Transform. This technique is applied to color images by averaging the resulting gradient images. Since, the use of a texture gradient does not solve over-segmentation problem, it is overcome by extending the minima, which computes the set of "low spots" in the image that are deeper than their immediate surroundings. Marker Controlled Watershed Color Image Segmentation Using Texture Gradient has proved very effective and computationally very efficient for this task.*

Key words - Texture gradient, Watershed algorithm, Non-decimated complex wavelet transform, Flaw detection

I. INTRODUCTION

The aim of image segmentation is to isolate/distinguish/ subdivide a digital image into its constituent parts or objects. Examples of image segmentation applications include remote sensing, medical image analysis and diagnosis, computer vision and the image segmentation necessary to enable region indexing in a CBIR application.

The watershed transformation is a technique for segmenting digital images that uses a type of region growing method based on an image gradient. It thus effectively combines elements from both the discontinuity and similarity methods described above. The ultimate aim of an automatic image segmentation system is to mimic the human visual system in order to provide a meaningful image subdivision. This is often unfeasible, not only because of the technical difficulties involved but also because scenes and objects themselves can be hierarchically segmented with no indication of what level of hierarchy is meaningful to an intended user. For example, a picture of a crowd can be segmented into either groups of people, individuals or elements of each individual e.g., torso, limbs etc. This generally means there is rarely any "correct" spatial segmentation for natural images [1][2].

Another difficulty of mimicking the human approach to segmentation is that a human can draw on an unconstrained and simply enormous set of object models with which to match scene elements. The usual methods of image segmentation rely on more primitive visual aspects of images such edges, color, texture, motion (for video) or various combinations.

Image segmentation can be done based on either gray scale information or the color information of the image. In many pattern recognition and computer vision applications, the additional information provided by color helps the image analysis process and yields better results than approaches using only gray scale information [3]. More researches have focused on color image segmentation due to its demanding need.

Early researches were based on gray scale information. As the revolution goes on, there was a need to identify images with more complex and minute information. Later, it was shown that color of an image carries much more information than the gray level . At present, color image segmentation methods are mainly extended from monochrome segmentation approaches by implementing in different color spaces. Gray scale level segmentation methods are extended to each component of a color space; then the results are combined to obtain the final segmentation result. Recently research has been focused on variety of Color image segmentation techniques: for example, stochastic model based approaches, morphological watershed based region growing, energy diffusion, and graph partitioning. The image segmentation problem is challenging attributing to the presence of large variety of texture contents. If an image contains only homogeneous color regions, clustering methods in

J.Angela Jennifa Sujana is with Mepco Schlenk Engineering College, Virudhunagar, Tamil Nadu, India (phone: 9865248527;e-mail: ang_jenefa@mepcoeng.ac.in).

N.Rajesh Jesudoss Hynes is with Mepco Schlenk Engineering College, Virudhunagar, Tamil Nadu, India (e-mail: findhynes@yahoo.co.in).

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color space such as are sufficient to handle the problem. In reality, natural scenes are rich in color and texture. Since, it is difficult to identify image regions containing color-texture patterns; one has to assume the following [11] while dealing with color image segmentation:

i. Each region in the image contains a uniformly distributed color-texture pattern.
ii. The color information in each image region can be represented by a few quantized colors, which is true for most color images of natural scenes.
iii. The colors between two neighboring regions are distinguishable - a basic assumption of any color image segmentation algorithm.

Color and texture are among the more expressive of the visual features. Considerable work has been done in designing efficient descriptors for these features for applications such as similarity retrieval. For example, a color histogram is one of the most frequently used color descriptors that characterize the color distribution in an image [4].

In this paper we propose a method to segment the color images using non decimated complex wavelet transform to obtain texture gradient and further to segment it using watershed transform. The combined watershed segmentation with other processing techniques serves us a power tool in automatic inspection of metal surfaces [13,14].

II. TEXTURE GRADIENT

A. Texture Characterization

The texture gradient can be produced by first characterizing the texture content of the image at each pixel. A number of methods have been proposed to do this. One of the most popular techniques is the use of a set of scaled and oriented complex Gabor filters. By suitable spanning of the frequency space, each pixel can be characterized in texture content. However, when considering the differences in texture within an image (e.g., the texture gradient) this often produces suboptimal characterization for segmentation. To produce an optimal system, the Gabor filters need to be tuned to the texture content of the image. The other schemes use arbitrary techniques that are entirely separate from the texture feature extraction process whilst also being excessively computationally complex.

In order to integrate an adaptive scheme with the texture feature extraction process we have used a Non-Decimated Complex Wavelet Transform (NDXWT). The magnitude of the coefficients of each complex sub band can be used to characterize the texture content. This is because the basis functions from each sub band (very closely) resemble Gabor filters, i.e., they are scale and directionally selective whilst being frequency and spatially localized.

Each pixel can therefore be assigned a feature vector according to the magnitudes of the NDXWT coefficients. A pixel at spatial position (x, y) has one feature for each NDXWT sub band coefficient magnitude at that position: defined as $T_i(x, y)$, where i is the sub band number. A feature vector $T(x, y)$ is therefore associated with each pixel characterizing the texture content at that position. [1]

III. NON-DECIMATED COMPLEX WAVELET TRANSFORM (NDXWT)

In order to develop the Non Decimated Complex Wavelet Transform (NDXWT), it is first instructive to develop a non adaptive version using the NDXWT transform. The structure of the Non Decimated Complex Wavelet Packet Transform is based upon the Non-Decimated Wavelet Transform (NDWT) combined with the CompleX Wavelet Transform (XWT) (defined in [12]).

A.Non-Decimated Wavelet Transform (NDWT)

The Non-Decimated Wavelet Transform uses the same structure as the DWT but without any sub sampling. This leads to a transform that has every subband having exactly the same number of coefficients as the number of samples in the original signal. This of course leads to an over complete representation. However, this transform has the advantage of being completely shift invariant, an aspect which has been exploited by applications such as image fusion, where it was described as the Shift Invariant Discrete Wavelet Transform (SIDWT). The structure of the NDWT is shown in Fig 1. This clearly shows that in order to retain the same effective filtering without the down sampling, the filters at each stage must be up sampled with the right number of zeros. The filters in Fig 1 are best represented in the z–transform domain with the filters $H_0(z)$and $H_1(z)$ representing the low and high pass filters respectively. The filters used at level i are $H_0(z^{2i-1})$ and $H_1(z^{2i-1})$. The z^{2i-1} terms represent the original filters up sampled with z^{2i-1} zeros in-between each original filter tap.

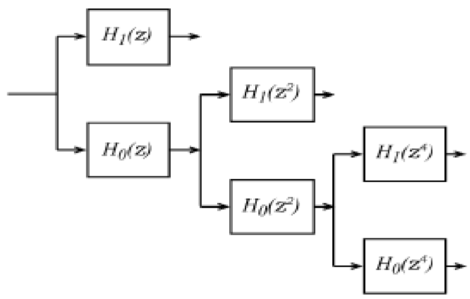

Fig1. Non-Decimated Wavelet Transform.

B. Complex Wavelet Transform (XWT):

The XWT was developed by Magarey and Kingsbury [12] for motion estimation. It was soon surpassed by the Dual Tree Wavelet Transform (DT-CWT) as the XWT wasn't found to be invertible and to have inflexible frequency characteristics. However, unlike the DT-CWT, the XWT is ideally suited to a conversion to a non decimated form.

1) Original Complex Filters: The original form of the XWT as used in [12] is based upon two complex valued FIR filters that approximate two Gabor filters:

$$h_0(n) \approx a_0 e^{(n+0.5)^2/2\sigma_0^2} e^{j\omega_0(n+0.5)} \quad (5)$$

$$h_1(n) \approx a_1 e^{(n+0.5)^2/2\sigma_1^2} e^{j\omega_1(n+0.5)} \quad (6)$$

for $n = -D,...,D-1$

This pair of complex high pass (h_1) and low pass (h_0) filters are used with a standard DWT structure to form the XWT in one dimension.

The key property of this transform is that (under certain conditions) given the Gabor like FIR filters h_0 and h_1 the equivalent wavelet $\psi^{(m)}$ and scaling $\phi^{(m)}$ filters are also approximately Gabor like

$$\psi^{(m)}(n) \approx a_m e^{(n-n_m)^2/2\sigma_m^2} e^{j\omega_m(n-n_m)} \quad (7)$$

$$\phi^{(m)}(n) \approx \hat{a}_m e^{(n-n_m)^2/2\hat{\sigma}_m^2} e^{j\hat{\omega}_m(n-n_m)} \quad (8)$$

For $n = -(2^m-1)D,...,(2^m-1)(D-1)$

For the parameters within (5)and (6) set to [ω_0=Π/6,ω_1=0.76Π,σ_0=0.97, σ_1=1.07, a_0=0.47, a_1=0.43j, D=2] the high and low pass filters can be closely approximated by the rationally valued filters

$$h_0 = \frac{(1-j,4-j,4+j,1+j)}{5} \quad (9)$$

$$h_1 = \frac{(-1-2j,5+2j,-5+2j,1-2j)}{14} \quad (10)$$

2) New Complex Filters: The use of the even length complex filters above will place the subband coefficients halfway between the original signal samples. When the subsequently presented non decimated form (see Section 4.B.3.) is used, this means that there will not be a direct one-to-one mapping relation between each subband coefficient and each image pixel. In order to overcome this problem, the filters are modified to have five instead of four taps. This is effected by initially removing the 0.5 offset within equations (5) and (6), i.e.,

$$h_0(n) \approx a_0 e^{(n)^2/2\sigma_0^2} e^{j\omega_0(n)} \quad (11)$$

$$h_1(n) \approx a_1 e^{(n)^2/2\sigma_1^2} e^{j\omega_1(n)} \quad (12)$$

for $n = -D,...,D-1$

For the parameters within (11) and (12) set to [ω_0=Π/6 , ω_1=0.82 Π, σ_0=0.97, σ_1=1.07, a_0=0.47, a_1=0.43j, D=2] the high and low pass filters can be closely approximated by the odd length, rationally valued filters

$$h_0 = \frac{(1-4i,19-11i,36,19+11i,1+4i)}{76} \quad (13)$$

$$h_1 = \frac{(-4+1i,9-14i,26i,-9-14i,4+1i)}{60} \quad (14)$$

These filters produce wavelet characteristics that are virtually identical to the original filters. These new filters also share or mirror the properties of the original filters:[1]

Symmetry: Each filter is linear phase. A linear phase filter response is often required for applications such as texture analysis where phase distortions of signal frequency components are not desirable.

Regularity: The regularity of the wavelets are determined by the number of zeros of at . In common with the original filters, . This means that the spatial filters are sampled versions of a continously differentiable wavelet.

DC gain: The DC gain of is unity. This ensures that the passband gain of the decomposition is consistently unity over the entire decomposition.

Length. Each filter is of length 5. Although longer than the original filters these are the minimum odd length filters that are practical. This minimizes the computational effort for the transform whilst placing the output coefficients coincident with the input samples. The use of rationally valued filters also increases the potential implementation speed of the transform.

C. Conversion From the XWT to the NDXWT

The implementation of the XWT is identical to the implementation of the DWT with complex valued filters. The conversion of the XWT to its non decimated form (NDXWT) is therefore identical to the conversion of the DWT to its non decimated form (NDWT).

D. Gradient Extraction From the NDXWT Transform

The texture content at each spatial position (x, y) using the feature vector $T_i(x, y)$ (where i is the sub band number) is defined as the NDXWT sub band coefficient magnitude at that position). This is made

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possible because the non-decimated wavelet sub bands are all the same size as the image.

A simple approach to obtaining the texture gradient of an image would then be to calculate the gradient of each sub band magnitude and sum them. This would work for purely textured images. However, all texture extraction methods will give high energy values over simple intensity boundaries found in non textured image regions (see the edge of the top of the hat in Fig.2). The gradient of the sub band magnitudes will give a double edge at such intensity boundaries. The gradient of each sub band should therefore aim at step detection rather than edge detection. A simple method to perform this is a $x-y$ separable median filtering on the magnitude image followed by gradient extraction. This has the effect of removing the edges and preserving the steps. The texture content can then be represented by the median filtered versions of the sub band magnitudes

$MT(x, y)$. This can be represented by:

$$MT_i(x, y) = MedianFilter(T_i(x, y)) \quad for 1 < I <= n \qquad (5)$$

where n is the number of sub bands. The median filtering should reflect the size of the edges in the complex sub bands produced by simple intensity boundaries in order to negate them, i.e., octave scale median filtering. The length of the separable median filtering is therefore defined as $2^{(l+2)}$ where l is the decomposition level of the given sub band. A morphological thinning operation would also be a possible solution to this problem but the median filtering was found to be an initially simple solution.

In order to calculate the gradient of the texture content one needs to consider the gradient within the multidimensional feature space. The simplest way to do this is to sum the gradients obtained for each of the individual features. Defining to be the magnitude of the texture gradient we have:

$$TG(x, y) = \sum_{i=1}^{n} \frac{\nabla(MTi(x, y)}{l2(MTi)} \qquad (6)$$

Where n is the number of sub bands and ∇ is approximated using a Gaussian derivative gradient extraction technique [3] [with the scale parameter set to 2.0]. l_2 is the norm energy of the median filtered sub band and is included to normalize the effect of each sub band on the gradient.

The gradient clearly highlights the edge of the texture regions in the artificial texture images together with the natural image (see edge of the feathers in the hat). Clearly this gradient is suited to the detection of texture boundaries. In order to preserve the ability of the system to detect intensity changes, this gradient is combined with a simple intensity gradient as follows:

$$G(x, y) = \frac{mix \times (|\nabla f|)^{1.2}}{F(|MT(x, y)|))^3} + (TG(x, y))^3 \qquad (7)$$

where $G(x, y)$ is the final combined gradient and *mix* is a suitably chosen constant for mixing the intensity and texture gradients. ∇f is just the gradient of the plain intensity image calculated using the Gaussian derivative technique defined in [3].

$F(|MT(x, y)|)$ is defined as

$$F(|MT(x, y)|) = \begin{cases} mean(|MT|) & if\ |MT(x, y)| \le mean(|MT|) \\ (|MT(x, y)|) & if\ |MT(x, y)| > mean(|MT|) \end{cases} \qquad (8)$$

The parameters within the definition of were obtained heuristically and are justified as follows:

The power 1.2 of $(|\nabla f|)^{1.2}$: This is included to increase the dynamic range of the gradient image emphasising the larger gradient values.

The power of 3 of $((|TG(x, y)|))^3$: This is included to emphasize the larger texture gradient values. This is necessary because the newly defined texture gradient has a smaller dynamic range.

The function F: The $(F(|MT(x, y)|))^3$ factor is included to reduce the effect of the spurious gradients within highly textured regions. The F function is included so the $(F(|MT(x, y)|))^3$ factor does not relatively elevate the importance of the regions where $(|MT(x, y)|)$ is small.

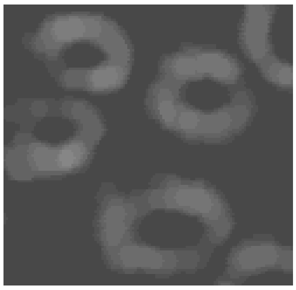

Fig.2 Gradient image

IV. WATERSHED SEGMENTATION

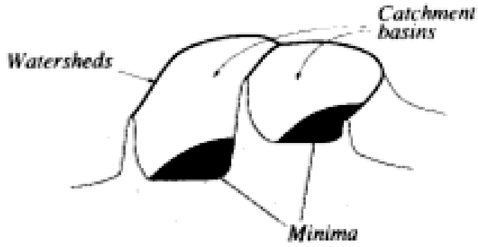

Fig 3 Minima, catchment basins, and watersheds

Watersheds are one of the classics in the field of topography. For example consider the ‘great divide’. This particular line separates the U.S.A. into two regions. A drop of water falling on one side of this line flows down until it reaches the Atlantic Ocean, whereas a drop falling on the other side flows down to the Pacific Ocean. This ‘great divide’ constitutes a typical example of a watershed line. The two regions it separates are called the Catchment basins of the Atlantic and the Pacific Ocean, respectively. The two Oceans are the minima associated with these catchment basins[6].

The watershed segmentation method, which is a mathematical morphology based technique, has been widely used in geological and histological images. The concept was formalized by Buecher and Lantuejoul [5] and was later turned into an ‘immersion-based’ algorithm by Vincent and Soille [6]. The strength of watershed segmentation is that it produces a unique solution for a particular image. However, noise in the image results in over-segmentation as shown in Fig 4. The placement of internal and external markers into regions of interest (the approach is explained in the next section) can easily cope with the over-segmentation problem. Another disadvantage of watershed segmentation, again related to the image noise and the image’s discrete nature, is that the final boundaries of the segmented region lacks smoothness[4].

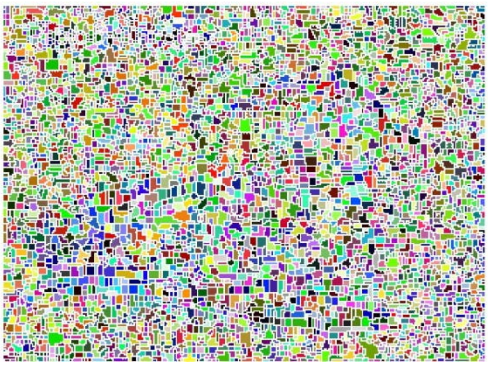

Fig 4. Oversegmentation while applying Watershed directly without texture gradient

Watersheds partition geographical landscapes based on ridges, or watershed lines, and the valleys between them. Water precipitating onto the landscape naturally collects to form pools in low-lying catchment basins, where its flow is blocked by dams or ridges. If we treat the values of an image as a relief map describing height in a geographical terrain then an image can be segmented by partitioning it into areas that correspond to catchment basins in the geographical watershed. The watershed transformation of an image is a mapping from the original image to a labeled image such that all points in a given catchment basin have the same unique label. Usually the watershed transformation is applied to a boundary map, which is a gray scale function, derived from the input image, that has low values within regions and high values along region boundaries. The gradient magnitude of an intensity-based image, for example, is often used as the boundary map, as well as higher order features such as isopod curvature.

There are many different algorithms for computing the watershed transform, but most of them fall into two basic classifications. The first class of algorithms associates pixels with catchment basins according to their shortest topological distance from local minima. Thus, a basin in the watershed transform is a set of all points whose paths of steepest descent terminate at the same local minimum [5]. The second approach floods the image from the bottom up, as if the metaphorical landscape were punctured at its local minima and then immersed in water. This is the strategy of the “immersion algorithm" [6]. The immersion algorithm imposes a discrete set of gray level values on the image and then expands each catchment basin from its minimum gray level by iteratively adding the closest connected component regions of the next highest gray level. Any pixels that are equidistant from two catchment basin are labeled as watershed lines.

The watershed transformation partitions images into patches that coincide with low values of the boundary measure, but it tends to over segment the image because it creates one catchment basin for every local minimum. Over segmentation is especially pronounced in noisy or highly detailed images. Several strategies exist to deal with the over segmentation problem. One common approach is to grow catchment basins using the immersion algorithm only from specific markers (seed points or seed regions), instead of from all image minima. The resulting segmentation is constrained so that it contains only one region per marker [5]. A second strategy, hierarchical watersheds, produces a multiscale set of [5],[10]Watershed Transforms.

Over segmentation can also be controlled by careful smoothing and thresholding of the background values in the original image, which flattens out shallow catchment basins in uninteresting regions. A good review of the many classes and variations of the watershed transform, as well as common solutions to the over segmentation problem is given in [5].

A. Marker-Based Watershed Segmentation

The principle of the immersion-based watershed algorithm by Vincent and Soille [6] can be illustrated by imagining the (magnitude of the) gradient image of the (smoothed) original image as a relief, with the 'height' variable being the grey-value for each pixel position. Imagine, water immersing from the bottom of the relief (at grey-level 0). Every time the water reaches a minimum, which corresponds to a region in the original image, a catchment basin is 'grown'. When two neighbouring catchment basins eventually meet, a dam is created to avoid the water spilling from one basin into the other. When the water reaches the maximum grey-value, the edges of the union of all dams form the watershed segmentation. As this approach usually leads to over-segmentation, we place one or more internal marker(s) in the region of interest (ROI) and one or more external markers in the other region(s).(background)[9] .Only catchment basins in regions with a marker are grown which results in a binary segmentation of the image, i.e. the ROI and the background. [10]

A practical solution to this problem is to limit the number of allowable regions by incorporating a preprocessing stage designed to bring additional knowledge into the segmentation procedure.

The best solution suggested for controlling Oversegmentation is to use marker. A "marker" is a connected compoenent belonging to an image. Marker is categorized as

a)Internal Marker and

b) External Marker.

"Internal Marker"- are inside the object of interest and "External Marker" –are contained within the background.

V. RESULTS AND DISCUSSIONS

Over segmentation is the major issue using watershed techniques as it is not known to what extent the ridge level could be considered.

The effect of over segmentation due to watershed technique is shown in Fig 4. The effects of the regional minima contribute to over segmentation. It can be overcome by extending the minima that computes the set of "low spots" in the image that are deeper than their immediate surroundings.

Similarly the external marker shows the watershed ridge lines in the binary image. With the Internal Marker and External Marker the gradient image is modified by superimposing regional minimum at the location of

the Internal Marker and External Marker.

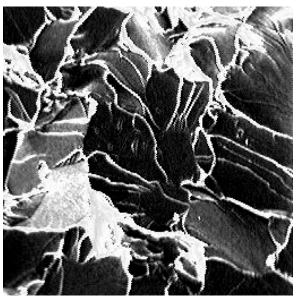

Fig 5. Original Image on microstructure of steel surface[14]

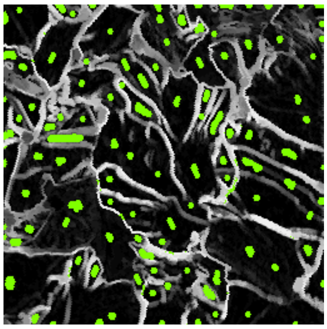

Fig 6. Gradient Image on microstructure of steel surface

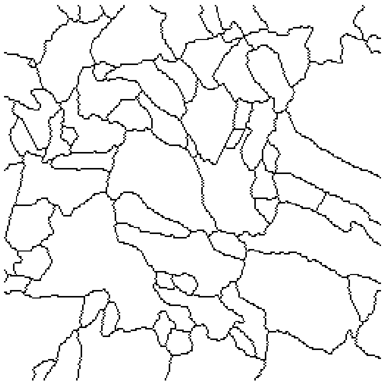

Fig 7. Segmented result on microstructure of steel surface

A. Cleavage Fracture in Steel

The problem here consists in extracting the cleavage facets from a fractured surface [13] in steel. Fig 5 is the original image that consists of the microstructure of steel component considered for our experiment. Fig 6 is the texture gradient image of the given image. The segmentation output of the image along with the boundary highlighted is shown in Fig 7. It is clear from the output the NDXWT shows promising results.

B. Detection of Indentation Mark on Steel surface

The indentation marks are localized depressions (swellings) on the plane steel surface(Fig. 8) caused by protrusions on defective rollers. Thus, these types of defects introduce some form of curliness on the metal surface, which serve as a distinctive feature of the defect [13]. Hence, for characterizing indents we go for modeling the surface of the defective regions. Typically, any type of surface (curved or plane) could be modeled by using higher order polynomials. However, modeling higher order polynomials is a

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computation intensive job and is not possible for real time implementations. More so, swellings or depressions being nearly quadratic surfaces, we go for two-dimensional second order polynomial modeling, whose parameters serve as the surface features[13].

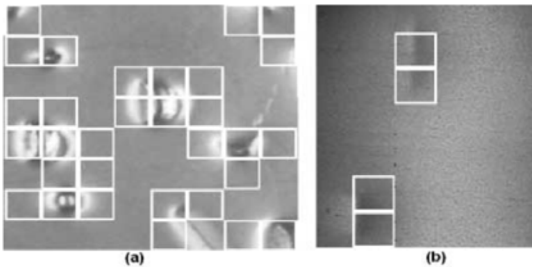

Fig. 8. Detection of Indents on steel surface [13](White margins enclose the defective region)

C. Detection of Hole

Detection of through holes on the steel surface requires the knowledge of the background, as it becomes visible through the material. Generally, the background is black due to the colour of the conveyor belt surface [13]. Thus, the visibility of a dark background through the material characterizes the presence of a hole. Hence, the process of hole detection involves the thresholding of the image (in gray scale) by a suitable value below which the pixels represent the dark background region. This threshold is dependent on the imaging system and is to be tuned manually with respect to the camera position and illumination.

The image is subdivided into a number of 2 x 2 blocks. The average pixel value of each block is computed and is compared with the set threshold. Blocks having average intensity less than the threshold are marked to be belonging to the dark background region. Fig. 9 & 10 shows the results of implementation of the hole detection algorithm[13]. The algorithm is executed on two different images acquired under similar imaging conditions and the threshold is set to 90 (Where, pixel intensity value may vary between 0 to 255).

Fig 9. Original image of hole on steel surface[13]

Fig 10. Hole detected image on steel surface

VI. CONCLUSION

This work focuses on a part of the visual inspection system of steel roll mills. The specific tasks involved are image acquisition, segmentation, feature extraction, and classification. Among these segmentation is investigated, which is very critical in the whole system. Watershed transform which is a well established tool for segmentation is used for color image segmentation in the present work. To avoid over-segmentation texture characterization is done at each pixel to produce texture gradient. This is done using non decimated wavelet transform. The combined approach of Watershed transform along with texture gradient helps us to make best use of the well understood theoretical basis and the large body of work associated with the Watershed transform. By averaging the resulting gradient images, this technique is effectively applied to the segmentation of color images. A marker based approach is subsequently is employed for enhanced color image segmentation. Implementation on this technique produces effective texture and intensity based segmentation for the application to content based retrieval of color images.

Swellings or depressions on the steel surface characterize the indents. The procedure of detection of indents thus tries to estimate the surface profile through the modeling of the same. The surface modeling approach is independent of the imaging setup and is thus a robust algorithm for indent identification. However, the surface parameter thresholds for indents should be chosen carefully to avoid false alarms. Unlike the indents, the ‘holes’ are actually discontinuities on the steel surface. These are characterized by the dark backgrounds (seen through the hole) of the hole regions along with their surrounding sharp edges (surface discontinuities). These characteristics of the hole are used in detecting the presence of the same.

Watershed segmentation when combined with various preprocessing techniques is indeed a powerful tool for Automatic metal surface inspection. Using this transformation we are able to segment the various kinds of steel defects like holes, indentation marks, cleavage fracture, roll marks etc. satisfactorily.

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Computer Simulation of Impact dynamics of tooth structure

N.Rajesh Jesudoss Hynes, N.J. Vignesh and J.Angela Jennifa Sujana

Abstract: Drill Less Dentistry is a re-emerging technology which helps in minimally invasive procedure of dental tooth caries excavation. It combines the use of high pressure air and abrasive particles entrained in the high velocity stream coming out from the tip of a small diameter nozzle to remove the tooth caries. Since, selection of process variables is critical, a numerical investigation has been carried out in the present work. Using Ansys Workbench 15.0 as a tool, the impact of abrasives on tooth structure is simulated. Standoff distance is varied and the numerical results are generated and studied. For spherical shaped abrasives, maximum amount of deformation is found at a distance of 10mm from nozzle tip to tooth structure. The obtained numerical results could be used as a tool for developing equipment for drill-less dentistry based on micro air abrasion technique.

Keywords: *Alumina, drill-less dentistry, micro air abrasion & tooth structure.*

1 Introduction

N.Rajesh Jesudoss Hynes is with Mepco Schlenk Engineering College, Virudhunagar, Tamil Nadu, India (e-mail: findhynes@yahoo.co.in).

J.Angela Jennifa Sujana is with Mepco Schlenk Engineering College, Virudhunagar, Tamil Nadu, India (phone: 9865248527;e-mail: ang_jenefa@mepcoeng.ac.in).

Drill less dentistry is an emerging technique which is aimed at the minimally invasive dentistry. It is very much useful especially to the pediatrics and those who are afraid of the painful drilling or high speed drilling dentistry. This technique has emerged in the past at about six decades back in 1950. But due to the unavailability of high volume suction to remove the abrasive powder and due to the invention of air turbine hand piece this technique did not gain popularity during the 1950s. Now the advancement in the field of abrasive materials and their handling procedures and also the invention of suction devices have made the air abrasion technique to re-emerge once again in the field of dentistry. It works on the principle of the kinetic energy of the abrasives. It is given by the formula

$$E=½mv^2 \qquad (1)$$

When a high velocity stream of abrasives is allowed to pass through the nozzle, the kinetic energy can be converted to remove the caries in the tooth structure under controlled conditions of pressure and velocity [1].

2 Methodology

In the drill less dentistry process, the methodology involved in the removal of tooth caries is affected by a number of parameters. Some of them include velocity, pressure, standoff distance, angle of nozzle, diameter of the nozzle, dwell time, particle size and abrasives types [2]. In order to select the best process parameters involved in the removal of the tooth caries, a preliminary simulation is to be carried out. In the present work, the simulation of standoff distance and its influence on the deformation of tooth structure has been carried out and the optimum distance has been predicted for effective removal of dental caries [3].

2.1 Procedure Involved

In this present work, we have used Ansys Workbench 15.0 as a tool to carry out the simulation using the Explicit Dynamics module. For this, the tooth structure has been initially modeled using Creo Parametric 2.0.

2.1.1 Numerical Simulation

Tooth structure is modeled using Creo Parametric 2.0 and it is imported to Ansys Workbench15.0. Using Explicit Dynamics tool numerical analysis has been carried out.

Tooth structure is edited in geometry design modeler and it is then imported to mechanical module.

The material properties for enamel, dentin, pulp and abrasives are available in Table.1. These properties are given as input during the analysis [4].

Table.1 Property Values of tooth structure and Abrasives

Layers of tooth/abrasive	Young's modulus (MPa)	Poisson's ratio	Density (kg/m^3)
Enamel	85000	0.33	2950
Dentin	19800	0.31	2140
Pulp	19800	0.31	8900
Alumina	413000	0.22	4100

The individual layer of the tooth structure is selected and the necessary material properties are assigned. Spherical shaped abrasive particle with diameter 0.5mm is considered as rigid structure throughout the analysis. The body interactions are assumed as frictional and a frictional coefficient of 0.3 is assigned. Fig.1 shows the geometry of the model imported into the Ansys Workbench.

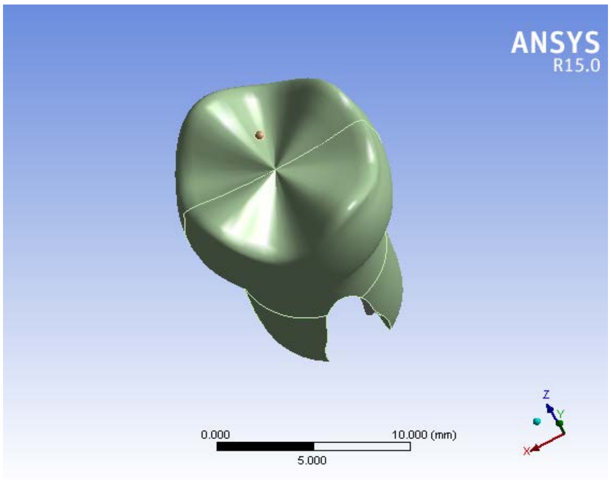

Fig.1 Geometry imported into Ansys

Then the meshing of the imported geometry is done by default mesh option. Fig.2 shows the generated meshed view of the tooth structure.

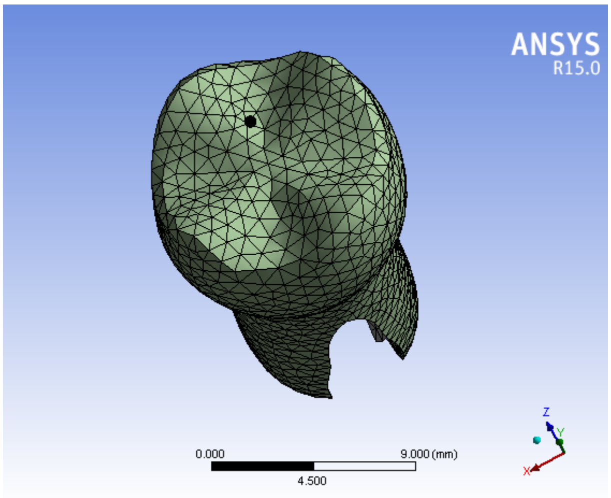

Fig.2 Meshed view of the tooth structure

Then the next step is to give the initial conditions and the analysis settings for the model imported. Input conditions such as velocity and pressure are given as 300m/s and 1.075MPa respectively. The root of the tooth structure is fixed.

Standoff distance in the order of 5mm, 7mm, 10mm, 15mm and 20mm are varied. For each analysis corresponding changes are made in Creo and Ansys. Numerical results are generated for total deformation, maximum principal stress and stress intensity. The appropriate end timing

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(Table.2) in the analysis settings is given by the formula

$$Time = (Distance / Velocity) \qquad (2)$$

Table.2 End time for various standoff distances

Standoff Distance(mm)	End Time(s)
5	0.000025
7	3.3333e-5
10	0.00004
15	5.6666e-5
20	7.6666e-5

3 Results and Discussions

The analysis has been carried out by varying the standoff distance as in Table.2. Then the obtained results are plotted in the graph using excel sheet as well. Fig.3 shows the total deformation plot of the tooth structure for 5mm standoff distance. Fig. 4 shows the maximum principal stress and Fig.5 shows the stress intensity value of the analyzed tooth structure.

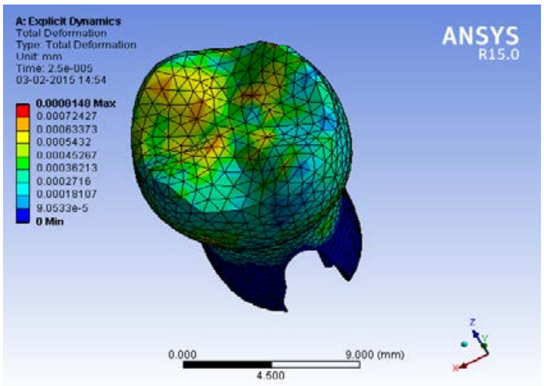

Fig.3Total Deformation Plot

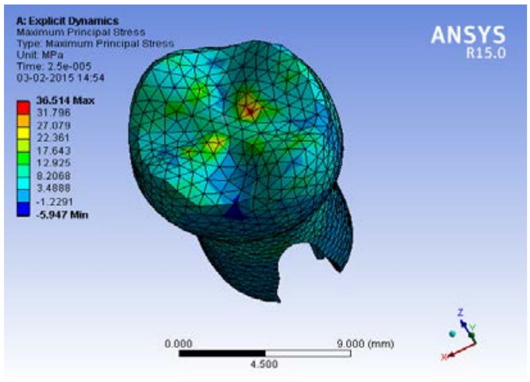

Fig.4 Maximum Principal Stress Plot

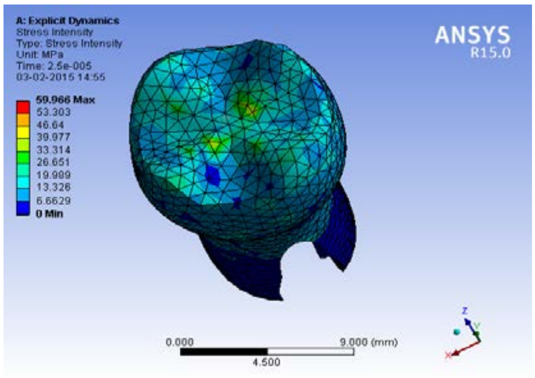

Fig.5 Stress Intensity Plot

Fig.6 shows that the deformation produced is maximum at 10mm standoff distance and it is minimum at 20mm standoff distance. Fig.7 shows that the maximum principal stress produced is maximum at 7mm standoff distance and it is minimum at 10mm standoff distance. Fig.8 shows that the stress intensity produced is maximum at 7mm standoff distance and it is minimum at 20mm standoff distance.

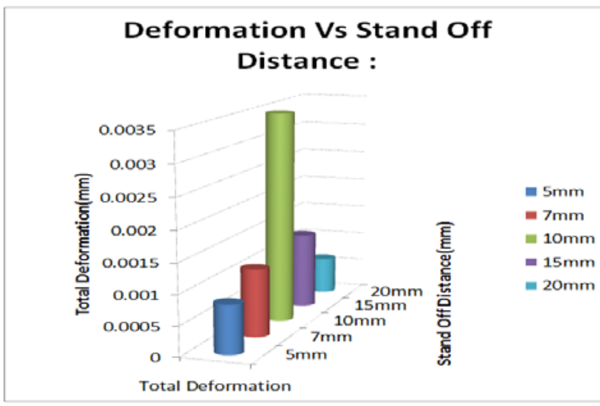

Fig.6 Effect of standoff distance on deformation

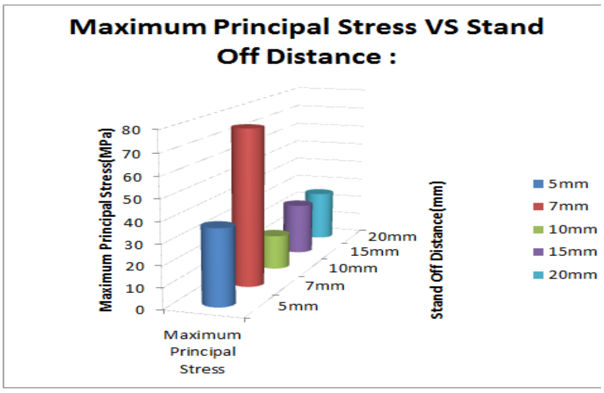

Fig.7 Effect of standoff distance on Maximum Principal Stress

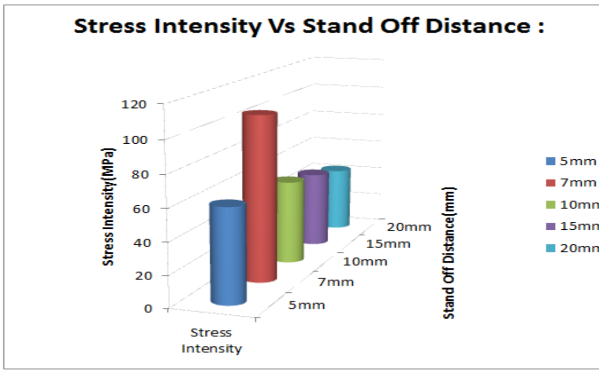

Fig.8 Effect of standoff distance on Stress Intensity

It can be seen from the above graphs that the deformation is maximum when the standoff distance is at 10mm from the surface of the tooth structure. And also it can be seen that the maximum principal stress and the stress intensity is maximum at about 7mm standoff distance.

4 Conclusions

Drill less dentistry is a re-emerging technology which can be used to remove the tooth caries under controlled conditions of pressure and velocity. It can be extended for preparation of internal tunnels and removal of previous amalgam fillings and for the cleaning of the stains in the tooth. Numerical simulation results shows that the deformation of tooth structure is maximum when the standoff distance is 10mm. It could be seen that the maximum principal stress and the stress intensity is maximum at a distance of 7mm from the tooth surface. These simulation results could be helpful in developing suitable equipment based on micro air abrasion technique.

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Numerical Analysis in Friction Drilling Of AISI1020 Steel and AA 6061 T6 Alloy

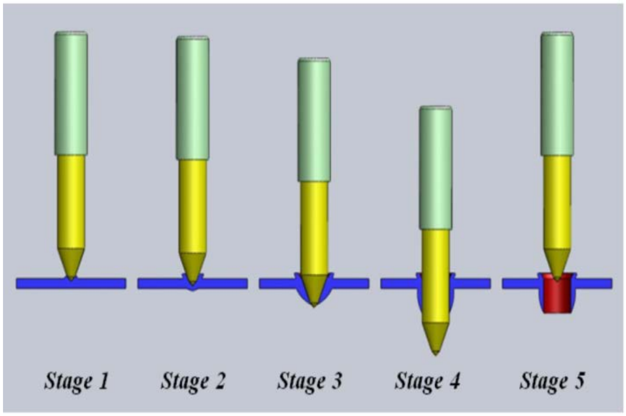
N.Rajesh Jesudoss Hynes, M. Muthu kumaran, N. Rakesh and C.K.Gurubaran

Abstract: Friction Drilling is gaining importance in the last decade due to the demand for making holes in aerospace and automobile applications. In this process, a rotating tool penetrates the work piece and creates a bushing in a single step without generating chips. In the present work, numerical analysis of the process has been carried to study the thermal behavior of the materials. The computed heat flux is applied to the numerical model and temperature distribution is predicted for work materials such as AISI 1020 Steel and AA 6061 T6. The point of contact between tool and work piece experiences maximum temperature during the first few milliseconds. In that heat affected zone the material softens and flows out to become a bushing so that subsequent internal threads could be made.

Keywords: *Friction Drilling, AA6061 T6, AISI 1020, Temperature distribution*

1. Introduction

Friction drilling, also known as thermal drilling, flow drilling, form drilling, or friction stir drilling, is a nontraditional hole-making method. The heat generated from friction between a rotating conical tool and the work piece is used to soften the work material and penetrate a hole. It forms a bushing directly from the sheet metal work piece and is a clean, chip less process.



a) b) c) d) e)

Fig.1. Stages of Friction Drilling.

Fig 1 shows schematic illustrations of the five steps in friction drilling. The tip of the conical tool approaches and contacts the work piece, as shown in Fig. 1a. The tool tip, like the web center in twist drill, indents into the work piece and supports the drill in both the radial and axial directions. The friction force on the contact surface produces heat and softens the work-material. The tool is then extruded into the work piece, as shown in Fig. 1b, pushes the softened work material sideward, and pierces through the work piece, as shown in Fig. 1c. Once the tool tip penetrates the work piece, as shown in Fig. 1d, the tool moves further forward to push aside more work-material and form the bushing using the cylindrical part of the tool. The shoulder of the tool may contact with the work piece to trim or collar the extruded burr on the bushing. Finally, the tool retracts and leaves a hole with a bushing on the work piece Fig. 1e. The thickness of the bushing is usually two to three times as thick as the original work piece. This leaves enough surface area for threading. Fig 2 gives

N.Rajesh Jesudoss Hynes is with Mepco Schlenk Engineering College, Virudhunagar, Tamil Nadu, India (e-mail: findhynes@yahoo.co.in).

J.Angela Jennifa Sujana is with Mepco Schlenk Engineering College, Virudhunagar, Tamil Nadu, India (phone: 9865248527;e-mail: ang_jenefa@mepcoeng.ac.in).

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details of one such critical applications of friction drilling in making holes of automobile chassis.

Fig 2 Drilling of holes in chassis of an Automobile

2. Related Works

In 1923, the Frenchman Jean Claude de Valiere [1] tried making a tool that could make holes in metal by friction heat, instead of by machining. It was only a moderate success, because at that time the right materials were not yet available. Moreover, he hadn't yet discovered the right shape for this kind of tool. Overy [2] and Bak [3] discussed the design aspect of the friction drilled holes. Kerkhofs et al [4], studied the performance of coated tools used in friction drilling process. Scott F. Miller [5] and H.Wang [6] developed finite element model to explain thermo-mechanical phenomenon involved in Friction Drilling. Considerable amount of experimental works were carried out by previous researchers such as Albert J. Shih [7], [8] and Wang [6]. The process variants introduced by Gefen [9] and Head et al. [10] have captured the attention of researchers as well.

But only very few researches [11], [12] have tried out modeling and simulation of friction drilling process so far. In the present work, numerical analysis of friction drilling process has been carried out to understand temperature distribution in the work material and heat flow of the process.

3. Numerical Modeling

In friction drilling, the frictional force created by the tool produces heat and softens the material. Hence, heat flux is computed from the power given to the drilling machine and contact area between the tool and work piece. Then, the heat flux is applied to different work materials such as AISI 1020 Steel and AA 6061 T6 and the thermal behavior is studied.

3.1 Tools used

To carry out the numerical study of friction drilling process Solid Works 2014 and ANSYS 15.0 are used in the present work.

3.2 Materials selected

Owing to the applications, AISI 1020 Steel and AA 6061 T6 are selected for the numerical investigation. Their properties are given in Table 1.

Material	Thermal Conductivity **W/(m.K)**	Specific Heat **J/(kg.K)**	Mass Density **kg/m^3**
1020 Steel	**51.9**	**486**	**7870**
AA 6061 T6	**166.9**	**896**	**2700**

Table 1: Material Properties

3.3 Meshed Model

Materials are modeled in the shape of discs with outer diameter as 12 mm and thickness as 1.2 mm. The tool-work contact is at the center of the work piece with an inner diameter of 1.94 mm. The meshed model is given in Fig 3.

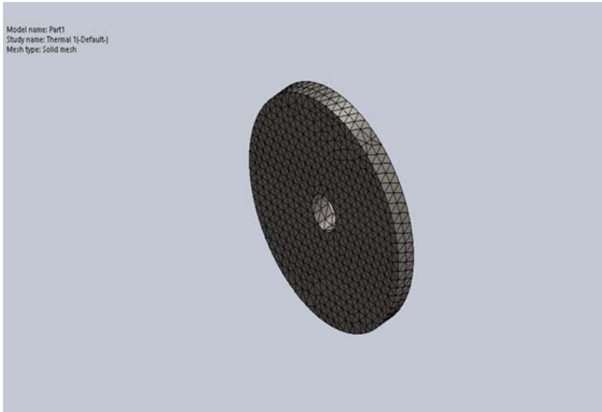

Fig. 3 Meshed Model

3.4 Heat Flux

Fig.3 gives the relation between the heat flux generated and the diameter of the tool. In the present work, maximum heat flux is considered with 2 mm drill diameter. Heat Flux is determined by dividing motor power with the contact area between tool and work piece. The process efficiency is considered as 0.5. In the numerical model, the Heat Flux 30 W/mm^2 is applied to see the thermal behavior of the work material.

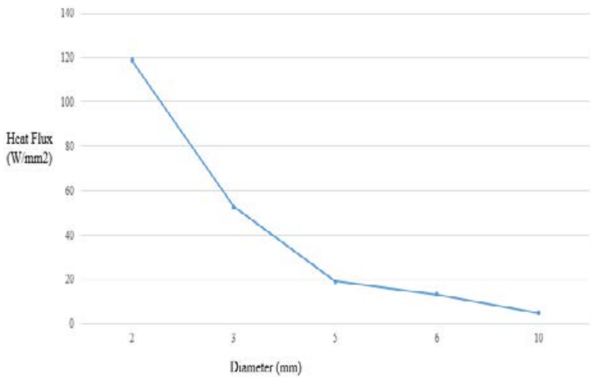

Fig 4 Effect of tool diameter on heat flux

3.5 Thermal load

The numerical analysis of Friction Drilling process is conducted on transient mode. Heat flux is applied at the center of the disc whereas the work piece is kept at 20^{0}C room temperature.

4. Results and Discussion

4.1 Heat flow in 1020 Steel

The analysis result of 1020 Steel is shown below:

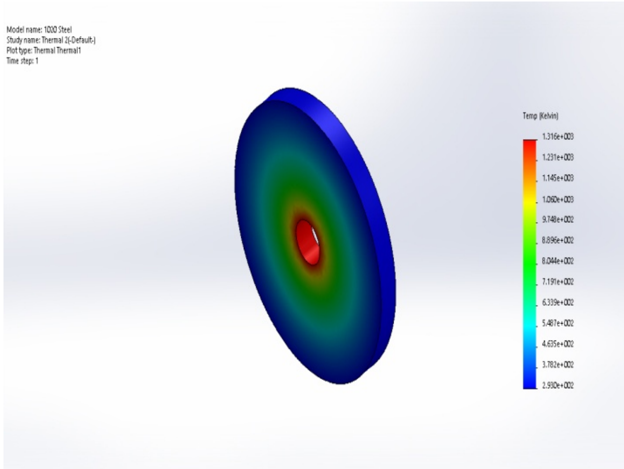

Fig. 5 Temperature Distribution in 1020 Steel during Friction Drilling

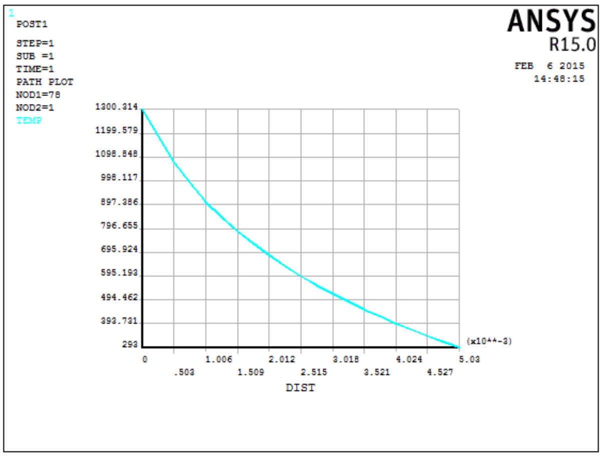

Fig. 6 Temperature vs. Distance (for 1020 Steel)

The analysis shows that the center of the disc experiences the maximum temperature i.e., 1300 K during first few milliseconds (Figure 5). It would be sufficiently high to melt the material. During the actual process the material gives in and plastic flow of the material is seen at the rear side of the work piece. Temperature distribution along the length of the work piece is shown in Figure 6.

4.2 Heat flow in AA 6061 T6

The analysis result of AA 6061 T6 is shown below:

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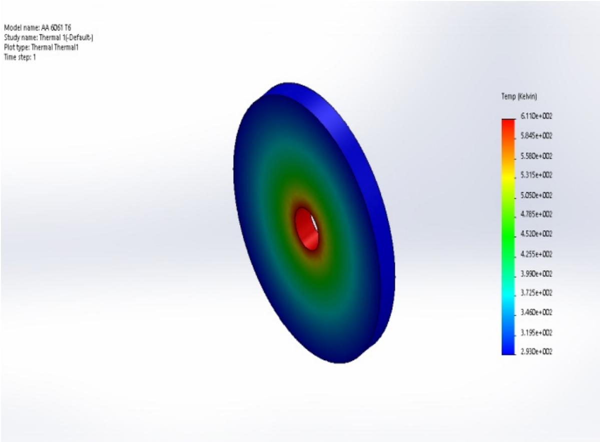

Fig. 7 Temperature Distribution in AA 6061 T6 during Friction Drilling

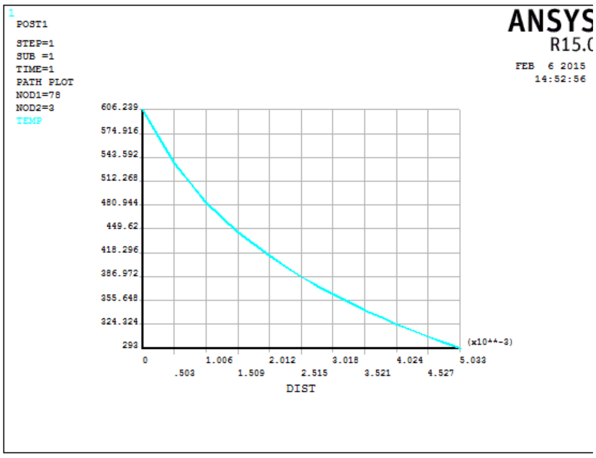

Fig. 8 Temperature vs. Distance (AA 6061 T6)

The numerical analysis shows that the center of the disc experiences the maximum temperature i.e., 606 K as in Figure 6. This is due to friction between the rotating tool and work piece. Under frictional heat the material becomes viscoplastic in nature and it flows outwardly.

In both the cases, the nodal temperature is maximum at the center and minimum at the ends (edge of the disc). But the rate of heat transfer is different for both the materials. Since the thermal conductivity of AA6061T6 is higher, heat dissipates at a faster rate. In AISI1020 steel heat is retained for some time. This may lead to the development of thermal stress. Hence, after friction drilling process, stress relieving has to be carried out.

5. Conclusion

In Friction Drilling, the heat generated from friction between a rotating conical tool and the work piece is used to soften the work material and penetrate a hole. This thermo-mechanical process is more dependent on the frictional heat developed between tool and the work piece. Hence, numerical analysis is carried out to understand the process for different work materials such as AA6061 T6 and AISI 1020 steel. Numerical results show that the point of contact between tool and workpiece experience maximum temperature near their melting point during the first few milliseconds. The material becomes viscoplastic and follows outwards during the course of the process. Hence, the material flows out to become a bushing so that subsequent internal threads could be made.

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Humidity and Temperature Control of a Metrology Laboratory

Jorge M. Jaimes Ponce, Jesús U. Liceaga C., Irma I. Siller A. and Enrique Arévalo Zamudio.

Abstract**—**In the industry there are situations in which a particular problem may require a low cost solution simple to design and manufacture rendering a system easy not only to operate but to repair and maintain. In this paper the design and implementation of a humidity and temperature control system for a metrology laboratory is presented. The control system must comply with the requirements of a metrology laboratory dedicated to the calibration and certification of industrial scales. A second requirement is that the control system must be designed using standard industrial components for both hardware and software. In this sense, the control system is based on the microcontroller PIC16F877A, the humidity and temperature sensor HMW61/71 and the well-known classical PID controller.

Keywords**—**Humidity and temperature control, PID control

I. Introduction

METROLOGY laboratories dedicated to the calibrations and certification of industrial and commercial scales require to operate under certain conditions regarding the humidity, temperature, air flow, airborne particles, etc. However, the most important variables are the humidity and the temperature. That is, this kind of laboratories must operate at 20°C±2% with a relative humidity of 50%±2%. Therefore, the control system focuses only in the regulation of the humidity and temperature within the laboratory. The control system reported in this paper is part of an industrial project which is subject to confidentiality in all the information concerning laboratory real time responses. Therefore, actual data of the laboratory cannot be published. Nonetheless, a general description of the designed control system together with important technical information is thoroughly described.

The control law to regulate de humidity and temperature was implemented using the microcontroller PIC16F877A [1] from which one input port is used to connect a keyboard and one output port to connect a liquid crystal display (LCD). Also, six A/D input channels were used to sense in three different positions the humidity and temperature -three channels for each variable-. One of the most important characteristics of the control system is that from the sensing of the humidity and temperature in three different locations of the laboratory it is possible to obtain a better measurement of these variables using the average of the three measurements, Figure 1. Moreover, the system is capable of detecting the number of sensors that are actually connected allowing the control system to keep operating even in the case of a failure of any sensor.

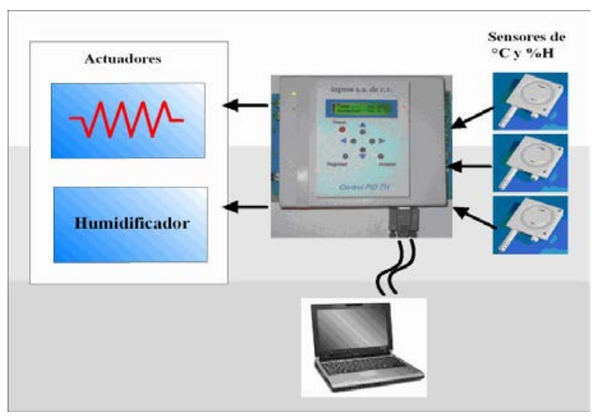

Fig. 1 Humidity and temperature Control System

To operate the electric heater and the ultrasonic humidifier it was necessary to design and construct 120 VCA power drivers. Another requirement from the client was that the system must keep a record of 4 measurements per hour during a period of 10 hours of operation for both the humidity and the temperature. This is important for quality control procedures. This information is stored in the microcontroller's *eeprom* and after that it is sent to a PC by a serial port.

Additional basic functions are performed using basic keys such as *arrows –up, down, right, left-, stop, reset,* and *enter*, as show in Figure 2.

Finally, the control law is based on the well proved classical PID controller.

J. M. Jaimes-Ponce is with the Electronic Department of the UAM-Azcapotzalco, Av. San Pablo 180 C.P. 02200, México (e-mail: jjp@correo.azc.uam.mx).

J. U. Liceaga-Castro is with the Electronic Department of the UAM-Azcapotzalco, Av. San Pablo 180 C.P. 02200, México (phone: 52-55-53189041 ; e-mail: julc@correo.azc.uam.mx).

I. I. Siller-Alcalá is with the Electronic Department of the UAM-Azcapotzalco, Av. San Pablo 180 C.P. 02200, México (e-mail: sai@correo.azc.uam.mx).

E. Arévalo-Zamudio is with the Electronic Department of the UAM-Azcapotzalco, Av. San Pablo 180 C.P. 02200, México (e-mail: enarza@hotmail.com).

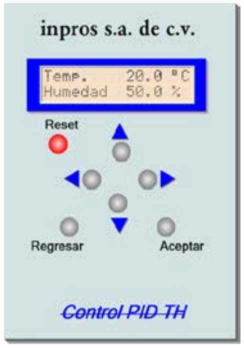

Fig. 2 Carátula del sistema de control de temperatura y humedad

Another alternative is to use commercial systems based on microcontrollers like Arduino. Arduino is a very economic microcontroller for which already exist many LabVIEW applications allowing the substitution of the data acquisition hardware.

A final option is the use of the National Instruments software, from which the modulus for USB data acquisition are the cheapest and sufficient enough for many applications.

II. General Description

The most important characteristics of the control system are:

a) A PID controller for each variable
b) It has 3 temperature sensors with output signals between 4 to 20 *mA*
c) It has 3 humidity sensors with output signals between 4 to 20 *mA*
d) Separate selection of Set Points for each variable
e) A 120V_{ac} electric heater
f) A 120V_{ac} ultrasonic humidifier
g) Data storage with the possibility of data transmission to a PC via a serial port.

A. PID Controller

Despite the existence of a great variety of control laws the classical PID [2] controller is still one of the most effective controllers for industrial applications. Also, it is a controller which is quite easy to implement. In the case of the humidity a temperature control system two digital PID controllers were implemented. The discrete definition of the PID controller is shown in Equation 1

$$u(kT) = K_p\left[e(kT) + T_d \frac{e(kT) - e(kT-T)}{T} + \frac{T}{T_i}\sum_{k}^{n} e(kT)\right] \quad (1)$$

Where

T: Sampling Period
k: k-th sampling instant
e(kT): error
$e(kT)=q_d(kT)-q(kT)$
$q_d(kT)$*=Process output or controlled variable*
$q(kT)$*=Set point or reference signal*
K_p*=Proportional gain*
T_d*=Derivative gain*
T_i*=Integral gain*
$u(kT)$*= Controller output or control variable*

The energy supplied to the actuators –electric heater and ultrasonic humidifier- is periodic and bursty. That is, every 10*sec* the actuators will be powered by 120V_{ac} during a period of time determined by the value of *u(kT)* which can be equal or less than 10*sec*

B. Sensors

The temperature and the humidity sensor is the HMW61/71 from VAISALA, Figure 3. The HMW61/71 sensor includes two sensors: One to sense the temperature with an output between 4 to 20 *mA* for a variation of temperature between -20°C to 80°C, and the second to sense the humidity with an output between 4 to 20 *mA* for a variation of a relative humidity of 0 to 100%.

The control system was constructed using three of this sensor, allocated in different positions inside the laboratory, to estimate the temperature and the humidity by the average of the measurements proportionated by the sensors. Moreover, the system can detect the number of sensors that are actually connected in order to adjust the average calculations. This is done by recalling that the minimum output signal value of the sensors is *4mA* so if the sensors currents outputs are passed through 250 Ω resistances a minimum voltages, different from zero, are produced; hence, if at zero voltage is detected at the microcontrollers input ports this data is eliminated from the averaging.

Fig. 3 Temperature and humidity sensor HMW61/71

C. Set Point

As any control system it is necessary to define a Set Point.

In this case, through the system menu it is possible to define the temperature Set Point from 15°C to 25°C. This range was stablished according to the temperature requirements for scale calibrations. The ideal condition is 20°C±2% with a relative humidity (RH) of 50%±2%.

D. *Actuators*

The temperature actuator is a 350 Watts resistance sufficient enough to heat a laboratory of $55m^3$. The resistance is powered with $120V_{ac}$ via a triac. To drive the triac the microcontroller uses the optocoupler MOC3030. In the same way the humidifier is operated. It must be noted that the humidifier does not induce a temperature increment.

Additionally, due to the physical characteristics of the actuators the control system actuates only when the error signals –Equation 1- are positive. In the case of negative error signals –when the temperature and/or the RH are above its Set Point values- the control system switch off and a cooling air condition system automatically is turned on.

E. *Data storage, Serial Transmission and Timer*

An important client requisite for the system was that it must have the possibility to keep a record of the temperature and humidity. Hence, the system keeps 4 samples per hour during 10 hours –normal every day work load- per day with a total of 40 samples for each variable. This is controlled by a timer implemented in the same system. This information is important for quality control statistics. The data is recorded in the microcontroller *eeprom* and can be sent to a PC computer via serial port. In order to

III. Hardware

A. *Microcontroller*

In Figure 4, the microcontroller PIC16F876A is shown. This microcontroller has 8 A/D inputs, although only 6 are used. It also has several digital input/output ports, a keyboard and a liquid crystal display. Other important features of the PIC16F876A [1] are that it includes a modulus for serial communication and an *eeprom* memory. The purpose of using this internal nonvolatile memory is to reduce the need of external hardware resulting in a compact and dependable system.

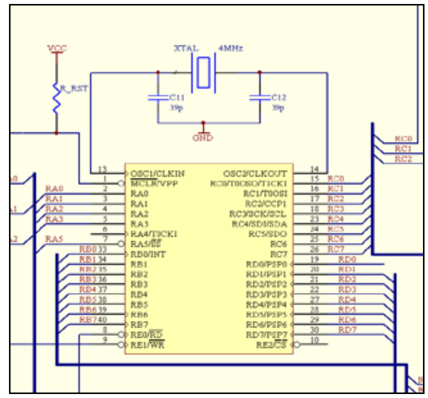

Fig. 4 Microcontroller PIC16F877A

B. *Analog Inputs and A/D Conversion*

To capture the sensors analog signals the input A/D ports are used, specifically the inputs AN0 to AN5, from the microcontroller ports A and E. However, it is necessary to transform the sensors current outputs into voltage signals. This is done by connecting the precision 250 Ω resistances RT1, RT2 and RT3, as shown in Figure 5. By a straight forward calculation it is clear that with the minimum current of 4 *mA*, the minimum voltage will be 1 *Volt.*

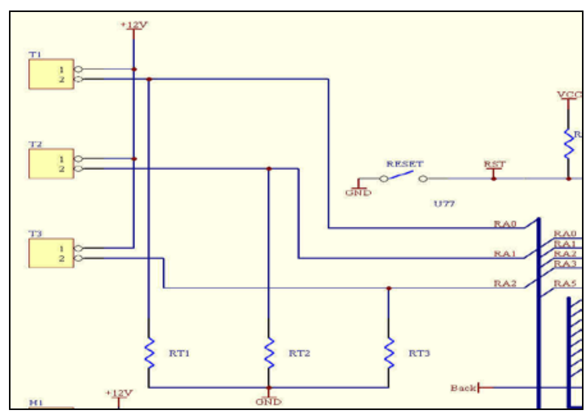

Fig. 5 Analog Inputs

C. *Serial Data Transmission*

The developed system has the necessary devices to connect to a PC. For the serial data transmission the microcontroller uses TTL signal –0*V* for the logic value “0” and 5*V* for the logic value “1”–. The PC uses the serial port RS232 [3] with 12*V* for the logic value “0” and -12*V* for the logic value “1”. Therefore, to connect the microcontroller to the PC the MAX232 circuit with the connector DB9 is used, Figure 7. The transmission characteristics are: 9600 bauds, without parity, 8 data bits and 1 stop bit.

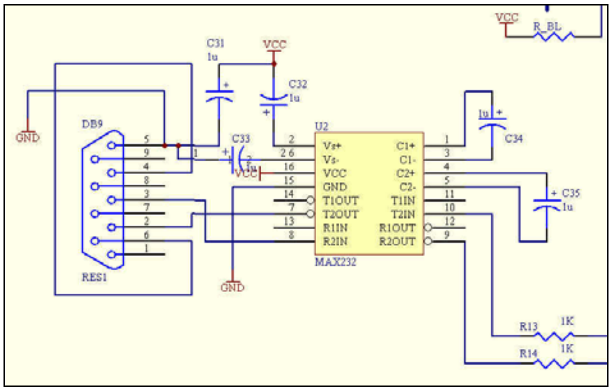

Fig. 7 Connector DB9 and MAX232

D. LCD and keyboard

Two significant elements of the system are the liquid crystal display (LCD) and the keyboard, Figures 8 and 9. Thanks to these elements it is possible to interact with the system; for instance, it is possible to select and visualize the set points for the temperature and the RH or to establish the serial communication with a PC.

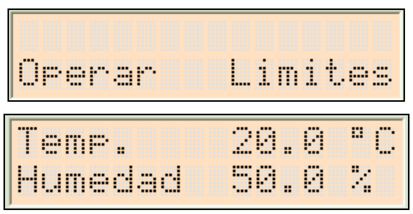

Fig. 8 Some LCD screens

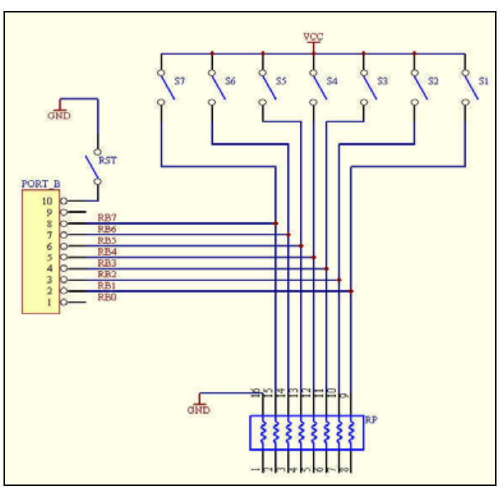

Fig. 9 Keyboard diagram

E. Voltage Source

The voltage source provides two voltages: the first is a TTL 5*V* source necessary to operate all the digital electronics, the PIC16F877A, the LCD, the optocouplers and the MAX232; the second is a 12*V* voltage source feeds the sensors.

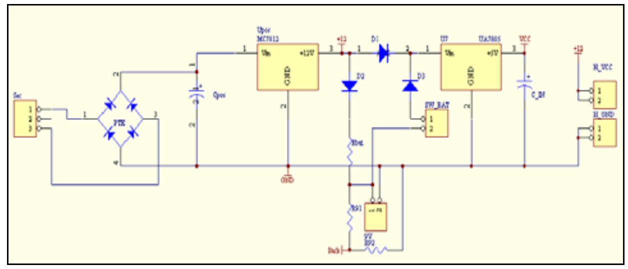

Fig. 10 Voltage source

IV. SOFTWARE

The development of the programming is based on the BASIC language for microcontrollers. BASIC is an excellent language due to its simplicity and because it allows high level applications programming, that is, it includes several functions or toolboxes. For instance, an important part of the program is the sensors detection, necessary to the average calculation of the temperature or RH variables. The BASIC program for this calculation is shown next.

```
n = 0
Sum_Temp = 0
temp_res = Adc_Read(0)
if temp_res > 100 then
   Temp_0 = (temp_res - 204) * 12
   Temp_0 = Temp_0 / 10
   Sum_Temp = Sum_Temp + Temp_0
   n = n + 1
end if

temp_res = Adc_Read(1)
if temp_res > 100 then
   Temp_1 = (temp_res - 204) * 12
   Temp_1 = Temp_1 / 10
   Sum_Temp = Sum_Temp + Temp_1
   n = n + 1
end if

temp_res = Adc_Read(2)
if temp_res > 100 then
   Temp_2 = (temp_res - 204) * 12
   Temp_2 = Temp_2 / 10
   Sum_Temp = Sum_Temp + Temp_2
   n = n + 1
end if

if n > 0 then
     temp_res = Sum_Temp
     temp_res = (temp_res / n) - 200
else
     temp_res = 0
end if
```

In the same way, the PID programming is shown next.

```
Err_T = Qdt - Qt
Prop_T = Kpt * Err_T
Deriv_T = Tdt * Err_T
Sum_Err_T = Sum_Err_T + Err_T
Int_T = Tit * Sum_Err_T

Ut = Prop_T + Deriv_T + Int_T
```

Part of the microcontroller programming includes additional options, such as:

a) Set the time
b) Define the set points
c) Define the when to initiate the data storage
d) Initiate the serial communication

In Figure 11 LCD display of some the previous options are shown.

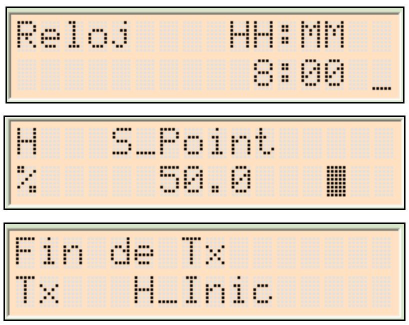

Fig. 11 LCD menu display

V. Conclusions

It was possible to design and construct a temperature and humidity control system for a metrology laboratory dedicate to the calibration and certification of scales. The control system fulfils the customer requirements: Low cost, easy to implement, operate and maintain, and constructed with standard industrial components. So far, the costumer reports that the system works as expected. Due to confidentiality issues it is not possible to present real time responses of the control system; nonetheless, in Figures 12-13 the hardware of the control system is shown.

Fig. 12 LCD and keyboard

Fig. 14. Microcontroller and power boards

Fig. 15. Controller board and asensor

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Water conservation at the building level

Daniela Kaposztasova, Martina Rysulova, Gabriel Markovic, Pavol Purcz

Abstract**—**To achieve sustainability of water resources the approaches taken must be economically, environmentally and socially acceptable and avoid negative impacts on future generation The decision to collect and use alternative water sources may be influenced by a range of factors. This article does not seek to recommend or discredit any particular system, rather to provide general guidance on the issues and information to support decisions on alternative water use at the building level and make it more attractive to public. The aim is to calculate all combination of portfolios of proposed water strategies and to describe how we can treat with this source of water, and demonstrate its potential utilization at the building level.

Keywords**—**water sources, water production, saving potential, water strategies, grey water, potable water, well water, rainwater

I. Introduction

THE total volume of water in the world remains constant. What changes is its quality and availability [1]. Many researchers confirmed that the importance of water savings is rising every day. The fresh water is our gold. Common household uses consume a lot of water. There is a need to manage its end use as sustainable as our conditions allow us. In EU it is common to use well and rain water source for purposes as irrigation, toilet flushing…etc. There are three main approaches to reduce water in household:

- water saving by good housekeeping and efficient water use in buildings
- alternative water supplies (rainwater…etc)
- recycling and reuse of water (grey water…etc)

The project titled "Building that Save Water" presented a decision tree approach to assessing options available for reducing mains water use [2].

The ability of different water types to meet the water demanded for various end uses within the building is significantly improved where less water in total is required. Consumers must be clear on how to operate water-using appliances correctly, and be aware of the implications of their water consumption [2].

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D. Kaposztasova, Technical University of Kosice, Faculty of Civil Engineering (e-mail: daniela.ocipova@tuke.sk).

M. Rysulova, Technical University of Kosice, Faculty of Civil Engineering (e-mail: martina.rysulova@tuke.sk).

G. Markovic, Technical University of Kosice, Faculty of Civil Engineering (e-mail: gabriel.markovic@tuke.sk).

P. Purcz, Technical University of Kosice, Faculty of Civil Engineering (e-mail: pavol.purcz@tuke.sk).

The ability of different water types to meet the water demanded for various end uses within the building is significantly improved where less water in total is required. Consumers must be clear on how to operate water-using appliances correctly, and be aware of the implications of their water consumption [2].

The main topic of this article is to describe, how we can treat with this source of water, and demonstrate its potential utilization, which means saving particular source of potable water and in parallel to water savings, bring financial savings.

II. Description of water sources

The quantity of water used by European households has increased significantly over the past 30 years and now represents approximately 70% of the total water use in buildings [3]. A report by the Office of Community and Economic Development (2002) estimates that 35-40% of household water consumption is used for personal hygiene (shower and bath), 20-30% for toilet flushing, and 10-20% for laundry. The research has shown that replacing high water-using devices with water efficient alternatives can reduce annual water consumption by 32-50% [4]. Focusing on household water consumption, and in particular the use of water efficient devices, offers significant potential for water savings [5].

A. Potable water

Potable water could be supplied from several possible sources.

- Municipal water supply
- Water wells – driven, dug, drilled

Tap water (running water, city water, municipal water, etc.) is water supplied to a tap (valve). Other typical uses include washing, toilets and irrigation. Indoor tap water is distributed through "indoor plumbing", which has existed since antiquity but was available to very few people until the second half of the 19th century. Water used for abstraction of drinking water is now covered by Water Framework Directive - WFD.

Water from well is s water supplied from groundwater sources. It could be used for potable or non-potable purposes according to its quality. About 14% of the Slovak population is individually supplied from well water. 80-85% of water resources for individual supply do not meet the hygiene requirements and are permanent risk to health or the water has poor sensory properties. The most common case of overflow values of indicators is faecal pollution, nitrate and iron. Water quality in individual water resources is adversely affected by poor technical condition of wells, lack of depth and poor disposal of sewage in their neighborhood. High risk of infectious diseases, especially in times of flood and case of failures drains.

B. Grey water

Grey water system can be described as system which is oriented on capturing waste water before its discharging from building. If we want to apply this system, the waste water has to be separated on grey water and black water. There are a lot of descriptions, what grey water means, for example according to British Standard, we can consider grey water as domestic wastewater excluding faecal matter and urine [6]. Grey water reuse is in our condition still rare.

C. Rainwater

Rain, a form of precipitation is the first form of water in the natural hydrological cycle. It is a primary source of water that feeds rivers, lakes, and groundwater aquifers and they became the secondary source of water [7].

Rainwater may be collected from any hard surface, such as stone or concrete patios, and asphalts parking lots. However, once the rain hits the ground it is no longer referred as rain, but as the storm water. Landscape can also be contoured to retain the storm water runoff. Rainwater harvesting captures precipitations and uses it as close as possible to where it falls [8].The potential of rainwater harvesting depends on location and weather. Precipitation monitoring is a very a common process all around the world

III. Water management portfolios

In the world a lot of authors have discussed the water issue from the different views [15,16,17,18,19,12]. This part defines and evaluates combinations of water management options, referred to as water management portfolios. The costs and benefits of the portfolios are described in the next chapter. The water management portfolios are scored and compared based on screening criteria presented in this section. We can divide them to two alternatives using the proposed portfolios.

1. House is connected to main water supply –Alternative 1
2. House is not connected to main water supply- Alternative 2

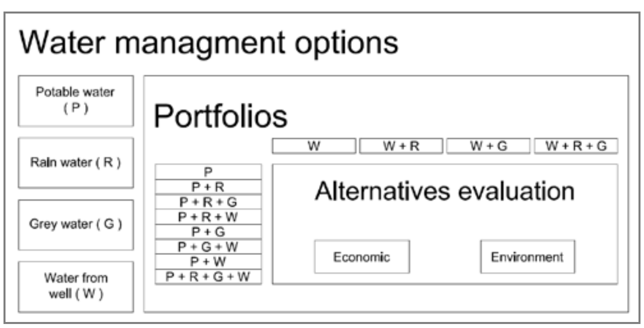

Fig. 1 Water management option vision at the building level

The 11 Case portfolios were prepared in two alternatives (Figure 1).

A. Portfolios description

First alternative gives us 8 portfolios how we can manage water consumption and demand. In this case all possible use purposes of four water sources are described for end use in Figure 2.

- Potable water (P)
- Rain water (R)
- Grey water (G)
- Water from well (W)

Portfolio1. Base Case – Potable water, Well water (water quality as drinking). It is represented by main water supply that reaches the highest water quality. Portfolio assumes that none of the other water management options presented here would be implemented. In case there is not possible connection to water supply only Well water that reaches quality requirements will be used.

Portfolio 2. P + R - this portfolio consists of the adding just the rain water use option to the base case portfolio. In some cases, this option is a must,

- ✓ if it is not possible to connect to the main sewage (overloading sewerage), this is happening often in the cities, while building a new house
- ✓ sewage system is not built (downtown areas, villages)
- ✓ subsoil is not suitable for infiltration.

In this case we cannot calculate the initial costs for the payback period because we have to invest in the system.
Each town has its own regulations to deal with the floods and problems of overloading sewers.

Portfolio 3. P+R+G - this portfolio consists of the adding the recycled water option to the P+R case portfolio. It means that the water according to its quality and availability will be divided for other purposes. For example grey water for flushing the toilets and rainwater for garden irrigation and laundry. It is also possible to build also a hybrid system.

Portfolio 4. P+R+W - this portfolio consists of the replacing the recycled water option by well water and works in the same way. The water from well is in this time the cheapest way how to have a good quality water, but it should be controlled at least 1 time per year.

Portfolio 5. P+R this portfolio is similar to the portfolio 2, the grey water is used for non-potable purposes. It becomes cost effective where water consumption is more than 500-600I/ day.

Portfolio 6. P+ R + W - this portfolio is combination of potable water, well water and rain water. Wells can recharge themselves, and can provide a constant, steady supply of water that is not easily impacted by dry weather conditions, so it is always a good idea.

Portfolio 7. P+W – the often used combination in our conditions. Potable water is used for all indoor activities and

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well water for the irrigation. The purposes of use are based on the quality of water.

Portfolio 8. P+R+G+W – the last portfolio is combination of all sources. The all options portfolio includes incorporating all of the water management option. It should be evaluated by case by case approach.

The same approach is used in **alternative 2** but potable water is replaced by water from well. In this case we have *four portfolios*: Well water, W+R, W+R+G, W+G.

The water audit equates the volume of water that goes into building to where it is used and where it ends up. A final decision on whether to proceed with a rainwater, well water or grey water system should take into account all changes in water use and viability assessed having addressed water efficiency issues at first [2].

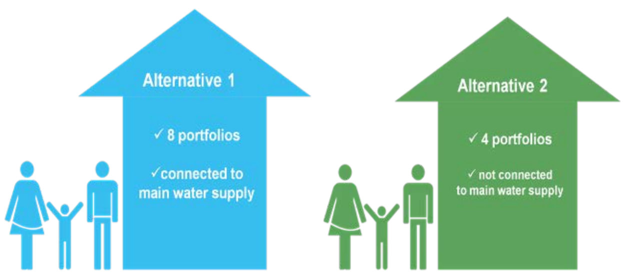

Fig. 2 Two alternatives of portfolios

The water audit equates the volume of water that goes into building to where it is used and where it ends up. A final decision on whether to proceed with a rainwater, well water or grey water system should take into account all changes in water use and viability assessed having addressed water efficiency issues at first [2].

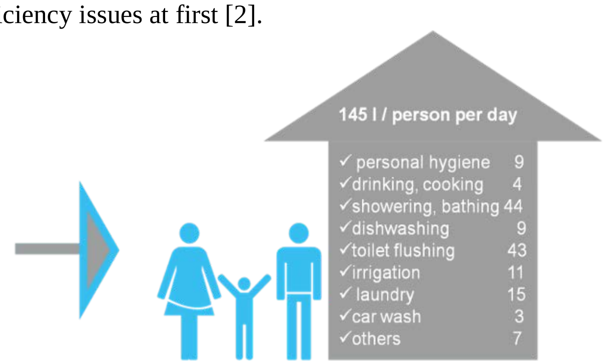

Fig. 3 Average water consumption in Slovak household [l/person per day)

B. Water use

We use large amounts of water each day, as water serves many different purposes, which we can divide to potable and non-potable water needs. Water with potable water quality parameters is used to personal hygiene drinking, cooking, showering, bathing and dishwashing. Water that does not require such quality parameters is suitable for toilet flushing, irrigation, laundry, car wash and others (Fig. 3).

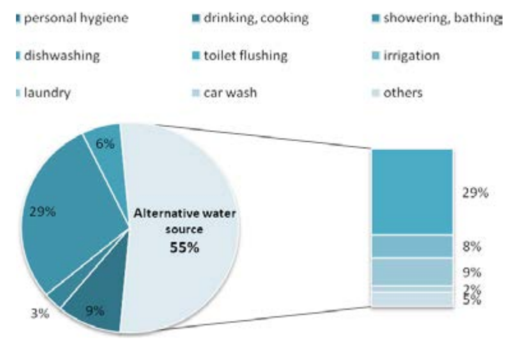

Fig. 4 purposes for non-potable use in household

According the presented 9 purposes all possible combinations with 4 or 3 water sources were calculated.

IV. Possible combinations of all portfolios – Mathematical approach

A. Combinatorial task

To define all possible combinations of water management options referred to as water management portfolios for both alternatives the classical combinatorial task of determining the number of combinations was used.

If we have e.g. 4 different water sources and define them by 9 end use purposes, then if we want to find the number of all the possibilities of application to a given source of water we need to use a classical combinatorial task approach of all tetrads of nine elements without repetition. This number is expressed in mathematics standard combinatorial numbers in the form $\binom{n}{k}$ where n is the number of elements where the k number of *k-tuples*. The calculation of the number of the combination is given by the formula:

$$\binom{n}{k} = \frac{n!}{(n-k)!n!} \qquad (1)$$

When trying to find the best solution it is, however, important to know all of these options and then choose the one best suited to each particular case. It is preferable to use commonly used software products, such as and Visual Basic on Microsoft Excel and so get the desired solution directly in the environment of Excel spreadsheets. Counting combinations is difficult from a programming standpoint, since it does not order the elements concerned, which is somewhat contrary to the strict deterministic approach to reigning in creating algorithms. From the perspective of a programmer is thus an easier to handle (even though mathematically seemingly extensive) process based on the calculation with variations without repetition, which in contrast to the combination depends on the order, after eliminating same solutions. The process started by identification of all permutations considered for 9 end purpose. Permutations in this context are a special case of variations without repetition, where n=k is the calculation of the simple relation as n! (n - factorial). There was need to eliminate the same solutions, after re-compile all of four variations in Excel tables. The important boundary conditions were set like daily capacity of the water resources, sanitary restrictions, etc. The calculation resulted in 996 options which are from the practical point of view not applicable. By specifying boundary conditions related mainly to the removal of some "irrational" clusters of activities in terms of connection to a water source. Final results have obtained an acceptable number of options, which are of the order of large number of different cases. We decided to choose most suitable ones. By setting up the boundary conditions for alternative 1 and 2 (Fig. 5) the results are as follows: In alternative 1 - four water sources were used in 63 combinations, in alternative 2 - 26 combinations of 3 sources.

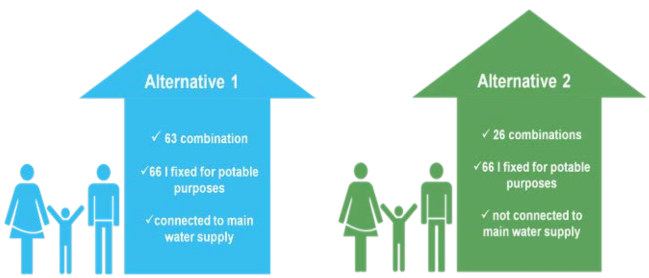

Fig. 5 Possible combination for both alternatives

B. Discussion and Results

The intent of the integrated water management is to consider water management options that were identified by the expert group that might be useful in enhancing the water sustainability and reliability. Described water management options that are considered at the building level were implemented on experimental house. According to the study eight portfolios are prepared for the house owner when connected to the main water supply and four without the connection.

Results for Alternative one are described on figure 6.

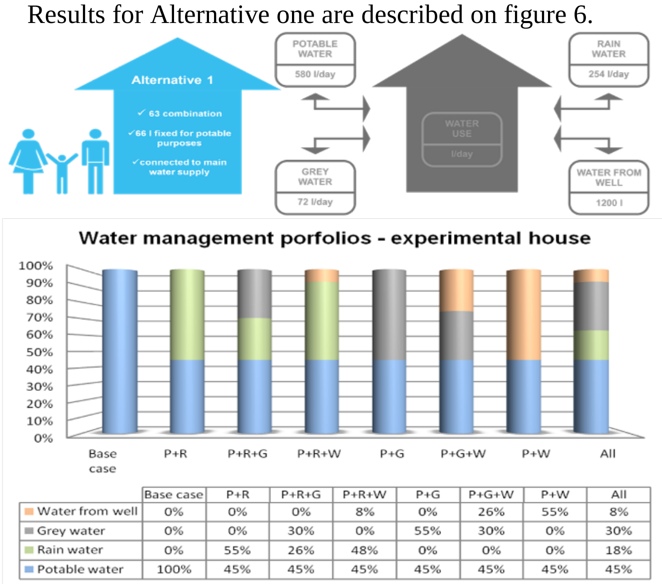

Fig. 6 Alternative 1 – 8 portfolios for experimental family house

Results for Alternative two are described on figure 7.

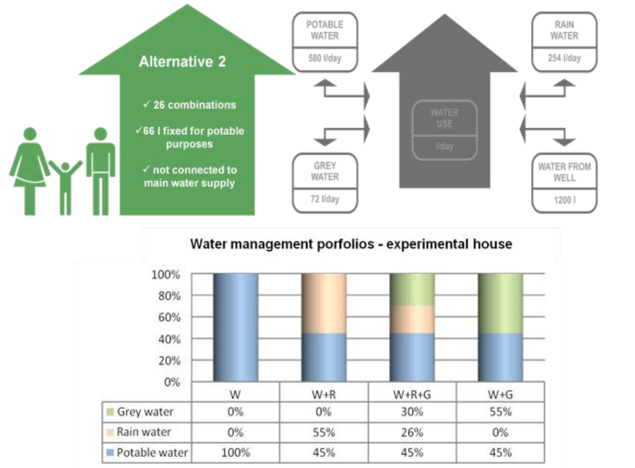

Fig. 7 Alternative 2 – 4 portfolios for experimental family house

Proposed eleven portfolios offer a plan how to deal with the water scarcity. The calculations of all combinations were set. It can help the investor to see all possibilities of water management strategies directly aimed at his case. Each case should be evaluated independent set on the boundary conditions. The economic and environmental evaluation approach will support investor's decision and interests. The main aim was to give as much as possible information to investor to change his thinking to sustainable solution even when they are not so cost effective.

Rain water and grey water can contribute to sustainability at the building level, particularly where:

✓ problems with water sources occur
✓ the cost of water mains is high
✓ user wishes to reduce the water consumption
✓ user wishes to be independent of water mains
✓ it is the only possibility of runoff disposal
✓ user wishes to support the sustainability and environment

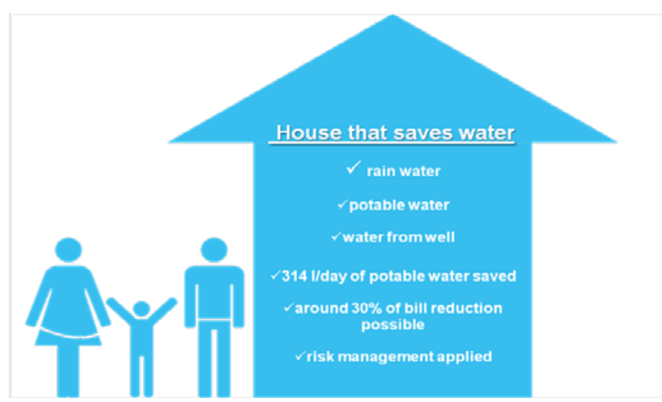

Fig. 8 Portfolio 4 – experimental family house

The change of a classic family house to a BLUE house by implementing the portfolio four led to reduction of water bills. The saved costs for water in the year 2016 will be around 160 € (Fig. 8).

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V. Conclusion

To achieve sustainability of water resources the approaches taken must be economically, environmentally and socially acceptable and avoid negative impacts on future generation. Now the systems are more viable where the consumption is above average and for rainwater systems if there is sufficient rainfall. As grey water systems become more popular, there is a need for standardization to protect the public and to ensure that reliable systems are designed, installed and maintained. A modern decentralised water infrastructure can include site-collected rainwater, grey water, storm water, and black water systems. These alternative water sources may never totally replace centralized system. They do help manage and store water and treat it to various levels of quality for use in buildings and the sites upon which they stand. The designers should complete the site and building as the one system – where water is conserved, energy saved and the costs are reduced. New technologies and better understanding of the in building water cycle allow us to reduce our water footprint. The provision of safe water and sanitation has been more effective than any other intervention in reducing infectious disease and increasing public health. The public expects to have safe water and sanitation; therefore, when recycling water, it is essential to protect public health and the environment.

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Daniela Kaposztasova is lecturer at the Faculty of Civil Engineering, Technical University of Kosice. She is specialized in Water supply and drainage systems. Recently she has been concentrated on the field of rainwater use and grey water reuse. She is a vice dean for education

Martina Rysulova is a PhD. student at the Faculty of Civil Engineering, Technical University of Kosice. She is specialized in water supply and drainage systems. Recently she has been concentrated on the field of grey water reuse.

Gabriel Markovic is lecturer at the Faculty of Civil Engineering, Technical University of Kosice. He is specialized in Water supply and drainage systems. Recently he has been concentrated on the field of rainwater infiltration systems.

Pavol Purcz is lecturer at the Faculty of Civil Engineering, Technical University of Kosice. He is specialized at mathematical and statistical approaches.

Evaluating Concentrated Photovoltaic Impact on Grid Flexibility and Required Storage Using Analytical Hierarchy Process

Ahmed A. Shetaya, Rasha El-Azab, Amr M. Amin

***Abstract*—** New renewable resources have many challenges that greatly depend on the own characteristics of each renewable type as wind, Photovoltaic (PV), Concentrated Solar Power (CSP) and Concentrated Photovoltaic (CPV). These new sources have many problems that related to power system integration as variability and uncertainty nature.

This paper proposes a new algorithm based on Analytical Hierarchy Process (AHP) to evaluate CPV impact on dispatchability of the power system. Power systems behavior is affected by the new complex CPV generation and loads that have uncertain and variable nature.

The proposed technique measures current power system flexibility index, and checks its ability to operate power system safely. It also determines the desired reserve sources or storage that must be added to improve the system flexibility for real-time operation.

***Keywords*—** Analytic Hierarchy Process (AHP); Concentrated Photovoltaic (CPV); Energy Storage Systems (ESS); Power System Flexibility.

I. INTRODUCTION

IN the near future, the conventional fossil fuel will be significantly consumed. All over the world, new alternatives Renewable Energy Sources (RES) will be used to cover the big shortage in traditional energy sources. The different energy sources types ensure reliability of the power system, but it will cause uncertainty and variability of the power sources issues.

The key principle of CPV usage over traditional PV or CSP is the cost efficient concentrating optics that decreases the area of high costly, high efficiency [1]. While in many areas in the Middle East as an example have sun-rich with direct normal irradiance. So, the usage of CPV is more efficient than another solar power systems [2]. Power system flexibility is defined as the capability of a grid to dispatch its resources to accommodate the changes in net load, where net load is defined as the residual of grid load that not served by variable generation.

The variety of generation sources have different flexibility limit in the grid. Therefore, the need to measure the flexibility impact of CPV becomes very essential. An accurate index is needed to evaluate the CPV impact and define the required traditional reserve and/or storage system [2].

There are many Frameworks and metrics for measuring power system flexibility are evolving. In [3], flexibility charts, are developed to deliver a snapshot overview of different types of generation-based flexibility at each country. These charts work offline to give useful information only for planners. They do not share in real time operation of the system.

Juan Ma, [4] introduces sampled flexibility measurement to evaluate and plan flexibility. But, the proposed technique is depends only on ramp rate, minimum and maximum power. Startup time and controllability criteria great impacts are neglected on the flexibility evaluation.

AHP is a structured technique for organizing and analyzing complex decisions, based on mathematics. There are many application of AHP as in ranking, choosing, prioritization, resources allocation and management.

In this paper, the proposed technique is based on the analytic hierarchy process (AHP). Consequently, the type and size of the flexibility sources (Conventional/Energy Storage Systems) will be defined, via an optimal efficient way, to increase the profit.

The proposed metric tool could be used to measure impact of CPV sharing in the grid on operation flexibility and introduce guidelines for planners to be aware when adding ESS.

II. CPV DISPATCHING CHALLENGES

CPV generation promises higher efficiency compared to flat traditional PV systems or CSP system, about 43%. CPV has low capital cost. As, CPV consumes less semiconductor raw materials compared to PV. In addition to, the area that

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A. A. Shetaya is with Department of Electrical Power Engineering, Faculty of Engineering, Helwan University, Cairo, 11792 Egypt and with Academy of Scientific Research and Technology (phone: +20-122-263-7779, e-mail: ahmed.shetaya@ h-eng.helwan.edu.eg).

R. El-Azab is with Helwan University, Cairo, 11792 Egypt. She is now with the Department of Electrical Power Engineering, Faculty of Engineering, and with Academy of Scientific Research and Technology (phone: +20-100-744-6228, e-mail: r_m_elazab@yahoo.com).

A. M. Amin is with the Electrical Engineering Department, Faculty of Engineering, University of Helwan, Cairo, 11792 Egypt and with Academy of Scientific Research and Technology, (phone: +202- 010-1069706, e-mail: amrmaamin@yahoo.com).

needed to install CPV is smaller than area that needed for PV one. Also, high energy capacity factor (KWh/ installed KW) that make the CPV beat PV or CSP [1].

In the other hand, there are still many challenges to use CPV as high penetration source in the power grid. The impact of CPV on the grid operation during dispatching its power should be evaluated. Also, Weather has a great influence on the efficiency and capacity of CPV. CPV variability due to weather condition such as clouds must be studied. With high CPV penetration in the grid, the variability problem becomes worse.

The yearly net load ramp rate (MW/hour) has high ramp rate during most of the year due to high CPV penetration. Dispatching of demand power is hard to be predicted or controlled. The expected high ramp rate in demand power needs high flexible sources or reserves to cover the shortage of the CPV output.

Due to the variability of the CPV output, the dispatcher is forced to curtail the CPV power in many cases to operate the power system safely. CPV curtailment causes losing a free power, and reduces the system profit [5]-[7].

To overcome all the challenges of the CPV penetration, the conventional reserve that driven from traditional sources as Steam, Gas or Hydro power generation should be used. By adequate dispatching between these traditional sources, any power shortages during CPV operation can be covered [8].

The conventional reserve sources have different flexibility characteristics and natures. Therefore, a flexibility index must be measured, to evaluate their appropriateness in covering the CPV power shortage.

According to the flexibility measurement, the operator may use Energy Storage System, as extra source for the reserve, to follow the power demand ramping and enhance flexibility [9].

III. Energy Storage Systems

Energy storage systems (ESS) provide more flexibility for the grid operation. There are many storage technologies used in power system such as, Pumped Hydro Storage (PHS), Compressed Air Energy Storage (CAES), Thermal Energy Storage (TES), Batteries, flywheels and super-capacitors technology.

The specifications of ESS are different with respect to unlike aspects. There are storage type used to follow the power changes in CPV uncertain and variable power as PHS, CAES, TES and Batteries.

Other types are used to smooth power fluctuation in small duration, and improve power quality of the power systems as Batteries, flywheels or super-capacitors [10].

On the other hand, the maturity of the storage technologies varies from type to another. In [11], PHS, TES and CAES are considered as more economical and commercial in following power variety than others .While, batteries, flywheels or super-capacitor are in demonstration stage. Fig. 1 shows the degree of different Storage maturity.

PHS is available with low cost with high power sharing. While, thermal storage system has ability to shift the power of CPV or CSP generation to peak-hour time.

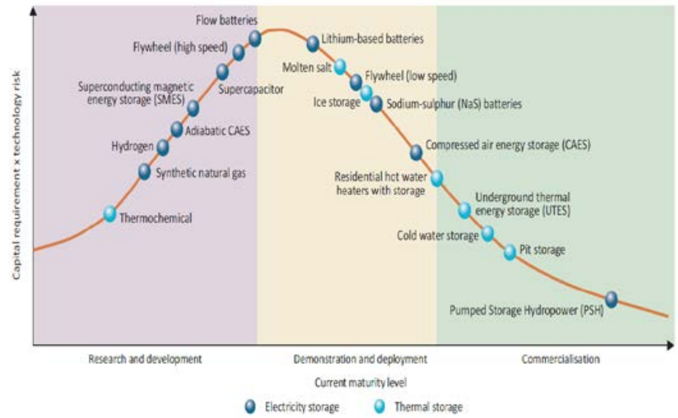

Fig.1 Maturity of energy storage technologies [10].

There are many types of thermal storage but the most economical storage one is underground thermal storage. CAES also is considered as great power storage technology, which is available in high power and relatively mature.

In last five years, the battery storage systems predicted to be greatly growth. Also, the new researches improve battery usage in medium and high power scales. So, it would be used in follow power variability in CPV generation or in renewable sources [10].

In this study, battery storage systems, PHS and TES are studied, as a complete solution of CPV generation challenges. The results verify the capability of these storage systems of healing the system flexibility.

IV. Flexibility Evaluation Criteria

The flexibility evaluation process depends on different criteria. From technical point of view, there are four criteria with large impacts on the flexibility. The minimum power of the generation unit, the ramp rate capability, cycling rate or startup time and controllability nature of the generating unit are the main characteristics of the flexibility. The following section discusses the importance of each criteria.

A. Minimum Power

The minimum permissible power could reserve unit operate. It plays important role in measuring flexibility. If the minimum power of the generating or storage unit is large, it can't meet different power changes, due to large variability of the renewable energy sources with high sharing in the power system.

B. Ramp Rate

The most important factor is the positive or negative ramp rate capability of the reserve source. It defines the degree of meet the ramp rate of the load minus renewable sources. The ramp rate is measured by MW/min. There are big verities in flexibility sources, from one can follow power in different time frame to another one that can regulate the power in very small time scale. Each unit must be utilized according to the dispatching process by depending on the flexibility measurement value and rate of change.

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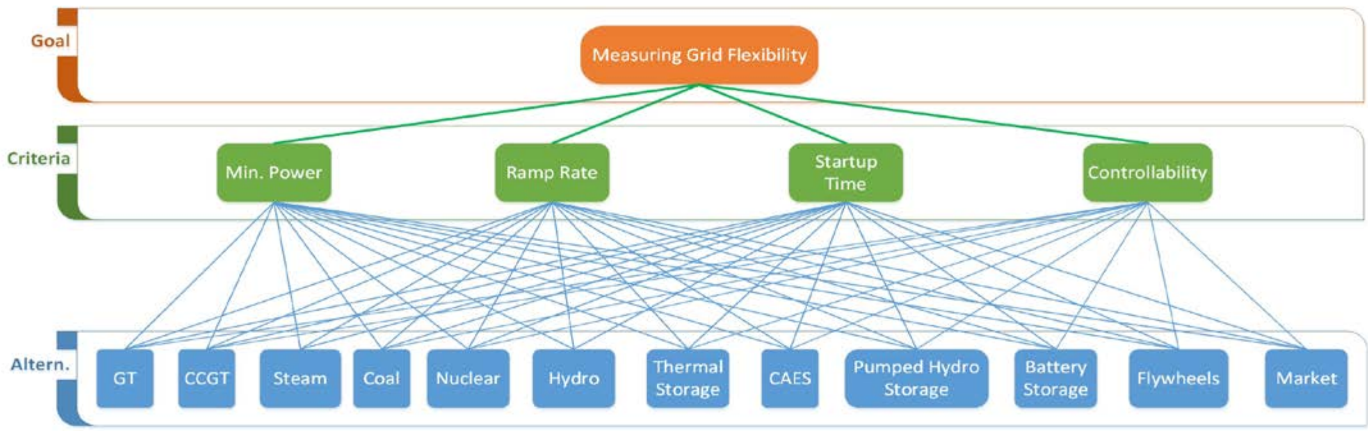

Fig. 2 flexibility evaluation criteria based on AHP.

C. Startup Time

The startup time gives information about how fast the power unit commitment. It plays a strong role during large change in the load or large variety in the uncertain variable generation sources.

D. Controllability

The criteria of controllability depend on different characteristics and factors that may limit the usage of generating or storage unit. For example, the usage of Nuclear power plant is difficult during power dispatching and operation due to safety and technical factor although the minimum power is low [12]-[15].

Fig. 2 shows proposed analytical hierarchy diagram in designing the flexibility metric tool. Sources of flexibility are listed in the last layer. Last layer defines all generation /storage alternates. Each type of alternates has its own criteria or specifications in the middle criteria layer. Each criteria source has specific weights that share in the proposed flexibility index.

Proposed flexibility tool ranks all alternatives from the best the worst flexible scenario for real time operation. The following section discusses how the proposed algorithm of AHP is used to solve multi-criteria problem to measure the flexibility index.

Also it is ranked from the best flexibility to the worst to be used during real time operation. The following section shows how the proposed algorithm of AHP is used to solve multi-criteria problem to measure flexibility index.

V. Analytical Hierarchy Process

The measurement of flexibility is built according to the four criteria that defined previously. Each criteria has its own priority in case flexibility measurement. To make decision of organizing the criteria according to their impact on flexibility, the choice should be decomposed into the following steps [16].

- Define the problem and find the available known specification.
- Build the structure of the hierarchy from the goal through the main four criteria to lower level of alternates.
- Construct a set pairwise comparison matrices with respect two each criteria and each criteria with respect to the main goal.
- Use the priorities to weight each alternate and to weight each criteria.
- Rank the alternates according to the goal to evaluate upon the available alternates and their weights.

Suppose that n, alternates, $A_1,.....,A_n$, whose weights $\omega_1,.....,\omega_n$, respectively, are known. The pairwise matrix contains the ratio of weights according to the fundamental scale. The comparison is made between each two alternates and the inverse of the comparison is made according to reciprocal of the weights as in the following matrix equation:

$$\begin{pmatrix} \omega_1/\omega_1 & \omega_1/\omega_2 & \cdots & \omega_1/\omega_n \\ \omega_2/\omega_1 & \omega_2/\omega_2 & \cdots & \omega_2/\omega_n \\ \vdots & \vdots & \vdots & \vdots \\ \omega_n/\omega_1 & \omega_n/\omega_2 & \cdots & \omega_n/\omega_n \end{pmatrix} \begin{pmatrix} \omega_1 \\ \omega_2 \\ \vdots \\ \omega_n \end{pmatrix} = n \begin{pmatrix} \omega_1 \\ \omega_2 \\ \vdots \\ \omega_n \end{pmatrix} \quad (1)$$

It could be summarized as:

$$A\omega = n\omega \quad (2)$$

The pairwise comparison matrices in AHP is based on the fundamental scale of intensity of importance, as shown in Fig. 3 [16], [17].

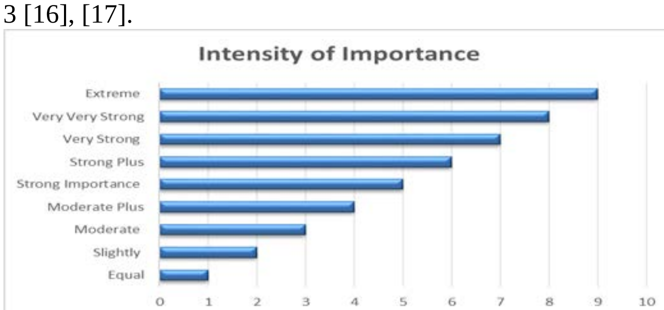

Fig. 3 AHP fundamental scale.

The solution of (2) is called the principle right eigenvector of A_i. To make weights ω_i unique; the entries must be normalized by dividing over their sum. After priorities calculation, the opinion must be measured to verify it's consistent. The consistency may be measured for judgment of solution by the following consistency index in (3).

$$CI = \frac{\lambda_{\max} - n}{n-1} \tag{3}$$

Where, $\lambda_{\max}$ is the largest principle eigenvalue in the eigenvector. The consistency index (CI) must be compared to random consistency index (RI) that shown in table 1 [12]. Then, the consistency ratio is calculated as in (4).

$$CR = \frac{CI}{RI} \tag{4}$$

Table 1: Random Consistency Index.

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	145	1.49

If the value of the consistency ratio is smaller than or equal to 10%, the inconsistency is accepted. While the ratio in (4) will be used for each alternates with respect to criteria and also in case of comparing the criteria with respect to the goal.

VI. AHP Implementation to Evaluate CSP Inflexibility Impact

The AHP is proposed to measure the flexibility of each reserve source and evaluate the inflexibility level of the CPV to estimate the grid needs of flexibility after sharing of CPV. The available reserve flexibility depends on the pre-discussed main criteria. The full specifications of each generation or storage type are listed in Table 2 [12]-[15].

The minimum power criteria define the minimum permissible power that taken from each reserve. The minimum dispatched power from thermal units between 40% and 50% of the unit size while, the hydro plant or pumped hydro storage are about 15% of the rated power of the unit. The thermal storage has greater value than normal thermal generation plant of value about 75%. Other storage units, in table 2, have no minimum power that mean no constraints during use these storage systems [15].

The second criterion is the ramp rate capability of generation/ storage units that considered as the most significant factor directly affect on the flexibility. The ability of the reserve source to follow the ramp rate of CPV generation is vital factor to measure the flexibility. In Gas Turbine (GT) and in Combined Cycle Gas Turbine (CCGT), the ramp rate lies between 10 to 20 % of size/ Minutes. But in the steam turbine and coal based power plant, is less ramp rate.

On the other hand, the nuclear power plant is difficult to follow the ramp rate of the net load because the ramp rate is approximately 20% of size/Minutes.

Table 2: the reserve sources specification with respect to main criteria.

Reserve Sources	Minimum Power (% of Size)	Ramp Rate (% of Size/Min)	Start Up Time (Min.)	Controllability
GT	40	20	15	Close to Full
CCGT	40	10	45	Half
Steam Turbine	40	5	300	Low
Coal	50	5	300	Half
Nuclear	50	2	2400	Very Low
Hydro	15	30	15	Close to Full
Pumped Hydro Storage	15	30	15	Close to Full
Battery Storage	0	100	0	Full
Thermal Storage	75	20	15	High
CAES	0	100	2	Full
Flywheels	0	100	0	Full
Market	0	100	0	Full

In Hydro power plant, the ramp rate is greater which reach to about 30%/Minutes, and in the other storage system is full dispachable. The third criteria is the startup time that shown in table 2 [12]-[15].

Another significant factor of the flexibility measurement goal is the controllability of the resources. GT, hydro plant and pumped hydro plant are close to be full dispachable, while, CCGT and Coal are half controlled due to its dependence on the steam boiler operation. In the thermal storage, the system is high enough to be de dispatched in some limitation.

But in the nuclear power plant, it is very difficult to be controlled while in the other side, the storage system and the market is nearly full controllable.

Fig. 4 shows the flowchart of the calculation steps of overall flexibility of the power system after adding the impact of CPV generation.

First, the algorithm reads the hourly production of the conventional generation and CPV generation.

Then, the proposed technique delivers the specifications of the conventional generation units and storage systems that in table 2.

After that, the flexibility index of the each conventional generation, storage and total reserve is calculated by using AHP. The source of inflexibility in this case is the CPV generation. AHP will calculate the inflexibility index of it based on its sharing value to the total generated power.

At that point, the overall flexibility is calculated by subtracting the flexibility index of conventional sources and storage from the inflexibility index of CPV generation.

Finally, the algorithm will check if the system is inflexible (negative overall flexibility), the system propose to add extra storage unit or size from the available type of the system according to its flexibility ranking and from economical point of view.

Table 3 shows the pairwise comparison of the reserve sources with respect to the ramp rate capability criteria. The comparison is made according to the fundamental scale of the AHP technique. The same comparison is made also with respect to the other three criteria. Also, another comparison is made between criteria with respect to the main goal.

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Table 3: the pairwise comparison matrix of comparing reserve sources with respect to the ramp rate criteria.

	GT	CCGT	Steam Turbine	Coal	Nuclear	Hydro	Pumped Hydro Storage	Battery Storage	Thermal Storage	CAES	Flywheels	Market
GT	1	3	4	4	6	1/3	1/3	1/7	1	1/7	1/7	1/7
CCGT	1/3	1	2	2	4	1/5	1/5	1/8	1/3	1/8	1/8	1/8
Steam Turbine	1/4	1/2	1	1	2	1/6	1/6	1/8.5	1/4	1/8.5	1/8.5	1/8.5
Coal	1/4	1/2	1	1	2	1/6	1/6	1/8.5	1/4	1/8.5	1/8.5	1/8.5
Nuclear	1/6	1/4	1/2	1/2	1	1/7	1/7	1/9	1/6	1/9	1/9	1/9
Hydro	3	5	6	6	7	1	1	1/5	1/3	1/5	1/5	1/5
Pumped Hydro Storage	3	5	6	6	7	1	1	1/5	1/3	1/5	1/5	1/5
Battery Storage	7	8	8.5	8.5	9	5	5	1	7	1	1	1
Thermal Storage	1	3	4	4	6	3	3	1/7	1	1/7	1/7	1/7
CAES	7	8	8.5	8.5	9	5	5	1	7	1	1	1
Flywheels	7	8	8.5	8.5	9	5	5	1	7	1	1	1
Market	7	8	8.5	8.5	9	5	5	1	7	1	1	1

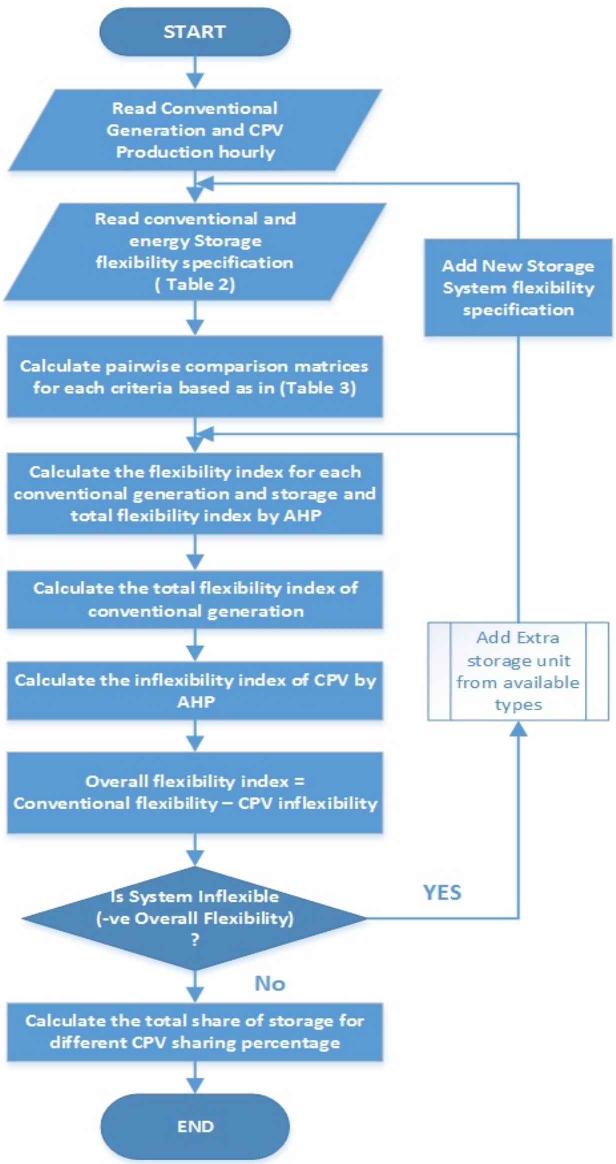

Fig. 4 flowchart of the flexibility metric based on AHP.

VII. Case Study and Results Discussion

The hourly production of different generation types for 5 days (120 hours) are given as an example to estimate the sources overall flexibility. Fig. 5(a) shows the sharing of sources as GT, CCGT, steam power plant, hydro generation and market sharing. In addition two sharing of CPV generation by about 10% of total sum of the load.

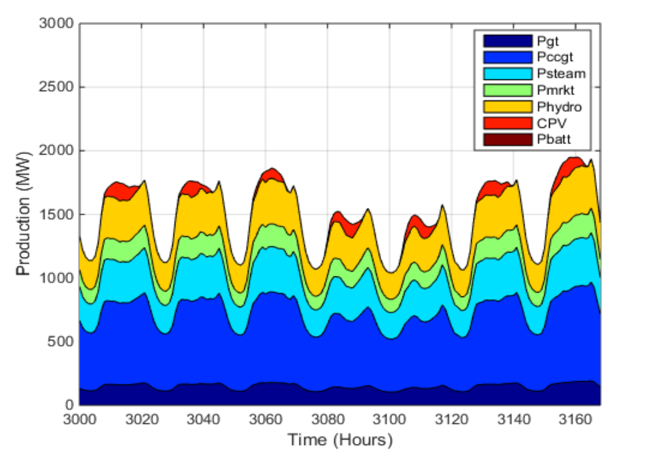

Fig. 5(a) production (MW) and 10 % CPV sharing.

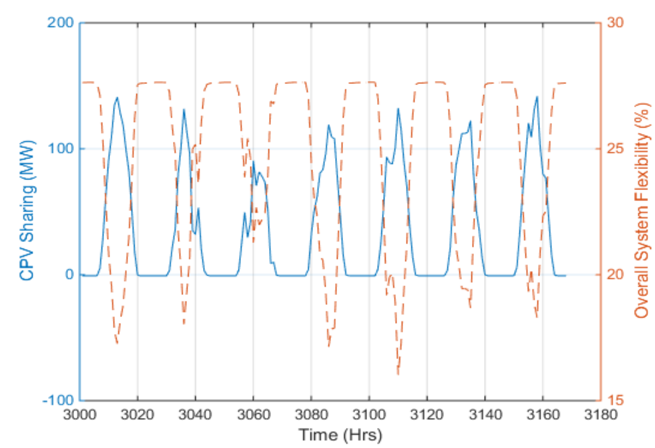

Fig. 5(b) CPV 10 % sharing and measured overall flexibility.

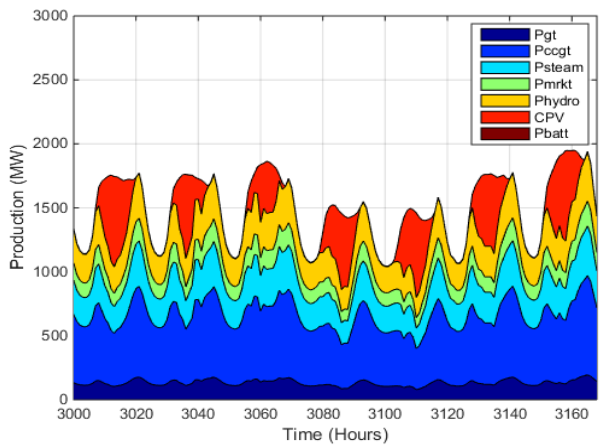

Fig. 6(a) production (MW) and 50 % CPV sharing.

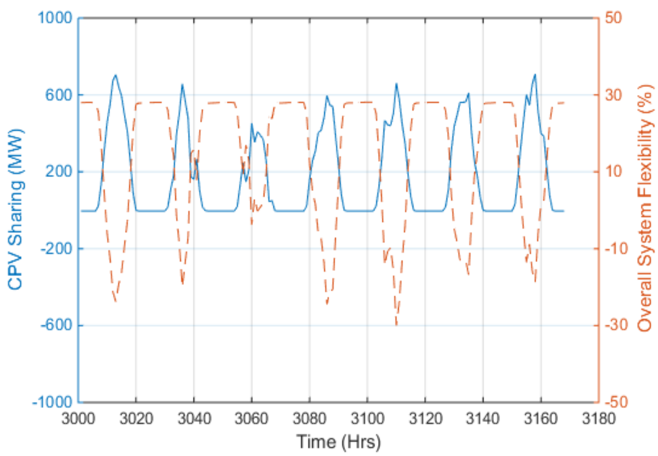

Fig. 6(b) CPV 50 % sharing and measured overall flexibility.

After the algorithm is applied on the system, the overall flexibility index verses CPV sharing is shown in Fig. 5(b). Also, Figure 6a and Figure 6b show another case by increasing the CPV sharing to 50%, it is clear that by increasing the CPV percentage of total load, the flexibility is reduced and reach to negative value. These mean that the system need a huge energy storage reserve to cover that problem. To study the effect of different storage system on the overall flexibility index of the power system, CPV is utilized by 40% sharing in the system, as shown in Fig. 7. The figure shows the worst day in the year.

First, the flexibility is evaluated without adding any storage to the system. Fig.7 clears that, the system needs extra reserve by about 20% to dispatch the total CPV power.

By adding 5% battery storage to the system, the flexibility performance is improve by about 4%, as shown in Fig.7. While, in case of 10% of battery storage, system flexibility index is improved by about 9%.

On the other hand, by adding a mix of 10% battery and 10% thermal storage to the system, the flexibility is improved less than the case of adding 15% battery, with lower cost than 15% battery. Fig.8 shows the evaluation of CPV impact with different sharing by steps from 10% to 50% CPV penetration. The figure shows the base case without storage and another two cases of adding 5% battery storage and 5% TES.

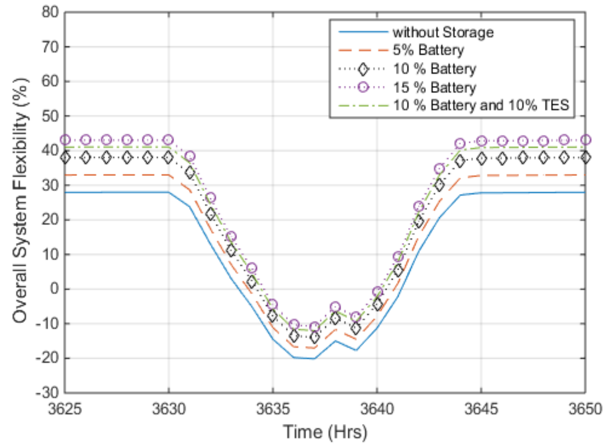

Fig. 7 worst day flexibility measuring in different storage.

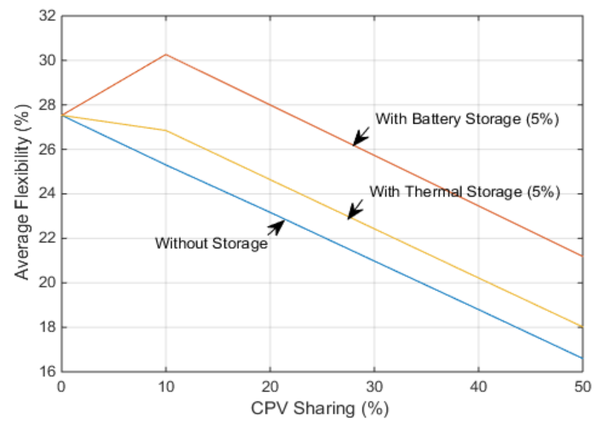

Fig. 8 the average flexibility with different CPV sharing at different storage.

Another solution for the flexibility is to curtail a part of CPV during a part of a day to reduce the cost of the storage system. The feasible study that based on the optimization of cost and technical behavior is made to optimize the operation of the grid with the high penetration of the CPV. So, the proposed flexibility metric tool must be taken into account of the optimal dispatching of the power as a very effective tool to retrieve the technical properties of the generation and storage systems.

VIII. Conclusion

CPV generation impact on power system flexibility has been evaluated. An AHP based technique is proposed to measure this impact. Proposed technique introduces the solution of covering expected flexibility shortage via selecting and evaluating different storage system. The results show that, the CPV has a great impact on the flexibility and the impact linearly increased by increasing CPV sharing. Also, the required storage system as battery and thermal storage system is evaluated to improve flexibility performance. Hybrid energy storage system with small CPV curtailment is also studied and evaluated. In the future research work, the factor of energy cost will be repossessed to evaluate the required storage impact with lower cost.

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Ahmed A. Shetaya Assistant Lecturer at Faculty of Engineering at Helwan, Helwan University, Egypt. A. Shetaya received the B.Sc and M.Sc degrees in electrical engineering from Helwan University, Cairo, in 2007 and 2012 respectively. Now he is studying for PhD in the Electrical Power System Engineering, Faculty of Engineering, Helwan University, Egypt. His research power system analysis and stability, wide area measurement systems, smart grid technologies and applications, new intelligent approaches to large scale power system integration in renewable energy resources.

Rasha M El-Azab is a lecturer at the Faculty of Engineering at Helwan University R. M. Elazab received the B.Sc and M.Sc degrees in electrical engineering from Helwan University, Cairo, in 1999 and 2005 respectively. She is granted double PhD degrees, in electrical power engineering, from Vrije Universiteit Brussels, Belgium and Helwan University, Egypt in 2012. Her research interests include wide-area protection and control systems, PMU applications, smart grid, and power system integration with renewable energy resources, load shedding and transient stability.

Amr M. Amin is a Professor and Dean of the High Technological Institute, 10th Of Ramadan Egypt. He participated and managed many national and multinational funded projects. These projects are in the areas of energy optimization, renewable energy, solar desalination, and educational developments. He is currently working on a project entitled 'Multipurpose Applications by Thermodynamic Solar (MATS)", EC Frame Work Programme 7, FP7, 22 M Euro and and STS-MED Small scale thermal district units for Mediterranean communities, 5 Meuro, EU-ENPI program.. He was a member of the study group organized by EASAC (the European Academies Science Advisory Council). He is serving as an evaluator for many EC funding schemes, FP7, TEMPUS, ENPI, and ERASMUS MUNDS. On the National level he is an evaluator for the Industrial Modernization Council IMC, Ministry of Industry and Commerce and the Research Development and Innovation RDI, Ministry of Scientific Research. He also serves as referee for many international and national journals and conferences.

A comparative Study on Photovoltaic and Concentrated Solar Thermal Power Plants

Mohamed Rashad A. A.El-Samahy Mohamed Daowd Amr M. A. Amin

Academy of Scientific Research and Technology (ASRT)
Cairo – Egypt

Department of Electrical power and machines Engineerin
Faculty of Engineering Helwan University (HU)
Cairo – Egypt

mrashad814@yahoo.com el_samahya@yahoo.com m_a_daowd@yahoo.com amrmaamin@yahoo.com

***Abstract* - Recently solar energy receives a great attention as an important source of renewable energy. Solar energy is converted to electrical energy directly through photovoltaic (PV) or indirectly through concentrated solar power (CSP) system which converts solar energy to heat energy which in turn can be used by thermal power station to generate electricity.**

This paper present a comparative study between the two types of solar power (PV&CSP). This study includes types, components, initial and running costs, efficiency, advantages, disadvantages and storage systems.

Index Terms - Renewable energy sources; solar photovoltaic; concentrating solar power; thermal engine; storage systems.

I. INTRODUCTION

The sun is the most plentiful energy source for the earth. All form of energy like wind, fossil fuel, hydro and biomass energy have their origins in sunlight. Solar energy falls on the surface of the earth at a rate of 120 petawatts, this means all the solar energy received from the sun in one days can satisfied the whole world's demand for more than 20 years. [1].

The potential of several renewable energy source based on today's technology is shown in Fig1. Future advances in technology will lead to higher potential for each energy source. However, the worldwide demand for energy is expected to keep increasing at 5 percent each year. Solar energy is the only choice that can satisfy such a huge and steadily increasing demand. [2].

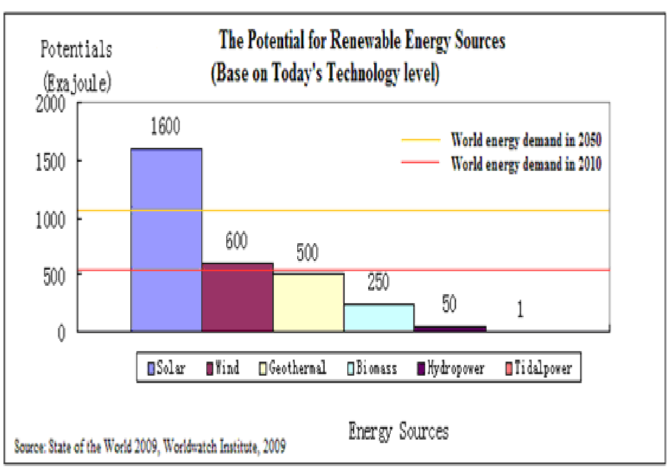

Fig. 1: The Potential for Renewable Energy Source

Renewable energy is the energy which comes from natural resources such as sunlight, wind, rain, tides and geothermal heat. These resources are renewable and can be naturally replenished. Therefore, for all practical purposes, these resources can be considered to be inexhaustible [3].

Among renewable energy source, solar technologies are capturing large interest. Most of the solar power systems in the market today can be divided into two major classes: the direct and the indirect solar power. The direct solar power refers to a system that converts solar radiation directly to electricity using a photovoltaic (PV) cell. The indirect solar power refers to a system that converts the solar energy first to heat and after that to electrical energy, as in the case of concentrated solar power (CSP). In a CSP plant, sunlight is focused on a heat exchanger; this heat is used to drive the turbine. The problems with these technologies are inefficiency and a very high capital cost. The typical efficiency of a CSP is about 15%. the highest efficiency of a silicon cell for example is 20%.On the other hand, Concentrating Solar Power (CSP) technology is now acquiring an increasing interest, especially if built with thermal energy storage, Moreover; economic issues have been treated for CSP in order to verify which the profits, the breakeven are and so on. [4].

The aim of this paper is to compare a PV plant with a CSP plant from technologies of system, types and components of system, efficiency, initial costs comparison, advantages, disadvantages, life cost of electricity (LCOE) and storage systems

II. PV SYSTEMS

Solar photovoltaic, also called solar cells or PV, are electronic devices that convert sunlight directly into electricity. The modern form of the solar cell was invented in 1954 at Bell Telephone Laboratories. Today, PV is one of the fastest-growing renewable energy technologies and is expected to play a major role in the future global electricity generation mix. A PV system consists of a number of PV cells grouped together to form a PV module, along with auxiliary components. [5].

A. PV plants

The PV plants can be categorized into two main typologies according to the installation mode: stand alone and grid-connected. The first one refers to PV plants which are not connected to the electrical grid of the local energy utility company. This typology of PV plants is usually used to feed

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small electrical load (e.g. for street lighting) or when the electrical grid is too far (e.g. an isolated rural house). Stand-alone PV plants have a storage battery with stabilizer in order to guarantee that: a) the battery is not over-charged by the PV plant; b) the charge of the battery is not less than a prefixed threshold; c) the electrical loads may be fed directly from the DC side of the inverter for DC loads or from the AC side for AC loads. Anyway, stand-alone PV plants are not used for high power. The second one refers to the PV plants directly connected to the electrical grid of the local energy utility company. In this case, there is no storage battery because the electrical storage is represented just by the electrical grid. In fact, the energy produced by the PV plants and not simultaneously absorbed by the electrical loads is injected in the electrical grid. Then, when the electrical loads require more energy than that produced by the PV plant, the lacking part is taken from the grid. [6]

B. PV Technologies

For describing the use of PV installations is used the maximum power (Wp) that theoretically the PV module can provide. The power of solar PV installations is therefore given in Wp (peak Watts). This power corresponds to the one given by the solar modules at 25ºC at irradiation conditions of 1000W/m2. There are four ranges of power for PV installations depending on the location and the number of housing supplied [7]:

1) *Small-sized installations of 3 kWp, up to 5 kWp*
2) *Medium-sized installations of 30 kWp, with a range between 5 and 100 kWp* t.
3) *Big-sized installation of 300 kWp, with ranges between 100 kWp and 1 MWp..*
4) *3MWp photovoltaic plants, with ranges between 1 and 50 MWp.*

C. PV Concentrators

Concentrating PV (CPV) systems use refractive lenses or reflective dishes to concentrate sunlight onto solar cells in order to make benefit of a higher concentration ratio (CR). There are many types of concentrators, the most known are [8]:

1) *Compound Parabolic Concentrator (CPC)*
2) *Paraboloid Reflector.*
3) *V-Trough Concentrators*
4) *Fresnel's Lenses*

Four important parameters are taken into consideration in order to make the comparison between most important PV concentrators; these parameters are:

- Construction.
- Concentration ratio.
- Reflection.
- Tracking system

The comparison of the studied photovoltaic concentrators is given in Table 1. Based on the obtained results in this table, and depending on any project requirements, the PV concentrator can be selected.

A. Components of the PV Plant

The complete system of typical photovoltaic plant includes different components that should be selected taking into account the individual needs, site location, climate and expectations. The functional and operational requirements will determine which components the system will include major components such as [7]:

1) ***PV Modules***, to convert sunlight instantly into DC electric power

2) ***Inverter***, to convert DC power into standard AC power.

3) ***Battery***, to store energy

4) ***Transformer***, to change the voltage in the installation for being able to connect with the distribution network. It is used a low voltage – medium voltage transformer.

5) ***Utility Meter****:* utility power is automatically provided at night and during the day when the demand exceeds the solar electric power production. The utility meter actually spins backwards when solar power production exceeds house demand, allowing you to credit any excess electricity against future utility bills.

6) ***Charge Controller***, to prevent battery overcharging.

Table1. Comparison between different types of PV concentrators. [9]

Types	Compound Parabolic	Paraboloid Reflector	V-Trough	Fresnel's Lense
Construction	Made by two segments of parabolas	Use an anodized Al or simply a glass mirror which has a high reflectivity	Use arrays of trough shaped mirror	Made of several prisms arranged either linearly or in concentric circles
Concentration Ratio (CR)	$1/\sin\theta a$	$\pi r2/Acell$	$\sin[(2n+1)\psi+\theta]/\sin(\psi+\theta)$	$L.W/Acell$
Reflection of parallel ray into	Point	Point	Line	Point or Line
Tracking system	Not continuous tracking	Two axis	Not exist	Two axis

In addition, there are some component of hardware to complete the system and to make balance of system such as; wiring, over current, surge protection and disconnect devices, and other power processing equipment.

B. Life Cost of Electricity (LCOE)

The LCOE varies by technology, country and project based on the renewable energy resource, capital and operating costs, efficiency and performance of the technology.

Fig. 2: shows the LCOEs resulting from achieving the installed PV system prices. These LCOEs are calculated using assumptions about O&M expenses, inverter efficiencies, and derate factors (due to losses in wiring, diodes, or shading) [9]

As shown in Fig. 2, assuming the targets are met by 2020, residential PV is projected to be increasingly competitive with residential electricity rates, commercial PV is projected to be increasingly competitive with commercial electricity rates, and utility-scale PV is projected to be increasingly competitive with whole sale electricity rates. Utility-scale PV LCOEs become competitive with California's Market Price Referent (MPR), which is used as a benchmark to assess the value of renewable generation in California (CPUC 2011), by 2015 at higher costs than those targeted in the scenario. This illustrates that, while achieving price targets will allow PV to compete broadly with conventional generation in several U.S. markets

C. Solar PV capital costs

The capital cost of a PV system is composed of the PV module cost and the Balance of System (BoS) cost. The cost of the PV module and the interconnected array of PV cells are determined by raw material costs, cell processing/manufacturing and module assembly costs. The BoS cost includes items such as the cost of the structural system (e.g. structural installation, racks, site preparation and other attachments), the electrical system costs include the inverter, transformer, wiring and other electrical installation costs) and the cost of the battery or other storage system.

Prices for PV modules have fallen by between 30% and 41% in the year to September 2012 and by between 51% and 64% for the two years to September 2012, depending on the technology and source for European buyers. [5]

Prices for PV systems in the United States have dropped by 50 percent or more in recent years, with the sharpest declines for large-scale projects. [10]

D. Electrical Storage Systems (ESS)

The major categories of ESS used in PV plants are [11]**.**:

- Electro-mechanical electrical energy.
- Flywheel Energy Storage Systems (FESS).
- Electro-chemical energy.
- Battery Energy Storage Systems (BESS) there is a wide variety of battery technologies both in production and as topics of research.
- Lead Acid batteries.
- Capacitor and Super-Capacitor Storage Systems
- Electro-magnetic Superconductor Magnetic Energy Storage (SMES).

III. The Concentrating Solar Power Plant

Concentrating solar power (CSP) is a power generation technology that uses mirrors or lenses to concentrate the sun's rays, in most of today's CSP systems to heat a fluid and produce steam. The steam drives a turbine and generates power in the same way as conventional power plants.

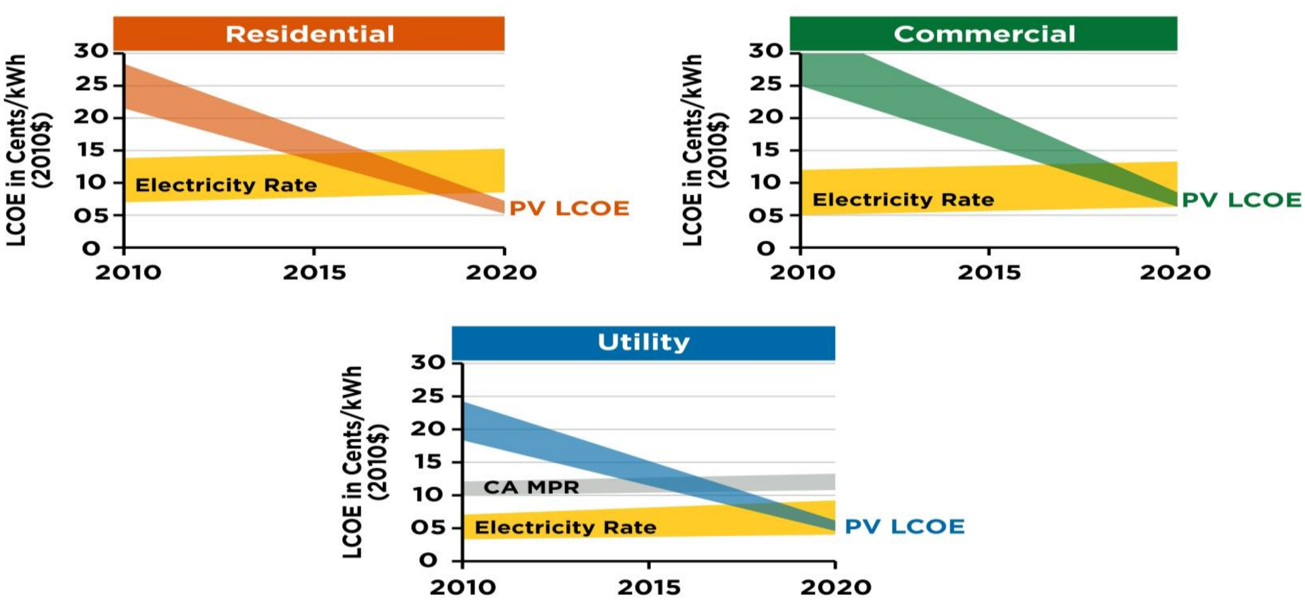

Fig. 2: PV LCOEs by Year and Market Segment

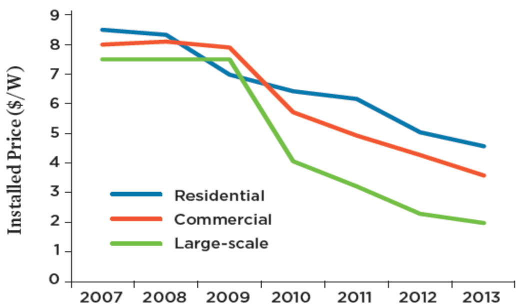

Fig. 3. The Falling Price of Solar PV by U.S. Sector, 2007–2013

A. CSP TECHNOLOGIES

CSP plants can be divided into two groups, based on whether the solar collectors concentrate the sun rays along a focal line or on a single focal point. Line-focusing systems include parabolic trough and linear Fresnel plants and have single-axis tracking systems. Point-focusing systems include solar dish systems and solar tower plants and include two-axis tracking systems to concentrate the power of the sun as shown in Fig 4. [12]

B. CSP Concentrators Assessment

The aforementioned CSP concentrators' comparison may have eight parameters .These parameters are: application, costs, axis, heat exchange, concentration type, receiver type, advantage and disadvantage.

The concentrators' comparative study is given in Table 2; the best result of the CSP can be deduced.

C. Cost Analysis of CSP

The cost of electricity generation from CSP is expected to decrease continuously. According to a study of renewable energy made by the IEA [14], the current CSP technology systems are implemented in the cost range of 0.19$/kWh to 0.25$/kWh. In the conventional power market, CSP competes with mid-load power in the range of 0.037$/kWh to 0.05$/kWh. As different scenarios have predicted, the costs of CSP can be reduced to competitive levels in the next 10 to 15 years. Competitiveness is affected not only by the cost of the technology itself, but also by potential price increases of fossil energy and by the internalization of associated social costs, such as carbon emissions. Therefore, it is assumed that in the medium to long term, competitiveness will be achieved at a level of 0.05$/kWh to 0.075$/kWh for dispatch able mid-load power.

According to another report prepared by Electric Power Research Institute, when the global cumulative capacity of CSP implementation reaches 4GW,the cost of electricity generation from new plants in 2015 could be as low as 0.08$/kWh (nominal 2015dollars) or nearly 0.05$/kWh (real 2005 dollars).

D. *Thermal Energy Storage in CSP Plan*t

Thermal energy storage (TES) system is an intermediate and critical subsystem of solar power plant to store and dispatch the concentrated energy into power block (electricity generation).

Thermal energy storage technologies are generally categorized in terms of applied process and loading method meant to direct thermal storage and indirect thermal storage. In direct systems, the heat transfer fluid acts as the storage medium simultaneously, whereas in indirect systems, a storage medium is different from the transferring fluid, the difference between them is determined according to the location of the thermal storage tank related to the medium and transfer material, heat exchanger (HEX) block, pump, valve and number of practical utilities. [15]

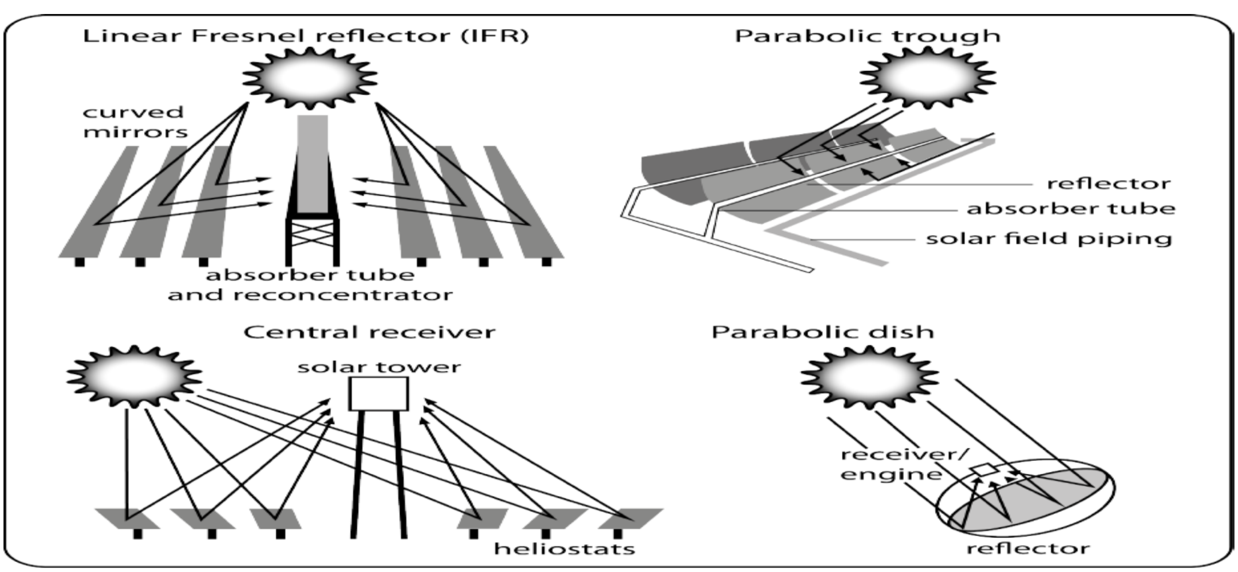

Fig. 4 Schematics of the Four CSP Approaches for Power Generation. [13]

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Table2. Comparison between different types of (CSP) [8]

Types	Solar tower	Parabolic trough	Parabolic-Dish	Linear Fresnel
Uses	For large grid-connected power projects in the 30-200 MW size	For large grid-connected power projects in the 30-200 MW size	In single application or grouped in dish farms	Single application
Cost (USD/W)	2.5 - 4.4	2.7 - 4.0	1.3 - 12.6	NA
Axis	Dual	Single or dual	Dual	Dual
Heat exchange	Needed	Needed	Not Need	Not Need
Concentration on (in case of parallel rays)	Focal point	Focal line	Focal point	Focal line
Receiver	Fixed	Mobile	Mobile	Fixed
Advantage	With a lower required salt inventory the operating temperature is high compared to in CSP Trough	Concentrating sunlight to produce ice	Can be placed on a varied terrain using small quantities of water	Doesn't require rotating coupling between the receivers and the field header piping thus providing additional design flexibility
Disadvantage	Each mirror must have its own dual-axis control	A transparent glass tube envelops the receiver tube to reduce heat loss	The conversion from heat to electricity needs the moving of heavy engine, which requires a strong tracking system	Requires a mirror above the tube to refocus the missing rays or a multi-tube receiver that is large enough to capture missing rays without putting a mirror

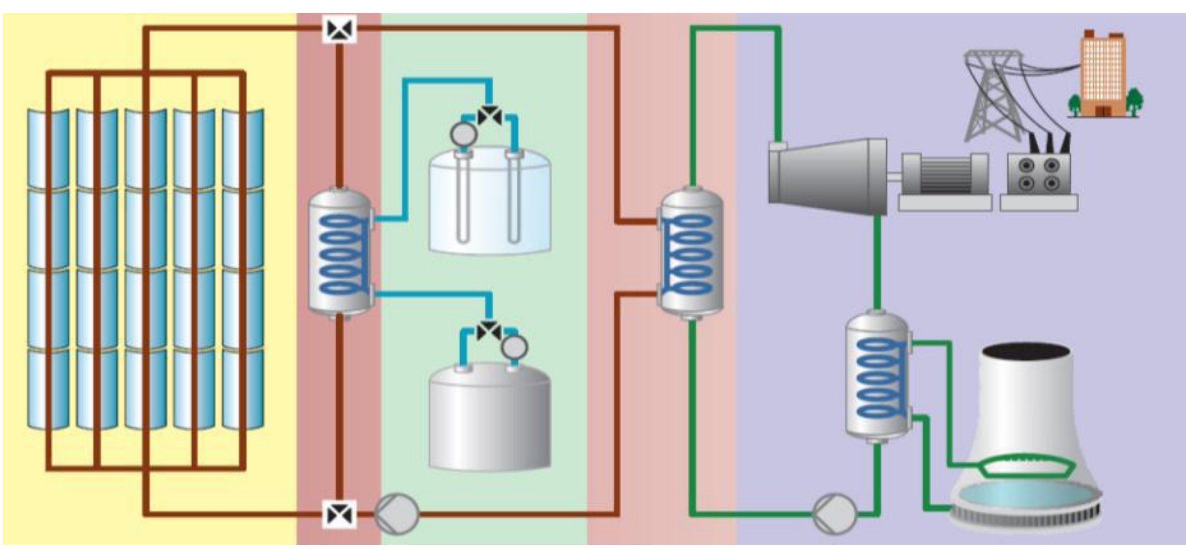

Fig.5: Conventional CSP Plant with thermal storage and oil as working fluid

Source: IEA (2011), "Solar Energy Perspectives"

E. CSP Plant Components

Generally, the CSP plants are consisting of three major components:

- Solar field
- Thermal conversion
- Power generation

Fig. 5 shows the CSP plant components, the concentrating system and solar receiver, heat transfer and thermal storage, heat conversion and power generation.

IV. Comparison between (PV) and CSP**.**

The (PV) and CSP are different in terms of technical aspects, but both techniques are essential clean energy alternatives to utilize solar power [14].

- PV converts sunlight directly into electricity (DC power) while CSP converts the light energy into thermal energy first, then use traditional turbine to convert heat into electricity (AC power).
- PV can use the solar diffuse radiation while CSP can only convert sun's direct radiation into power.
- Unlike PV's technique relies mostly on developing individual cell and module, the CSP technology relies heavily on the on-site constructing and final assembling and system integration.
- Energy storage of CSP is considerably lower than that of PV. With storage, power production can be shifted according to demand therefore is less dependent on the time period and daily weather conditions.
- The CSP technology is a still undeveloped industry, which is forced to face the competition and cost challenge come from the PV system.
- The Advantage of CSP over PV and many other renewable energy technologies is its ability to store the sun's energy as heat in molten salts, and to use it to generate electricity when the sun is no longer shining and at times when it may be most valuable to the grid. The molten salt heated by concentrating the sun's energy can be stored and kept hot for several hours. When electricity is needed, the heat stored in the salts can make the necessary steam. This storage lets CSP systems extend the "rush hours" of their generation patterns and generate electricity a few hours before the sun rises and a few hours after it sets, making it easier to integrate electricity from such plants into the grid [10].
- Cost comparison between PV versus CSP is presented in Table 3.

Table 3: Cost Comparison – PV vs. CSP [9]

	Utility PV		Residential Rooftop PV		Commercial Rooftop PV		CSP					
	SunShot	Ref.	SunShot	Ref.	SunShot	Ref.	SunShot			Ref.		
	$\$/W_{DC}$	$\$/W_{DC}$	$\$/W_{DC}$	$\$/W_{DC}$	$\$/W_{DC}$	$\$/W_{DC}$	$\$/W_{AC}$	hours storage[b]	CF (%)	$\$/W_{AC}$	hours storage[b]	CF (%)
2010	4.00	4.00	6.00	6.00	5.00	5.00	7.20	6	43	7.20	6	43
2020	1.00	2.51	1.50	3.78	1.25	3.36	3.60	14	67	6.64	6	43
2030	1.00	2.31	1.50	3.32	1.25	2.98	3.60	14	67	5.40	6	43
2040	1.00	2.16	1.50	3.13	1.25	2.79	3.60	14	67	4.78	6	43
2050	1.00	2.03	1.50	2.96	1.25	2.64	3.60	14	67	4.78	6	43

V. Conclusion

Photovoltaic solar panels (PV) and concentrated solar power (CSP) are the most two commonly deployed technologies and are expected to have a rapid growth in both the short- and long-terms. Installations of CSP and PV electricity generation devices are growing rapidly. The PV share of electricity generation is greatly reduced as CSP is introduced into the model.

This paper provided a brief summary for those who are interested in solar energy technologies and as a reference for those who want to invest or work in this field. PV and CSP technologies were discussed and

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reviewed their structure, performance, advantages and drawbacks. In addition, they have been evaluated and compared their mechanism, structure, and efficiency, along with other technical details.

This study shows that PV systems present a noticeable cost reduction as compared with CSP systems. However, the effective energy storage offered by CSP systems make than relevant competitors to PV systems.

Acknowledgement

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Potential savings of potable water by the use of rainwater in TUKE campus

Gabriel Markovič, Daniela Kaposztásová, Zuzana Vranayová

***Abstract*—**Rainwater harvesting as a part of the source control measures could contribute to the sustainability in stormwater management as well, by supporting potable water conservation and sustainability in water management in general. Submitted paper describes potential savings of potable water by the use of rainwater in buildings of TUKE campus. This paper contains overview of the possible rain water use for non-potable purposes in school buildings as a part of the planned concept of rainwater management for TUKE campus.

***Keywords*—** potable water, rainwater harvesting, runoff, stormwater

I. Introduction

RWH technique creates more added values than any other stormwater management measure. It supports sustainable water use, helps to conserve potable water consumption and contributes to the integrated water cycle as well [4].

There are several definitions of stormwater management regarding different approaches. According to Marsalek and Chocat (2002), stormwater management is a process employing various non-structural and structural measures to control stormwater runoff with respect to its quantity and quality [1].

Prior to development, stormwater is a small component of the annual water balance. However, as development increases, the paving of pervious surfaces with new roads, shopping centres, driveways and rooftops all adds up to mean less water soaks into the ground and more water runs off. Overall, urban drainage presents a classic set of modern environmental challenges: the need for cost-effective and socially acceptable technical improvements in existing systems, the need for assessment of the impact of those systems, and the need to search for sustainable solutions. [2].

When we know what affect water in general, we can understand the importance of conserving water and helping to protect it from pollutants [8,9]. It is even more important when we realise that demand is continuously increasing also because of urbanization and development. It is up to us therefore to ensure that the Water Framework Directive (the main EU water directive, will be more described below) is implemented effectively, that there is enough water for future generations and that this water meets high quality standards [3].

II. TUKE Campus – Current Situation

Figure 1 shows the average daily consumption of water of a household - 150 l/person per day. It shows that about 60% of potable water may be replaced by rainwater.

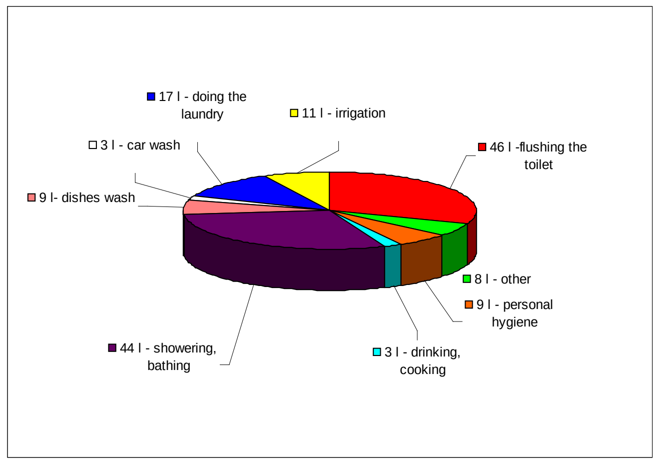

Fig. 1 average water consumption of a household (average consumption 150 l/(person per day))

In the case of school-type buildings potential of water savings replaced by rainwater is significantly higher. It result from absent purposes as showering, bathing (30%), laundry, etc., so the most volume of potable water is consumed for flushing toilets.

Figure 2 represents view of the Technical University of Kosice campus site in Kosice-city. Blue rectangles indicate school buildings for all faculties of Technical University of Kosice. These buildings have a classical drainage system for rainwater runoff consist from traditional direct channelling of surface water through networks of pipes to sewer system.

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Ing. Gabriel Markovič, PhD., Technical University of Košice, Faculty of Civil Engineering, Institute of Architectural Engineering, Vysokoškolská 4, 042 00 Košice, mail: gabriel.markovic@tuke.sk

Ing. Daniela Kaposztásová, PhD., Technical University of Košice, Faculty of Civil Engineering, Institute of Architectural Engineering, Vysokoškolská 4, 042 00 Košice, mail: daniela.ocipova@tuke.sk

Prof. Ing. Zuzana Vranayová, PhD., Technical University of Košice, Faculty of Civil Engineering, Institute of Architectural Engineering, Vysokoškolská 4, 042 00, Košice, e-mail: zuzana.vranayova@tuke.sk.

Fig. 2 TUKE campus

But there are two buildings – PK6 and PK5 which have a drainage system for rainwater runoff designed through an infiltration facilities – infiltration shafts. Measured real volumes from PK6 building are shown in chapter IV.

III. TUKE CAMPUS - PLANNED SITUATION - POTENTIAL SAVINGS OF POTABLE WATER BY THE USE OF RAINWATER IN TUKE CAMPUS

A planned situation of rainwater management in TUKE campus consider about replacing of traditional rainwater drainage into the sewage system by the use of rainwater in the school buildings. All of school buildings respectively the roofs of these buildings in TUKE campus (figure 2) represent a potential source of rainwater for non-potable purposes especially for flushing toilets.

The rooftop area of school buildings (table 1) determine maximum volume of rainwater possible to capture and accumulate.

Determination of the theoretical volume of rainwater from the catchment area can be determined by the equation:

$$V_{rain} = z_{year} .A.C \qquad (1)$$

Where:

V_{rain} – theoretical volume of rainwater

z_{year} – average precipitation depth for chosen locality (mm),

A – roof or another catchment area (m^2),

C – runoff coefficient (non–dimensional coefficient).

Tab. 1 roof areas of buildings in TUKE campus

Building	**Roof area (m^2)**
BN3	1766
BN5	1511
L9	6091
PK10	1615
PK2	1003
PK3	407
PK4	563
PK5	425
PK6	548
PK7	777
PK8	746
PK9	489
PK11	1506
PK12	1640
PK13	841
PK14	2572
PK15	854
PK17	497
PK19	3591
UK	1946
V4	3453
W4	1525

For the determination of theoretical volume of rainwater we need also data of rainfall intensity. The resource that provide us information about the rainfall intensity is rain gauge and is located on the roof of University Library.

Rain gauge is joined with its own concrete foundation using a steel rod. Flat roof helped us fixing the rain gauge into horizontal position which is the first condition for receiving correct data. We use recording heated rain gauge for all year round measuring. There are known unheated rain gauges as well used for limited part of year when the temperatures aren't so low. Heated rain gauge is used for measuring liquid precipitation (rain) and solid precipitation (snow) as well. Rain gauge is made of stainless material. Rain gauge's round catchment area is 200 cm^2 and its function is based on tipping bucket mechanism. Tipping bucket is located inside the rain gauge body right under the funnel outlet. Rain or snow fall down the funnel outlet into the divided bucket. The bucket does not move until it is filled with calibrated 0.2 mm amount of water, then it tips and second half of bucket can be filled with rain water. When the bucket tips it empties the liquid from the half of the bucket into a drainage hole. Tipping bucket is made of plastic with very thin layer of titanium and it is hanged on stainless steel axial holder. Tipping continues according to the length of rainfall (figure 3) [6,7].

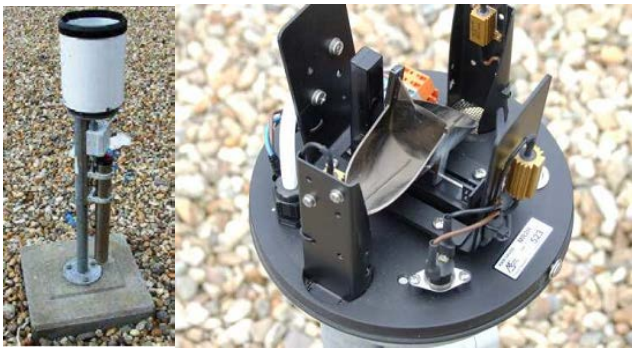

Fig. 3 rain gauge

Figure 4 represent the measured monthly rainfall totals during our research. Data are presented for the period August 2011 to December 2014.

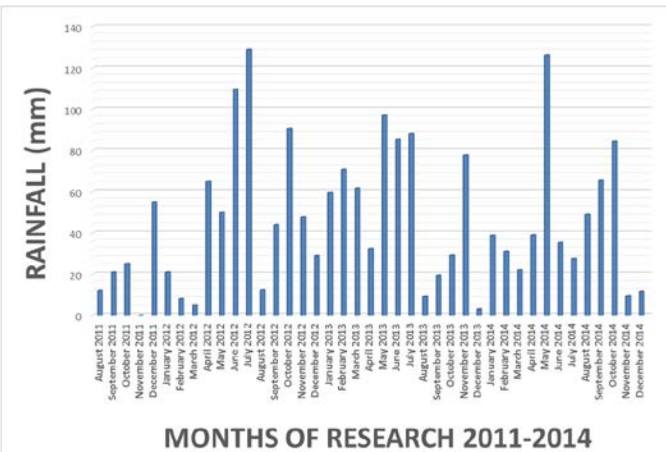

Fig. 4 measured values of rainfall during our research August 2011-December 2014

According our measurements of monthly rainfall totals, figure 5 represent theoretical monthly volumes of collected rainwater from roof areas of buildings in TUKE campus. Data are presented for the period August 2011 to December 2014.

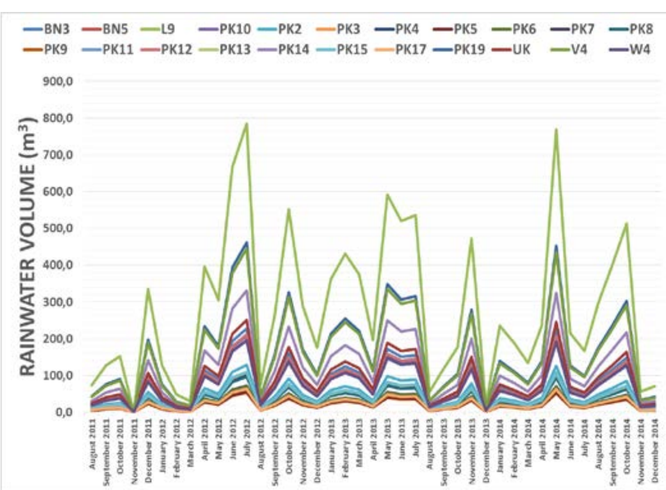

Fig. 5 measured values of rainfall during our research August 2011-December 2014

Tables 2-5 summarizes theoretical volumes of collected rainwater for all building in TUKE campus according the measured yearly rainfall totals as potential savings of potable water by the use of rainwater. Data are presented for the period August 2011 – December 2014.

Tab. 2 roof areas of buildings in TUKE campus

Building	**Roof area (m^2)**	**V (m^3) - 2011**
BN3	1766	200
BN5	1511	171
L9	6091	688
PK10	1615	182
PK2	1003	113
PK3	407	46
PK4	563	64
PK5	425	48
PK6	548	62
PK7	777	88
PK8	746	84
PK9	489	55
PK11	1506	170
PK12	1640	185
PK13	841	95
PK14	2572	291
PK15	854	97
PK17	497	56
PK19	3591	406
UK	1946	220
V4	3453	390
W4	1525	172

Tab. 3 roof areas of buildings in TUKE campus

Building	**Roof area (m^2)**	**V (m^3) -2012**
BN3	1766	1078
BN5	1511	922
L9	6091	3717
PK10	1615	985
PK2	1003	612
PK3	407	248
PK4	563	344
PK5	425	259
PK6	548	334
PK7	777	474
PK8	746	455
PK9	489	298
PK11	1506	919
PK12	1640	1001
PK13	841	513
PK14	2572	1569
PK15	854	521
PK17	497	303
PK19	3591	2191
UK	1946	1187
V4	3453	2107
W4	1525	931

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Tab. 4 roof areas of buildings in TUKE campus

Building	Roof area (m^2)	V (m^3) -2013
BN3	1766	1116
BN5	1511	955
L9	6091	3851
PK10	1615	1021
PK2	1003	634
PK3	407	257
PK4	563	356
PK5	425	269
PK6	548	346
PK7	777	491
PK8	746	472
PK9	489	309
PK11	1506	952
PK12	1640	1037
PK13	841	532
PK14	2572	1626
PK15	854	540
PK17	497	314
PK19	3591	2270
UK	1946	1230
V4	3453	2183
W4	1525	964

Tab. 5 roof areas of buildings in TUKE campus

Building	Roof area (m^2)	V (m^3) - 2014
BN3	1766	952
BN5	1511	814
L9	6091	3282
PK10	1615	870
PK2	1003	540
PK3	407	219
PK4	563	303
PK5	425	229
PK6	548	295
PK7	777	419
PK8	746	402
PK9	489	263
PK11	1506	811
PK12	1640	884
PK13	841	453
PK14	2572	1386
PK15	854	460
PK17	497	268
PK19	3591	1935
UK	1946	1049
V4	3453	1860
W4	1525	822

IV. Measurements of quantity of rainwater runoff in TUKE campus

We have started our research and own measurements in scope of stormwater quantity and quality parameters at the campus of Technical University of Košice within the project relating to the management of stormwater. The objects of research represent two infiltration shafts in the campus of TU Kosice that were made before the start of our research. These infiltration shafts represent drainage solution for real school building PK6 and all of the runoff rainwater falling onto the roof flows into these underground shafts (figure 6) [6].

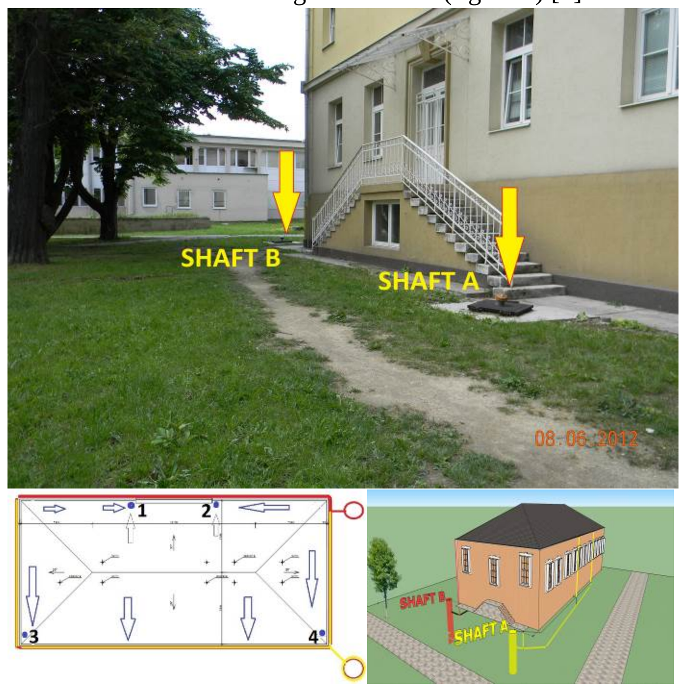

Fig.6 Location of drainage shafts near the PK6 building [6]

The measuring devices for information about volume of incoming rainwater from the roof of the building PK6 and also information about the quality of rain water are located in both infiltration shafts [1]. All devices are connected with registration and control unit M4016. Unit M4016 automatically sent measured and archived data into the server database (data hosting) via GPRS in regular intervals [5]. Under inflow, respectively rain outlet pipe in the shaft, there are measurement flumes for metering of inflow rainwater from the roof of a building PK6 in both of infiltration shafts. Rainwater from the roof of the building PK6 is fed by rainwater pipes directly into measurement flumes, which are placed under the ultrasonic level sensor which transmitting data of the water level in the measurement flumes to the data unit M4016 (figure 7) [6,10].

Fig. 7. Measurement devices - Data unit M4016 in shaft A, Measurement flume with ultrasonic level sensor

Table 6 summarizes the measured monthly rainfall totals with corresponding theoretical volumes of collected rainwater. Data are presented for the period April 2012 to December 2014 because at that time began measuring of the flow from all roof area of the building PK6 and precipitation measurements simultaneously. (Notice: August 2012 without data due to equipment failure) [11].

Tab. 6 theoretical volume of rainwater from PK6 building (548 m^2) according to the measured values of precipitation from April 2012 to December 2014

Month	Rainfall (mm)	Theoretical volume from 548 m^2(m^3)
April 2012	65	35,6
May 2012	50	27,4
June 2012	109	60,0
July 2012	129	70,6
August 2012	12	6,7
September 2012	44	24,0
October 2012	91	49,6
November 2012	48	26,1
December 2012	29	15,8
January 2013	59	32,6
February 2013	71	38,8
March 2013	62	33,8
April 2013	32	17,6
May 2013	97	53,2
June 2013	85	46,8
July 2013	88	48,2
August 2013	9	4,9
September 2013	19	10,5
October 2013	29	15,9
November 2013	78	42,5
December 2013	3	1,6
January 2014	39	21,2
February 2014	31	17,0
March 2014	22	12,1
April 2014	39	21,3
May 2014	126	69,2
June 2014	35	19,4
July 2014	27	15,0
August 2014	49	26,7
September 2014	66	35,9
October 2014	84	46,1
November 2014	9	5,0
December 2014	12	6,4

Table 7 summarizes the real measured monthly rainfall totals with corresponding theoretical volumes of collected rainwater and real amount of rainwater from roof of PK6 building.

roof area of the building PK6 and precipitation measurements simultaneously. (Notice: August 2012, September 2014, October 2014 without data due to equipment failure).

Tab. 7 measured monthly rainfall totals with corresponding theoretical volumes of collected rainwater and real amount of rainwater from roof of PK6 building (548 m^2)

Month	Rainfall (mm)	Theoretical volume from 548 m^2(m^3)	Real volume from 548 m^2(m^3)
April 2012	65	35,6	26,7
May 2012	50	27,4	18,9
June 2012	109	60,0	40,8
July 2012	129	70,6	49,6
August 2012	12	6,7	-
September 2012	44	24,0	17,9
October 2012	91	49,6	36,5
November 2012	48	26,1	16,9
December 2012	29	15,8	12,1
January 2013	59	32,6	19,9
February 2013	71	38,8	23,5
March 2013	62	33,8	22,8
April 2013	32	17,6	11,8
May 2013	97	53,2	30,6
June 2013	85	46,8	30,2
July 2013	88	48,2	36,6
August 2013	9	4,9	3,8
September 2013	19	10,5	8,9
October 2013	29	15,9	13,7
November 2013	78	42,5	38,4
December 2013	3	1,6	1,3
January 2014	39	21,2	10,9
February 2014	31	17,0	12,4
March 2014	22	12,1	8,3
April 2014	39	21,3	13,3
May 2014	126	69,2	44,9
June 2014	35	19,4	12,6
July 2014	27	15,0	13,9
August 2014	49	26,7	20,8
September 2014	66	35,9	-
October 2014	84	46,1	-
November 2014	9	5,0	4,1
December 2014	12	6,4	4,7

V. Conclusion

Theoretical and also real volumes from our measurements show a big potential savings of potable water by the use of rainwater in TUKE campus. In the case of school-type buildings potential of water savings replaced by rainwater is significantly higher what result from absent of purposes as a showering, bathing, laundry, etc. The most volume of potable water of school buildings in TUKE campus is consumed for flushing toilets which is precisely the most suitable purpose for

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use of rainwater.

Rainwater harvesting in educational type of building has not only financial benefits but also educational and ethical benefits. Education of students leads to awareness of value of potable water and would avoid of wasting precious drinking water which is used for example - for flushing toilets in our society.

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Gabriel Markovič is researcher at the Faculty of Civil Engineering, Technical University in Kosice. He is specialised in Water supply and drainage systems. Recently he has been concentrated on the field of rainwater harvesting and rainwater infiltration systems.

Daniela Kaposztasova is lecturer at the Faculty of Civil Engineering, Technical University in Kosice. She is specialised in Water supply and drainage systems. Recently she has been concentrated on the field of hot water distribution systems and rainwater reuse.

Zuzana Vranayova is the professor at the Civil Engineering Faculty, Technical University in Kosice, Department of Building Services. She is conducting various researches on her major field of study of water supply and drainage system in buildings. She is also actively involved in governmental and academic institutions and committees related to her field of study as chief coordinator and board member. She is a vice dean for education

Cost Management and Cost Behavior in Manufacturing Enterprises – Preliminary Research

Petr Novák

Abstract— This paper presents results regarding a pre-test of the quantitative research within the project focused on cost variability and cost management systems. The main goal is to analyse and then introduce principal findings resulting from searching for the level of cost management as well as for understanding various types of cost behavior in manufacturing enterprises in the Czech Republic.

The first part of the paper analyses present theories regarding approaches to cost management with the emphasis on overhead cost management, general and asymmetric cost behavior.

In the second part, procedure as well as methodology of research is presented. The hypotheses that are the base for the analysis of particular areas within the cost management are also presented in this part.

The third part presents research results themselves that were also verified by a statistical check-up of dependence relations. Rather significant drawbacks and reserves of manufacturing enterprises in their overhead cost management mainly were found out. These results are then discussed in the final part of the paper.

Keywords— cost variability, cost behavior, asymmetric cost behavior, overhead cost management.

I. Introduction

The changes in business environment in the second half of the 20th century had the significant impact on the structure of the company costs and due to this, we can observe a continuously growing importance of cost management systems. The ability to analyse company costs is one of the most important prerequisites of the effective cost management and it is one of the most important area of company performance. The most important feature of the cost analysis is cost classification when costs are classified into defined categories according to the particular characteristics. Another important area is the analysis of the cost behavior.

Due to a growing competition on globalized markets, companies need more detailed and precise information about the cost efficiency and profitability of their products, projects or customers. All these problems are connected with a higher need for understanding the consumed costs and other areas where the costs play an important role.

Knowing how costs change as activity output changes is an essential part of planning, controlling, and decision making [1]. Ways to proceed with the assessment of costs and their analysis are numerous. In traditional models of cost behavior which appears in literature, costs are described as fixed or variable with respect to changes in volume production. In this model, variable costs change proportionately with changes in the volume of production [1], [2], [3], [4], implying that the magnitude of a change in costs depends only on the extent of a change in the level of production, not on the direction of the change. But some allege costs rise more with increases in activity volume than they fall with decreases [5], [6], [7], [8], [9]. In fact, not knowing and understanding cost behavior can lead to poor and even disastrous decisions. And this is the reason why we constantly talk about the variability of costs and how they translate into costing systems and hence the price of the product.

The main goal of this paper is to present results of the pre-test of the quantitative research done within the research project called "Variability of cost groups and its projection in the costing system in manufacturing enterprises". **The partial goal** is to analyse current situation regarding cost management in practice within manufacturing enterprises in the Czech Republic. **The attention is paid** to particular results of the questionnaire survey with the emphasis on overhead cost management in manufacturing enterprises as well as perception of potential asymmetric cost behavior. The analysis of management approaches regarding overhead costs mainly, and their dependence on particular factors will be made.

II. Literature review

Financial and management accounting in different countries usually offers different approaches to cost classification. Financial accounting uses the cost classification on financial

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P. Novák is with the Department of Enterprise Economics, Tomas Bata University in Zlín, Faculty of Management and Economics, nám. T. G. Masaryka 5555, Zlín, 76001, Czech Republic (phone: +420576032512; e-mail: pnovak@fame.utb.cz).

statements [10]. This classification assorts natural types of costs based on a type of the consumed input.

E.g. Drury states the main division into direct and indirect costs [4, p. 24-25]. Among the direct costs then classified primarily direct materials and direct labor as represent those which could be easily and accurately identified with a particular cost object. Indirect costs then cannot be identified specifically and exclusively with a given cost object. [4, p. 25], [11, p. 33].

Another division is according to the cost behavior to the variable costs, fixed costs, semi-variable or semi-fixed costs. e.g. [1]–[4], [12], [13], etc. In connection with this issue Hansen adds, that then cost assignment is one of the key processes of the cost accounting system [1]. **And just the correct identification of variability in each cost groups due to production is the key to the exact allocation**. It is necessary to realize that costs need to be split to variable (links to load capacity) and fixed (independent to load capacity). How Popesko says, in practice it is really necessary to distinguish these sets of costs. We can distinguish for example costs united with dose and its level, which are going to be change in addiction at quantity of doses, but stays fixed in link to individually produced units or products. [14] Next possibility is to distinguish costs related to group of products or services. These costs are independent of made products quantity of certain type, but they have tend to grow in case of product type number produced by company grows. We could continue in this enumeration of variability, for example through costs, theirs formation is induced by specific customers and individual attitude to them (e.g. in marketing, support of customers etc.)

Many authors have stressed the need for exploring the cost behavior, depending on various factors in this current turbulent period of economic fluctuations and instability of production.

For example Weiss has examined the effect of sticky cost behavior in estimating analysts' earnings forecast and how the earnings forecast can affect the market responses in any surprise earnings announcements [15]. Similar research performed also Banker and Byzalov when examined the sticky cost behavior by using a global Compustat data from 20 countries, to see whether the sticky cost is a global phenomenon or it is more pronounced in the US only. They have tested 5 hypotheses to analyze the cost behavior of firms along with managers' optimism and pessimism about the future economic outcomes. [16]

From earlier performed (and published) researches then went out Shust and Weiss when examined the sticky costs behavior between reported operating expenses in the annual report versus the operating expenses paid in cash by analyzing three models given by Banker and Byzalov [17], [16]: according to Anderson, Banker a Janakiraman specification (ABJ) [18], the liner ABJ model given by Balakrishnan et al. and Weiss firm specific nature of stickiness [19], [15]. They argue that, financial reporting choices of operating costs induces stickiness, more than the costs paid in cash, which is noted as economic costs.

Cost stickiness becomes a phenomenon of present time. Yasukata and Kajiwara found out from their researches, that, the difference in cost stickiness even larger when managers are more optimistic about the future sales even when sales decline, hence keeping the slack resources for future uses. When analyzing the individual stickiness between selling, general, and administrative (hereafter, SG&A) costs and cost of goods sold (hereafter, COGS), they find that, SG&A costs are stickier than the COGS costs. In this case, managers are reluctant to cut the administrative costs or any downsizing costs of selling personnel with an expectation that they need to higher again the selling personnel when sales restore. [20]

In connection with this issue Chen etc. found out, that SG&A costs increased by 0.80% if sales increased by 1%, whereas SG&A costs decreased by 0.74% per 1% decrease in sales where the manger is less confident and further decrease by 0.61% where the manager is overconfident. Thus, the result is showing that, overconfident manager is less willing to cute resources when sales reduce due to his perceives believe that sales will increase in the near future. They differentiated the sticky cost behavior beyond the managerial agency theory and economic behavior of the cost accounting. Authors argue that, in an agency theory, stickiness cost behavior arises due to opportunity seeking behavior of the managers. However, overconfident manger is not looking for any personal benefits, however he is driven by his self-stream about the positive future outcome, and that is why he is keeping the unutilized resources to increase the value of the firm in future. [21], [22]

All these (and many other) studies clearly demonstrate the need for such exploration, comparison and verification of this issue also in terms of manufacturing firms in the Czech Republic.

III. Methodology

In accordance with the goals of this paper, the partial research results are also presented. This quantitative research was done as a pre-test of the complex quantitative research focused on the issue of cost management in manufacturing enterprises. This is done from their variability cost perspective as well as taking into account costs in particular cost and calculating systems within the enterprises.

The questionnaire was divided into 4 basic areas that fulfil the goals and hypotheses of this research project. These are following:

- General information about the enterprise – the emphasis on the size of it, ownership and type of production
- General information about the costs – structure of the costs according to their classification, the attention paid to the costs (frequency of their monitoring and evaluation, what types of costs are monitored in more detail, etc.)
- Costs and calculations (the emphasis on overhead costs) – what types of calculations are made, how the overhead costs are reflected in calculation formulas, how the overhead costs

are matched with an expense item, and so on.

- The area of cost variability – whether the enterprises have knowledge and consider the fact that costs do not have to be dependent on production capacity only, how they work with overhead costs in relation to various factors (number of customers, production batches, orders, etc.), the approach to semi-fix or semi-variable cost management
- Additional information – information environment, methods regarding cost processing, and so on.

For this quantitative research, the firm´s range of exploration was bounded in the manufacturing industry – NACE from 10.10 to 33.20. 200 randomly chosen companies were addressed. It managed to find 57 respondents out of these companies, which is a 30% return rate. The results obtained from the questionnaires were evaluated by relative frequency and the hypotheses were tested using χ2 Tests (Goodness of Fit Tests and Contingency Tables) for determination dependence between categorical variables. The null hypothesis is that the actual distribution can in fact be represented by the theoretical distribution, and that the discrepancies between them are due to chance.

We compute test statistic [23]

$$\chi^2 = \sum_{i=1}^{k} \frac{(n_i - n\pi_{0,i})^2}{n\pi_{0,i}} \qquad (1)$$

where n_i are observed sample frequencies and $n\pi_{0,i}$ are theoretical (expected) frequencies in the ith group. χ2 has (if n is large enough) a χ2 distribution with (k − 1) degrees of freedom (df).

Decision rule: we reject the null hypothesis if

$$\chi^2 \geq \chi^2_{1-\alpha}(k-1) \qquad (2)$$

otherwise we do not reject it. The measure of dependence is the Pearson´s contingency coefficient:

$$P = \sqrt{\frac{\chi^2}{\chi^2 + n}}; \quad P \in \langle 0;1) \qquad (3)$$

The level of infallibility was defined on 0.05, which means that the hypothesis of independence of two variables can be rejected if the calculated p-value will be lower than this level defined. In such case, it is possible to consider the statistical dependence of two variables. Despite the total number of respondents, which is not too high and the results can be rather distorted for this reason, it is possible to make certain conclusion regarding this pre-test. This pre-test based on questionnaires also verified the relevance of questions in connection with the companies studied. Having the test corrected shall enable us to do a standard research when 150 respondents are expected to take part in. This sample should be sufficient enough to generalize particular findings.

Based on the project goals, the following hypotheses were stated regarding this part of result evaluation:

H1: There is a statistically significant dependence between the company size and the attention that is paid to manage its fixed costs.

H2: There is a statistically significant dependence between the company size and considering the cost variability evaluation according to other quantity than production capacity.

H3: Medium and large enterprises concentrate more on the development of overhead costs than small enterprises.

H4: In fact, there are certain groups of costs that are increasing when the production capacity is getting higher. However, when the capacity is getting lower, these are to stay on the same level. Such costs do not decrease again. This does not depend on the company size, type of production or the ownership structure.

IV. Results

In this part, some of the research results will be introduced. First, regarding the goals and hypotheses, it was essential to evaluate enterprises from the following perspectives – their size, ownership structure and type of production.

Table I: The company size (number of employees)

Number of employees	Absolut freq.	Relative freq. in %
10 - 49	21	37 %
50 - 99	6	10 %
100 - 249	17	30 %
250 - 499	5	9 %
500+	8	14 %

Source: own

Table I illustrates the structure of respondents regarding their size[1]. Here as the most important criterion was the number of employees. From the table above, it is evident that the highest number (about 77 % of companies) belong to small and medium enterprises with 0 – 249 employees. About one third of the companies can be classified as small enterprises with 0 – 49 employees. About 23 % of companies are large enterprises with over 250 employees.

The aspect of company ownership was also studied as there are other various dependences that can occur. The aspect whether the companies are owned by a domestic or foreign proprietor is rather important. Regarding this aspect, three quarters of respondents were owned by a domestic proprietor, 19 % of companies were owned by a foreign proprietor, and in case of 5 % of companies, there was a joint ownership of both domestic as well as foreign proprietors.

The type of production is also essential for the purpose of further conclusions and research. It is possible to search for connection between cost behavior and particular types of products. The table below shows this feature.

[1] Commission Regulation (ES) no. 800/2008

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Table II: Type of production

Type of production	Absolute freq.	Weighted average percentages of production
Piece production	32	24.86%
Project production	20	16.61%
Small batch production	31	20.61%
Large batch production	23	25.37%
Mass production	11	13.51%

Source: own

Note: Number of cases in which at least 1% of the respective type of production was indicated.

The respondents were to choose more possibilities when also mentioning the percentage of these types of production. Therefore, the evaluation had to be based on weighted average. Table II shows that numbers of particular types of production are rather balanced. We can state that no type of production considerably predominates.

For the purpose of cost management, it is necessary to find out a structure of costs from the perspective of their classification. The table below shows the portion of overhead and fixed costs.

Table III: Overhead (fixed) cost portion.

	Portion on total cost		Portion on total cost
Unit cost	62 %	Variable cost	65 %
Overhead cost	**38 %**	Fixed cost	**35 %**

Source: own

Table III illustrates that average portion of overhead costs is about 38 % whereas regarding fixed costs it is only 35 %. There we can also identify a small disproportion between overhead and fixed cost portions. This is caused by the fact that it possible to include a part of overhead costs within production into variable costs. It is positive that companies understand the differences in costs. From other questions and answers to these, it is evident that companies do not pay special attention to overhead costs. The respondents mentioned (almost 55 % of cases) that they pay as much attention to overhead cost management as to variable cost management. 28 % of respondents mentioned that they focus on variable (unit) costs mainly. Only 7 % of respondents specified that they concentrate directly on fixed cost management. Then, 22 % of respondents specified that they tend to focus on cost division in detail after having them divided into particular categories. This means that they also pay attention to overhead cost management. To sum up, **only about 30 % of respondents focus on overhead cost management in detail.**

To have an overall view on the issue of cost management, it is interesting to mention that about 10 % of respondents do not use calculations for their cost management. In other cases, the companies (more than half of the cases – 54 %) make use of full absorption costing. To compare these findings with previous studies, it is also interesting to mention the use of a modern method called Activity-based costing, which was used in 7 % of the cases only. This confirms its low usage, which also emerged in previous studies that were already published by the author. [24] As the proof of these findings, we can state that there is **the least possible cost management based on other cost drivers than production capacity.** This was confirmed also by other respondents´ answers when only 20% of these mentioned that they are aware of the fact that cost variability can also be considered in relation to other quantities than in relation to production capacity only. On the contrary, 75 % respondents stated that they are aware of the above mentioned but they do not make usage of such knowledge for the cost management itself. 5 % of respondents mentioned that they have never heard of this issue. This confirmed also other findings when majority of the companies (up to 60 %) mentioned that they do not distinguish semi-fixed or semi-variable costs. About 27 % of respondents have never heard of these issues. This means that only 13 % of respondents distinguish the categories of semi-fixed and semi-variable costs. This was again confirmed by the answers to the last question from this category when 72 % of respondents do not see the possibility of having other groups within the company that are increasing in relation to a growing production capacity. However, when the production capacity is getting lower these will stay on the same level and do not decrease again.

Based on the above mentioned facts, a more thorough research was carried out in order to find out potential connections among various areas of companies. Firstly, we assume that there is a strong dependence between overhead cost management and the company size. Logically, a larger company is to have a more complex system of costs and will have to pay more attention to overhead cost management mainly as in this area, there are possibilities how to save costs almost in any company.

Table IV: Dependence between the company size and the attention paid to management of particular cost groups.

	Mainly variable cost management	Mainly fixed cost management	Variable and fixed cost management
Small enterprises	33%	19%	38.10%
Medium and large enterprises	21%	25%	54%
χ^2	2.119		
p-value	0.55		

Source: own

Based on the calculated feature of $\chi 2$ (p-value = 0.55), it is evident that the hypothesis of independence is not possible to be rejected. This means that the research carried out **did not confirm statistically important dependence** between the company size and the attention paid to management of particular cost groups. It cannot be assumed that in connection with a higher company size there is a greater emphasis on the attention paid to, for example fixed (overhead) costs contrary to variable costs. Nevertheless, this does not mean that the companies do not pay any attention at all to overhead cost management. This fact was also confirmed by other hypothesis (*H2*), which has to be rejected as well for the reason of being tested on statistical dependence with the result of having p-value on the level of 0.71, which is a higher value than the critical one of 0.05. **The hypothesis** of two variables independence cannot be falsified and therefore, the statistically significant dependence between the company size and the cost variability assessment done by other cost drivers than production capacity **was not confirmed.**

Although there was no proof of dependence between the company size and paying a special attention to certain cost groups, majority of companies (up to 85 %) monitor structure and development of overhead costs. The statistical dependence between the company size and detailed study of overhead costs was confirmed (*H3*). In this case, p-value was lower than 0.05 (0.016), which enable us to reject the null hypothesis regarding the independence of these two variables. It is possible to state that **medium and large enterprises statistically monitor in detail their overhead cost structure more often than small enterprises.**

The final hypothesis made (*H4*) describes *the fact regarding asymmetric cost behavior. These are costs that are increasing when the production capacity is getting higher. However, when the production is getting lower these are to stay on the same level and do not decrease again. This does not depend on the company size, type of production or the ownership structure.* This hypothesis **was found valid** due to three partial conclusions of statistical check-ups. The first conclusion made was based on study regarding dependence between the company size and understanding the fact of having asymmetric costs. In this case, relative frequencies did not show significant differences between small and larger enterprises. Consequently, the statistical test did not confirm the differences as p-value on the level of 0.726691 did not enable to reject the null hypothesis regarding the independence of two variables. In a similar way, it is possible to evaluate dependence between perception of asymmetric cost behavior and type of production. Even relative frequencies show that for example companies with a project type of production or a small-quantity production see the disproportionality of some of the costs more clearly than other companies perceive them. Still, these differences were not found to be statistically significant. The p-value of 0.649411 does not enable to reject the null hypothesis regarding the independence of two variables. This was also confirmed by the third conclusion regarding the study of dependence on property structure. The most significant relative differences were visible between the companies owned by a domestic proprietor and the companies of a joint ownership. The statistical testing confirmed that there is no dependence between the company ownership and perception of the costs (p-value of 0.559).

V. Discussion and Conclusion

This survey together with the previous ones carried out show that in many manufacturing enterprises, **the share of overhead (fixed) costs increased** up to about 40 % of total costs (38% in the year 2014, 39.5 % in the year 2009, 40.7 % in the year 2007[2]). The positive aspect of the findings is that companies are aware of the importance and significance of cost management as well as detailed monitoring and overhead cost management. This was stated by 85 % of the companies studied. Still, we cannot declare that companies pay a greater attention to analyses and overhead cost management than to variable cost management.

Then, it is necessary to state that there is no sign of application of detailed cost analyses that would monitor the cost behavior within the companies from other perspectives than production capacity only. This is confirmed by survey thanks to which we can declare that up to 75 % of respondents concentrate on studying the relation to a quantitative factor, i.e. production capacity or total of sales. To find out the reasons for the above mentioned, the research project is to focus on carrying out a qualitative research. However, one reason can be mentioned at this very moment. The research has proved that there is only a minimum awareness regarding asymmetric cost behavior. Almost three quarters of respondents (senior executives of the companies studied were addressed) are not aware of the fact regarding asymmetric cost behavior or the influence of other factors than production capacity only. Concerning this fact, no connection was proved in relation to the company size or a type of production, which again draws attention to drawbacks in the area of cost management within many companies.

In general, out of 4 hypotheses, there were 2 of them rejected and 2 of them confirmed. We consider mainly the result of hypothesis *H1* rather surprising. In this case, it will be essential to do further research regarding this hypothesis, and this should be done on a larger sample of respondents. These findings will also be verified in the future by a qualitative research within companies selected.

In conclusion, although many authors have discussed the issue of cost management, there is still a great need of reactions and attitudes towards changing economic situation. It is important to provide companies with possibilities regarding problem solving in the area of planning and cost prediction thanks to which they can reach higher economic efficiency. As shown by the research, there are still reserves regarding cost management in companies, and majority of companies still follow the practice of historically rooted models of cost management. Since there is a growth in overhead cost portions, it is vital to pay a greater attention to these, to make detailed analyses, and search for various possibilities of savings. It is essential that monitoring as well as overhead cost evaluation are then reflected in calculation methods, which are to offer a better view on allocation of these costs on the basis of relevant relational quantities.

[2] Result of research investigations that were conducted by the research team of Popesko and Novák in the years 2004 – 2009. The surveys were conducted as quantitative surveys of a random sample of manufacturing firms belonging to the manufacturing sector in the Czech Republic.

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Petr Novák is the assistant professor of management and economics. Works as the senior lecture of the Department of Enterprise Economics at Faculty of Management and Economics of Tomas Bata University in Zlín. He finished his master degree in 2003 on Tomas Bata University and PhD in 2009.

His major field of study is management accounting, he focused on the field of costing system application in healthcare organizations. He focuses on costing system research and research of enterprise economics and he is at present a researcher of the grant "Variability of Cost Groups and Its Projection in the Costing System in Manufacturing Enterprises" registered at Czech Science Foundation.

Water cycle and green roof and wall role in it

Zuzana Poórová, Mohammed Salem AlHosni, Zuzana Vranayová

***Abstract*—**How inappropriate to call this planet Earth when it is clearly Ocean. ~Arthur C. Clarke. Natural ability of the land to absorb excess rainfall is lost under new hard landscaping and existing surface water drainage systems. Claim of this article is pointing at natural water cycle that is being broken and examples of solutions that might solve many problems. Retention features of green roofs and walls using natural blue principles. The article points at positive effects of green roofs and walls in terms of water management.

***Keywords*—** catching water, green roofs and walls, hydrological cycle, water loop, water retention.

I. Introduction

THERE is about 1400 million km3 of water on the Earth. The water in the seas, the water on the land, the water in the atmosphere and the water in living organisms. Of course water meant in all its states. The gaseous state, liquid state and solid state.

II. WATER

The water of the seas and oceans covers 70,8% of the Earth's surface and forms the largest part, up to 97,25%, of all water on the Earth. The seas and the oceans the planet would be suffering from changing of extreme temperatures, what would make life as we know it impossible. Even a slight fluctuation of temperature compared to the current temperatures could have fatal consequences for food security on our planet. Among other functions of the seas and the oceans is interesting water supply to precipitation on the land [1].

The water on the land. The water is often being fixated on the water in the rivers or natural or artificial lakes. Water in solid form ice, snow) forms 2,05 % of all water on the Earth and shelters up to 70% of the world's freshwater supplies. Visible surface water in rivers forms only 000001 % and in lakes (including salt lakes and inland seas) 0,01 % of all water on the Earth. Groundwater and water forming soil moisture 0,687 % presents besides eccentrically placed glaciers the greatest wealth on the land that exceeds several times the volume of water in all rivers and lakes of the entire world. Water in the soil in terms of the quantity of benefits is more important than water in rivers. This undiscovered treasure is misunderstood and overlooked, neglected and destroyed [1].

The water in the atmosphere. The volume of the water in the atmosphere, in all three states is approximately 10 times biger than the volume of water in all the rivers. Theoretically, if all the water in the atmosphere felt in time in the form of precipitation, it would create on the imaginary ground surface 25 mm layer of water. Just like the seas and oceans have key global thermoregulation role on the planet, the water in the atmosphere has crucial local thermoregulation function [1].

The water in the biota. The water surrounds us. It is not just around us, but it is inside us. In living organisms, water volume is about 0,00004% of all the water on the Earth, what is the smallest amount of total volume of the water, but what is lacking on the volume is the highly balanced in crucial importance of this water for daily individual form of life. For example, the human body contains more than 60% of water, and all the physiological processes take place in a medium whose main component is water. The water content in plants varies depending on the species and often is much higher than water content in animal perionyx. The volumes of water accumulated in the vegetation cover are not negligible, just like the volumes of water stored in the soil due to the existence of vegetation. The vegetation on the land, among other functions, has in particular the critical role in the regulation of evaporation from the soil. Therefore, on the land greatly aids thermal stability. Upon which depends its own prosperity and even its existence. On the existence and prosperity of vegetation depends consequently all higher life on the Earth [1].

III. HEAT

Water is very unique. At temperatures common on Earth can naturally exist in all three states. The solid state, the liquid state and the gaseous state. During the change of state heat is consumed, respectively released. During the change of state from solid or liquid state to gaseous state, it gains high mobility thanks to which it is capable of quick motion. Thanks to the motion, is capable of quick moving in large volumes in horizontal and vertical directions. Water also has the highest specific heat capacity, thus the ability to receive thermal energy from known materials. With its ability to bind and release energy, and transfer skills, reflection and dissipation of

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Zuzana Poórová, Ing. arch., PhD student, Technical University of Košice, vysokoškolská 4, Košice 042 00; e-mail: zuzana.poorova@ tuke.sk

Mohammed Salem AlHosni, Ing., PhD student, Technical University of Košice, vysokoškolská 4, Košice 042 00; e-mail: mohammedsalem.alhosni@ tuke.sk

Zuzana Vranayová, prof. Ing., Phd. professor, Technical University of Košice, vysokoškolská 4, Košice 042 00; e-mail: zuzana.vranayova@ tuke.sk

energy, water in all its states according to the needs cools or heats the planet. It is keeping it at a temperature that supports life on Earth.

Water **balances** the temperature differences between day and night, between seasons and between different areas. Thus water also reduces weather extremes. Water vapor is the most wide-spread greenhouse effect in the atmosphere. The content of water vapor in the atmosphere is highly variable, but its typical range is 1-4 % (for comparison , the CO2 content is 0,0383%). The more water in the atmosphere, the stronger effect of temperature balance. Thus there are less weather amplitudes. The less water in the atmosphere, the weaker effect of temperature balance Thus there are more extreme weather amplitudes. Where is the lack of the water in the soil and lack of the water in the atmosphere, extreme temperature conditions usually persist. Water and water vapor affect the climate in the most significant way on the Earth. Nevertheless, the role of water and water vapor in the atmosphere is poorly understood and little discussed issue [2].

IV. THE COOLING EFFECT

Incident solar radiation evaporates water from the seas, lakes, rivers, wetlands, soil from plants into the atmosphere. Evaporation of each molecule of water consumes heat, which cools the Earth's surface. Evaporated water creates clouds in the atmosphere (including fog, rain-fall or ice crystals). Rised vapor higher in the atmosphere condense under the influence of cold, releasing heat. Cooled higher in the atmosphere return back in the form of rain. Repeating this process is an effective mechanism for the elimination of spare heat and is similar to the sophisticated refrigeration device. There is a rule that about half of the earth's surface is all the time in a cloud´s shadow. Clouds restrict the entry of solar radiation into the atmosphere and on the Earth's surface. Limitation of solar radiation that reaches the earth's surface, reduces evaporation and the formation of clouds [2].

Function of clouds. Clouds play an essential role in regulating of energy balance of the Earth concerning the sun radiation. They reflect part of shortwave solar radiation, thus limiting its entry into the atmosphere and on the Earth's surface, thus protecting the Earth from overheating. Clouds capture part of the longwave (thermal) radiation from the Earth, which otherwise would escape to the space, waht has a warming effect. The cooling or warming effect of clouds depends on their type and height. Low situated cumulous clouds (cumulus) cool the Earth, high situated thin clouds (cirus) warm the Earth. The research of thermoregulatory effects of clouds and their balance, with regard to the current problems of mankind proves to be very promising and interesting [2].

Function of vegetation. When the solar radiation hits water well-stocked area, most of the solar energy is consumed for evaporation and only the rest is consumed for sensible heat, heating the soil, reflection, or photosynthesis. When the solar radiation hits the drainage area, most of the solar energy turns into sensible heat, in the year-long sufficiently humid areas, most of the solar energy is consumed for evaporation. Therefore, water areas, soil saturated with water and vegetation have important role in the water cycle on the land. Functional vegetation fulfills the function of the valve between the soil and the atmosphere. It protects the soil from excessive overheating and thus drying out and optimizes the amount of the water evaporation through the transpiration of amount of air channels on the leaves. Vegetation well stocked with water thus has a significant cooling and air conditioning feature. Vegetation, its quantity, type and quality significantly affect the runoff in the watershed. Deforestation, agricultural and urban activities are changing the amount of water in the country. Man unwittingly changes flow of huge amount of water and energy [2].

V. ROOFS

Extensive green roofs are lightweight veneer systems of thin soil or substrate layers of drought tolerant self-seeding vegetated roof covers. Extensive green roofs require special types of plants. Plants are usually native from dry locations, semi-dry locations, stony surfaces such as alpine environment. These kinds of plants have typical mechanisms to survive extreme conditions. Mechanisms like water storage organs, thick leaves, thick leaves surfaces, narrow leaves etc. Extensive green roofs are known by using colorful sedums, grasses, mosses and meadow flowers requiring little or no irrigation, fertilization or maintenance after establishment. Extensive green roofs can be constructed on roofs with slopes up to 33%. Also, they can be constructed on existing structures with little, or no additional structural support. Construction of this kind of roof is mostly single-wall, or double-wall [3].

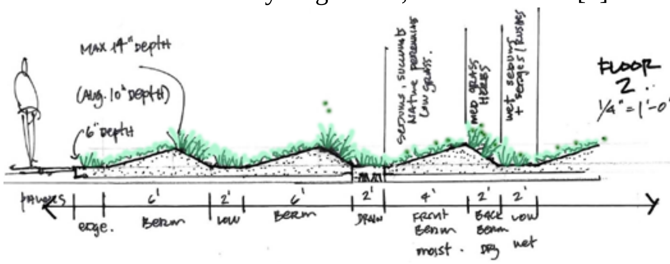

Fig. 2 Green roof sketch [4]

Intensive green roofs are designed to look like gardens, landscapes. They need similar management as ground gardens. Urban rooftops are really challenging places for design. We could say they are useless places. But these typical useless spaces in our towns are becoming a remedy of constructing healthier environment through more sustainable practises. People in the city on the roof usually look for the view. Positive change happens, when habitant of the city is not forced to be looking for the views, because it is in front of him on the rooftop. Unexpected blue and green grasses, colourful flowers in the middle of concrete, steel and glass. Contemporary technological conditions allow many things. Waterproof membranes help to capture water for irrigation, drainage support growing medium and resist invasion of roots of plants. During the day, temperature of asphalt roof is unbelievably high. On green roof, soil mixture and vegetation act like an insulation. Reducing heating, cooling the building. When it is raining, water floods down to city´s artificial canyons. A living roof absorbs water, filters it and slows it down [5].

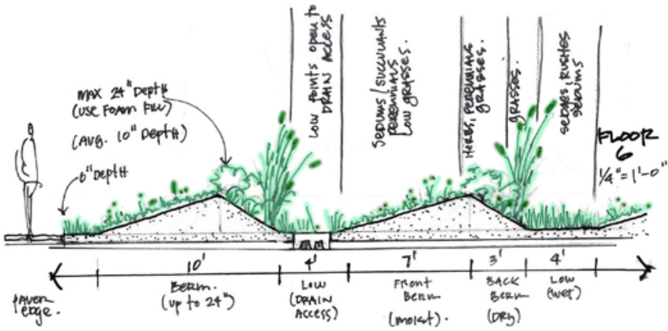

Fig. 3 Green roof sketch [4]

Green facades use climbing plants (lianas, vines and scramblers) to cover building walls, offering a flexible and adaptable tool for environmental design Like other forms of green infrastructure, they cool building walls by intercepting and absorbing solar radiation (shading), providing cooling, increasing albedo (reflecting solar radiation), providing a thermally insulating air cavity, depending on the distance of the green facade from the wall and reducing surface wind speed on the wall.

Fig. 3 Green wall sketch [6]

Green facades offer many benefits to their surrounding environment including buffering building temperatures, cooling the local air temperature, providing air filtration, reducing storm water runoff, ameliorating noise pollution, removing carbon from the air, providing shade, and creating habitats for plants and animals. In many cases , green facades are intended to be aesthetically pleasing. Research shows this aesthetic makes people more relaxed, productive, studious and mentally healthy.

Green facades can potentially reduce energy consumption. Plants on the facade shade a structure’s surface, as well as cool the surroundings through the process of evapotranspiration. Green facades reduce wall surface temperatures by as much as 25°F (14°C) compared with exposed wall surfaces

VI. GREAT WATER CYCLE

The great water cycle is an exchange of water between the ocean and the land. About 550 000 km3 of water evaporates into the atmosphere each year. From the seas and the oceans around 86% evaporates, from the mainland 14% of the total evaporation from the surface of the Earth. Out of the total atmospheric precipitation, which arise from the evaporation, 74% drops over the seas and the oceans, and 26 % drops over the land. The seas and the oceans through the evaporation and precipitation subsidize land with some volume of water. This amount of water by the atmospheric and thermodynamic flows is getting through long distances over continents where expires (or falls in the form of snow).

VII. SMALL WATER CYCLE

The small water cycle is a closed water cycle in which vaporized water falls in the form of precipitation over the same terrestrial environments on the land. Just like small water cycle exists over the land, it exists over the sea or ocean. Between the small water cycles, over the large territories with different morphology and surfaces with varying humidity, ongoing interactions are going on. The small water cycle performs horizontal water circulation, but unlike the large water cycle, it is characteristic vertical movement for it. Evaporation from neighboring areas with different temperatures can cooperate on the design and conduct of cloud. We can say that small water cycles circulate around the country at the same time. We can say that above the landscape the water is circulating in many small water cycles that are donated by the amount of the large water cycle.

The collapse of water cycle. If there is a widespread disruption of vegetation cover (deforestation, agricultural activities, urbanisation), solar energy hits all the surfaces with low vapor and a part is converted to heat. This is how extreme gives rise to significant variations in temperature and the temperature difference between day and night, or only between sites with a different temperature regimes grow. Air circulation will increases, hot air is drifted away and most of the evaporated water from the country is being lost. Small and frequent rainfall decrease and more powerful and less frequent rainfall from the sea increase. The cycle opens, large water cycle starts to dominate, which is in contrast to the small one characteristic with erosion and washing away of soil and nourish to the sea. Restoring the dominance of the small water cycle, which is for man, vegetation and landscape suitable depends on the functional recovery of plant cover area and water areas in the country [7].

VIII. CONCLUSION

The green roof and green wall is a very well known sustainable tool that can be used for solving many ecological issues [8,9,10]. All named problems in the article are pointing at failing water cycle. Lack of soil, vegetation, moisture, water, wet lands, drainaging continents. One possible way how to help humans thus Earth is to start building green roofs on the tops of the buildings that took place from nature and turned it into piece ruining the water cycle. Creating natural surface on the top of the building means creating natural surface that will help the small thus great water cycle. The problematic of green roofs and green walls is not the main point of this article, the aim was to show the importance of water in urban area and the idea of green roof and wall that might be solving this problem in very easy way.

ACKNOWLEDGMENT

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Using Compound Parabolic Solar Collectors in Asphalt Industry

Ahmed E. Ismail and Manoel A.Fonseca-Costa

Abstract**—**This paper presents thermal, economic and environmental evaluation of a solar heating system (SHS) which is used in an asphalt plant from computational simulation with TRNSYS 15. The process chosen is the bitumen heating from the storage up to the mixing temperature, using mineral oil as heat transfer fluid (HTF). The system components are the HTF-bitumen heat exchanger, the compound parabolic concentration solar collector (CPC), the auxiliary heater and the circulation pump. The TRNSYS simulation computes the mass and energy balances in the HTF closed loop every hour. Rio de Janeiro typical meteorological year (TMY) hourly weather data was used in order to perform this paper. In many instances, HTF temperature reached more than 210˚C, showing that the CPC is suitable for this application. Fuel savings and avoided emissions were taken into account for economic and environmental analysis. The results, though, made it possible to address environmentally sound public policies to encourage solar energy use in the Asphalt Industry. Moreover, it will help in reducing the high emission of the green house gases in this industry.

Keywords**—**Asphalt Plant, Compound Parabolic Collector, Solar Heating, Thermal Simulation.

I. INTRODUCTION

The world is moving towards using the renewable energy sources more efficiently to reduce the usage of conventional energy sources and consequently the green house gases (GHG) emissions. The solar energy can intensively contribute to achieve this goal. Sukhatame [3], Kalogirouet al [4] and Luminosu & Fara [11] , among others who address the incipient participation of solar energy on industrial process heating, due to some technical difficulties and many economic barriers, though the same researchers emphasize its huge potential.

This paper presents a technical and economical study for solar heating system (SHS) application in an asphalt plant in Rio de Janeiro (Brazil) using the international fuel prices. It focuses only on the heating of bitumen, from the storage temperature up to the mixing temperature, without encompassing any other asphalt plant heating processes.

The Asphalt Industry is a very fossil fuel consuming, emitting high amounts of the green house gases, given that each ton of asphalt needs 10 liters of fuel in order to reach the mixing temperature [1]. The choice for this particular kind of industry and thermal process was based on data from the temperature range for the most common processes. For the application treated in this paper, the compound parabolic concentration solar collector (CPC) has shown to be the most suitable type.

There are few studies reported in the literature about process heating using the solar heating systems (SHS) in the asphalt industry, mainly done throughout the past 40 years. Henderson, Wiebelt and Parker [10] have constructed, operated and researched a solar-heated asphalt storage system in Oklahoma City, USA for two years. The storage of the asphalt water emulsion which was used in highway maintenance had required the control of temperatures between about 18 °C and 60 °C in order to avoid physical separation of the emulsion. The solar-heated asphalt storage system had performed satisfactorily and proved to be both cost-effective and maintenance-free. Hankins [12] researched other plant in Texas, USA in which the solar energy was used to compensate the energy losses from the high temperature asphalt to the environment. Luminosu and Fara [11] have constructed a laboratory installation for researching on bitumen preheating by using solar energy in Timisoara, Romania and found that the daily average temperature reached by the bitumen is within its softening temperature range.

Gudekar et al. [13] presented an experimental demonstration unit of CPC system for the application of process steam generation, highlighting that it is easy for fabrication, operation and has a lower cost compared to other available concentrating solar collector systems with further possibility of lowering the cost. Panse [19] constructed a CPC system for steam generation for industrial purpose which proved to be economic and efficient. Kalogirou [9] researched the application of solar energy in sea-water desalination. The parabolic-trough solar-collector was selected mainly due to its ability to function at high temperatures with high efficiency. The economic analysis performed, showed that results could be achieved at low investment cost.

Although the solar resource is countrywide available throughout all seasons, there is few published works about solar application in the Brazilian industry, as Dantas & Fonseca-Costa [15].On the other hand, the industrial sector

Ahmed E. Ismail is with the State University of Rio de Janeiro, Rio de Janeiro, Brazil (phone: +5521980866858; e-mail: ahm.ismail@yahoo.com).

Manoel A.Fonseca-Costa is with the State University of Rio de Janeiro, Rio de Janeiro, Brazil (phone: +5521999630864 e-mail: manoelantonio.costa@gmail.com).

accounts for 25% of energy use GHG Brazilian emissions [20]. In 2009, as a result of the 15th Conference of Parties to the UNFCCC (COP 15), Brazil has committed to reduce by at least 36% its projected emissions of greenhouse gases for the year 2020, with an expected contribution of the industry sector through a voluntary 5% emissions cut [21].

As about half GHG emissions from the Brazilian industry comes directly from process, very expensive or even impossible to reduce without undesirable production cuts, it is expected that the largest mitigation contribution in the short and medium term will come from energy efficiency measures and the use of renewable energy sources, both directed to thermal applications, because almost 80% of the electrical power production in Brazil comes, already, from renewable sources [22].

II. Materials and methods

A. Computational Simulation Tool

Solar energy simulations were executed using TRNSYS 15, which is a computational tool developed and commercialized by the University of Wisconsin, U.S.A. It is used to simulate the transient behavior of systems and is commercially available since 1975 [14], being developed and updated constantly.

The graphical user interface called IISiBat, one of the parts of the program package, can be used for mounting the systems. Each component is modeled mathematically by a system of equations and TRNSYS solves these systems for each time interval, using analytical and numerical methods and information flow between components. Moreover, new TRNSYS components can be created using FORTRAN language

The components have a number of parameters for defining the calculation models and constants that will be used in the simulation. After choosing the units that will be part of the system, the components must be properly connected, that is, the inputs and outputs must be properly configured, ensuring the flow of information.

B. Site and Weather Data

The case studied is heating bitumen to reach its mixing temperature in an asphalt plant in Rio de Janeiro (Brazil). Typical meteorological year (TMY) data for the city of Rio de Janeiro were used which were built from EPW files obtained at LabEEE (2013) web site [24], loaded to TRNSYS using TYPE 9a component. Data consisted on total and diffuse horizontal irradiation both hourly (I, I_d), ambient temperature (T_a) and also the temperature of the bitumen (70 ˚C) before entering the heat exchanger. Tables 1 and 2 shows the Parameters and inputs, respectively, for TRNSYS component TYPE 16 Solar Radiation Processor

Table 1 Parameters configuration for TRNSYS component TYPE 16 Solar Radiation Processor

Parameter	Value
1 (Horizontal radiation mode)	5 (I and Id)
3 (Sky method)	1 (isotropic diffuse)
5 (Latitude)	Local latitude
6 (Solar constant)	1,353 W/m2

Table 2 Inputs for TRNSYS component TYPE 16 Solar Radiation Processor

The inputs	Value
1-I	EPW file
2-Id	EPW file
5-ρ (ground reflectance)	0.2
6-β (collector inclination)	Local latitude
7-γ (azimuth)	0° (to the equator)

Available solar radiation was calculated using the isotropic diffuse sky method developed by Liu and Jordan (1963), detailed in [5]. The radiation on the tilted surface is considered to include the three components: the beam radiation, the isotropic diffuse radiation, and solar radiation reflected from the ground.

From the horizontal values of global (I) and diffuse (I_d) radiation, available in the EPW file, the value of beam radiation on a horizontal surface (I_b) was calculated by making the simple subtraction:

$I_b = I - I_d$

C. Case Studied

The case studied is heating bitumen to reach its mixing temperature (more than 150˚C) with mass flow rate of 9tons/hr in Rio de Janeiro (Brazil). The industrial site consists on a medium size industry, using very typical machinery that is used in many of the asphalt plants all over the world.

There are two most commonly used types of Asphalt Plants: Batch heater and the drum mix asphalt plants.

The batch heater has the capacity ranges from 50 to 200 ton/hr. Moreover, it is working in batches, this means that this type produces one batch each time interval while heating the other batch in the mean time. The capacity of the plant is determined by the type of the mixture and the batch size [1].

Secondly, the Drum Mix Plants which have the capacity ranging from 100 to 700 ton/ hr. The aggregates are dried and heated on a large drum on continuous bases then go through the mixing process. This type is recommended for large contracts where large quantities of the same material are required over a long period of time [1].

Asphalt Mix need about 5-10 % of bitumen that should be mixed with 90-95% of aggregates which should be previously dried in 160 ˚C to remove the moisture from it [1].

The System is to raise the temperature of the Heat transfer fluid (HTF) in order to achieve the desired temperature of the bitumen. Therefore, the plant will produce from 90 to 180 tons/day of asphalt mix. Moreover, mineral oil will be used as the heat transfer fluid due to its high boiling temperature. Table 3 shows the properties of HTF and the Bitumen

Table 3 properties of HTF and the Bitumen

Properties	**HTF (Mineral oil)**	**Bitumen**
Mass Flow Rate (kg/hr)	4400	9000
Density (Kg/m^3)	822	1010
Minimum Desired temperature (°C)	210	150
Specific heat capacity(KJ/Kg. °C)	2.13	1.82

D. The Solar Heating System Model

The proposed solar heating system (SHS) (figure 1), in which the HTF is circulating in closed circuit to feed the heat exchanger.

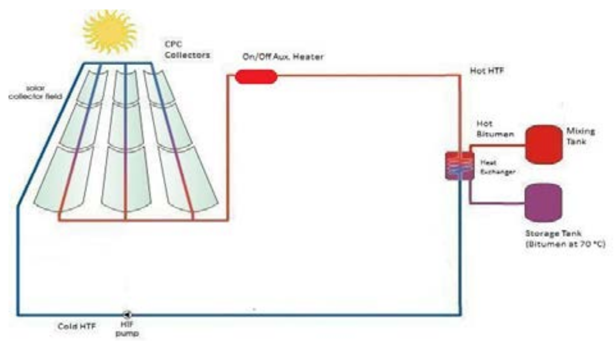

Figure1: Solar Heating System Model

It consists of a pump with a controller to circulate the HTF to the CPC´s through steel pipes, only if there is a net solar energy gain. The HTF will be heated by the CPC´s then it will flow through the pipes to go for the coil inside the heat exchanger at which the bitumen enters at 70°C. The Heating of bitumen will take place in the tank using the following equations in order to reach a minimum temperature of 150 °C.

$Q = C_b (T_{b,o} - T_{b,i}) = C_f (T_{f,o} - T_{f,i})$

In which Q is the heat transfer rate inside the exchanger, while subscripts b, f, i and o is bitumen, HTF, inlet and outlet respectively, C_b and C_f is the heat capacity rates of the bitumen and HTF while T is temperature.

Maximum temperature difference that can occurs is

$\Delta T_{max} = T_{f,I} - T_{b,i}$

Maximum Possible Heat transfer is

$Q_{max} = C_{min} (T_{f,i} - T_{b,i})$

While C_{min} is equal to the smaller value of $C_f = \dot{m}_f C_{pf}$ and $C_b = \dot{m}_b C_{pb}$.. $\dot{m}$ and C_p are mass flow rate and specific heat capacity respectively.

There is an on/off auxiliary heater that has T_{set} = 210°C which is the lowest temperature of the oil to make the bitumen reaches 150°C. This has a control system to measure the oil temperature before entering the heat exchanger. When the auxiliary heater inlet temperature is above the set point temperature, the auxiliary heater will not work so it will not add any heat to the HTF. On the other hand, when the auxiliary heater inlet temperature is below the set point temperature, the auxiliary heater will work to add the heat needed to the HTF in order to reach 210 ˚C.

The hot bitumen after will go to the mixing process with the aggregates while the cold HTF will go again to the collectors through the pump and so on.

This way in heating bitumen is widely used in many asphalt plants that are using conventional fuel.

E. Compound Parabolic Concentration Solar Collector

Table 4 shows different types of solar collectors and their temperature ranges [4]

Table 4

Motion	Collector type	Absorber type	Concent. ratio	Temp. range(°C)
Stationary	Flat-plate collector (FPC)	Flat	1	30-80
	Evacuated tube collector (ETC)	Flat	1	50-200
	CPC	Tubular	1-5	60-240
Single axis tracking			5-15	60-300
	Linear Fresnel reflector (LFR)	Tubular	10-40	60-250
	Cylindrical trough collector (CTC)	Tubular	15-50	60-300
	Parabolic trough collector (PTC)	Tubular	10-85	60-400

In order to reach the above mentioned temperature, the most efficient solar collector with the least price that is able to reach it should be chosen.

CPC is the most appropriate in this case as it can reach till 300 °C without tracking system. On the other hand, the Flat Plate Collector (FPC) is the cheapest and the most available but it cannot reach this temperature level. Therefore, it can be used only as preheating solar system or in fluidizing the bitumen only. On the other hand, FPC is generally used for domestic solar water heating, while the application of CPC lies in industrial process and power generation.

CPC is a special type of solar collector fabricated in the shape of two meeting parabolas. It belongs to the non-imaging family, but is considered among the collector having the highest possible concentrating ratio. Normally, it does not require tracking and can accept incoming radiation over a relatively wide range of angles by using multiple reflections [17].

The height and aperture area for a CPC are calculated as per the desired operating temperature. To reduce the cost the height is generally truncated to half as it slightly affects the concentration ratio [6]. Table 5 presents parameter configuration for TRNSYS component TYPE 74 CPC

Table 5

Parameter	Value
2. area of collector	700m2
3. Cp of HTF	2.13 kJ/kg°C
6. wall reflectivity ρ_R	0.9
7. θc half acceptance angle	36°
8. height truncation ratio of CPC	0.67
10.absorbtance of the absorbance plate	0.95
11.no. of cover plates	1
12.index refraction of material (glass)	1.526

III. Economical Analysis

The whole economic modeling uses the United States Dollars (USD). Price surveys were carried out on April/2015.

The SHS is used in order to raise the temperature of the bitumen from the storage temperature (70°C) to the mixing temperature of (135 °C to 190.6 °C) [16], on the other hand, it should not exceed (230°C) in order to prevent auto-ignition [2]. The system used in this research can make a maximum temperature of bitumen below this temperature and with minimum temperature of 150°C. This is because the heat losses are excluded in the heat exchanger. It can permit the efficiency of the heat exchanger till 90 percent.

In order to reach this temperature range by conventional fuel, will be so costly and will have a very high emission of GHG. On the other hand, it is not cost effective to operate the system solely on solar energy due to the relatively high cost of the equipment and the high percentage of inactive time. Therefore, there is an on/off auxiliary heater that has T_{set} = 210°C which is the lowest temperature of the oil to make the bitumen reaches 150°C.

In order to reach this temperature Range with each system were calculated the British Thermal Units (BTU) required monthly and yearly so the system need a yearly total of 4,028,865,409 BTU. Depending on that the plant is working from 9:00 to 16:59 (Monday –Saturday)

On the other hand, the difference in the amount conventional fuel used between the two systems is calculated. Therefore, it is translated to amount of money depends on the price of the fuel. The price was compared to a CPC that is already installed in India as a reference.

$$\dot{Q} = \dot{m}\, C_p\, \Delta T$$

Where ΔT in the points that did not reach the mixing temperature is:

1. Fuel System: the difference between the exit and the inlet temperature of bitumen which is equal to (150°C – 70°C)
2. SHS: the difference between the set 210 °C and the inlet temperature of the HTF in the auxiliary heater.

Figure 5 The Monthly Btu required from conventional Fuel for the bitumen heating between Fuel and Solar Heating Systems

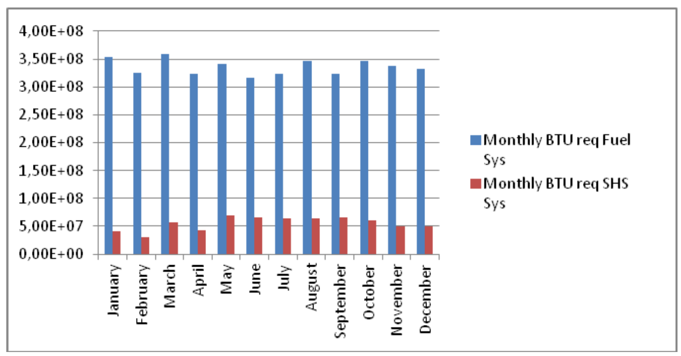

Figure 5

After calculating the net BTU required by both systems the yearly Solar Fraction found is about 83.7%. By using the low heat value (LHV) and the universal price (USD) of each fuel, a yearly difference was calculated by USD using the discount rate of 15% and the operating life-cycle of 15 years.

It was difficult to find the price per m^2 for the CPC but there was a system that was already installed in India by Enersun Power Tech Pvt. Ltd [19]. The Price of the CPC per m^2 is 100 USD. Therefore, it will be 70000 USD for our model because our model has area of 700 m^2.

Table 6 shows the properties of each type of fuel that is used in the comparison and the economic criteria allover the life-cycle of the CPC [7]-[23]

Table 6

Fuel Type	LHV (Btu/gallon)	Price/gal (USD)	Yearly Difference (USD)
Crude Oil	129670	1.43	37219.3
Diesel	129488	1.2	31498,2
LPG	84250	0.56	22410.8

Fuel Type	NPV (USD)	Payback Period (years)	IRR
Crude Oil	147,635	3	53%
Diesel	114.182	3	45%
LPG	61,044	5	31%

IV. Environmental Study

Emission avoided, presented in Table 7, were calculated from official Brazilian official emission factors, those are in accordance with the International Panel of Climate Changes (IPCC).

Table 7

Fuel Type	Emission Factors (t CO_2/t)	Saved fuel tons (t/year)	Avoided emissions (tCO/year)
Crude Oil	2.91997	83.33	259.74
Diesel	3.11685	83.13	259.36
LPG	3.11997	76.96	224.71

V. Conclusion

The World faced many energy crises in the last century and in the beginning of this century too. This leads to more research about renewable sources of energy. In 2002, the amount of solar energy that reaches the Earth's surface every hour is greater than humankind's total demand for energy in one year [18]. The CPC proved to be economically and thermally efficient for such application, despite of its high investment cost and the large area of land that should be occupied by the collector. The study case serves as an indicative that energy policies are needed for increasing the solar energy penetration of high temperature industry. The urge to increase sustainability and reduce the environmental footprint on all human activities, promote the continuous pursuit of solutions for the constraints involving industrial solar heating systems.

The results, though, made it possible to address environmentally sound public policies to encourage solar energy use in the Asphalt Industry. Moreover, it will help in reducing the high emission of the GHG in this industry.

Acknowledgment

The authors thank Pablo de Abreu Lisboa, researcher from Cepel (Centro de Pesquisas de Energia Elétrica) and Fabrício dos Santos Dantas from INT (Brazilian National Institute of Technology) for the support with TRNSYS.

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Theoretical Study of Thermal Performance of Rock Bed Storage

Suad H. Danok, Ehsan F. Abbas, Mousa M. Weis

Abstract--- In this theoretical study, heat transfer and pressure drop in two cases of rock bed thermal storage has been studied, in the first case the equivalent diameter is changed when the mass flow rate per unit area is constant, and in the second case is inversely. The unsteady numerical simulation is employed to analyze the performance of the heat flow and temperature field in the storage. While the best thermal storage is obtain at equivalent diameter is (0.01) m. and show that the relation of pressure drop is decrease with increase in equivalent diameter except in a range of (0.025 to 0.038) m is constant.

Key words--- Rock bed, thermal storage, Pressure drop.

I. Introduction:

THE limited amount of fossil energies has forced scientists all over the world to search for alternative renewable energy source. The use of renewable energies has, therefore, seriously been considered in the last three decades by researchers. The sun has been the major source of renewable energy from long time ago. This energy has had determinate contribution to the life of human being from the information of life on the earth up to now. Solar energy collectors are employed to gain energy incident solar radiation. Solar air heater is a type of solar collectors extensively used in many applications such as in industrial and agricultural field. The various configurations of solar heater have been developed to increase the heat transfer rate or to diminish heat loss like packed bed thermal storage. There are some works on both theoretically and experimentally studies of rock bed thermal storage. Sanderson [1] studied theoretically a simple model of packed bed has which explains how a varying (D_R) (the equivalent sphere diameter of the packing) will influence the degree of axial dispersion. This model was further verified with experimental results in paper achieved by Sanderson et al. [2]. On a vertical flow packed bed consisted of hollow high density polyethylene spheres filled approximately 95% with water, and water was also used as the working fluid. The experimental result shows the effect of altering (D_R) on the degree of axial dispersion in thermally short packing's. The significance of thermally short system is discussed and the average temperature wave during heat exchanger operation is also demonstrated. They have shown that the one dimensional temperature profiles in the packing can be obtained using rectangular storage tank in conjunction with flow distributors. Choudhury C. et al.[3] studied the optimization of design and operational parameters of rock bed thermal energy storage device coupled to a two pass single cover solar air heater, i.e., charging time, rock bed size, and cross- sectional area for square cross section, rock size ,air mass velocity per unit bed cross-sectional area and void fraction. The optimization has been accomplished by investigation the effects of the above parameters on the total energy stored and the cost per unit energy stored in the rock bed for winter climatic condition of Delhi. Anthony G. Dixon[4] developed an improved equation of overall heat transfer coefficient in packed bad as new formula $\frac{1}{U}=\frac{1}{h_w}+\frac{R_t B_i+3}{3k_r B_i+4}$ and based on a single radial collection point whose position depends on the wall Biot number, which gives an error less than 3.8% in the exact asymptotic values of (U) over the entire range of (Bi).A formula is also gives (U'), the overall heat transfer coefficient based on the difference between tube wall and bed center temperatures where (Bi, h_w, R_t and k_r) are tube Biot number, wall heat transfer coefficient, tube radius, and effective radial thermal conductivity respectively. Hessari et al.[5] studied the behavior of packed bed by set of differential equations. A numerical solution is developed for packed bed storage tank accounting to the secondary phenomena of the thermal losses and conduction effect. The effect of heat loss to surrounding, conduction effect and air capacities are examined in the numerical solution. The solution indicates the profiles of air and rock bed temperatures with respect to time and length of the bed. The current study is including the effect of equivalent diameter of the rock (D_R) and mass of air flow rate (G) on the thermal performance of the cylindrical thermal storage as well as on the pressure drop (Δp) by two cases as shown in the Table (2). In the first case they will be used a rock of four different in (D_R) as (0.01, 0.025, 0.038, and 0.05) m. with a (G) is a constant at 1.018 $kg/s.m^2$, and in the second case they will be used a rock of (D_R=0.01m) with a four different quantity of (G) as (0.51, 0.764, 1.018, and 1.53)$kg/s.m^2$.

Suad H. Danok, is a teaching staff member in Refrigeration & Air Conditioning Technical Eng. Dept., Kirkuk Technical College, Iraq.(em. talebshebab@yahoo.com, Mobile No. +964 770 1261807).
Ehsan F. Abbas, is a teaching staff member in Refrigeration & Air Conditioning Technical Eng. Dept., Kirkuk Technical College, Iraq.(em. ehsanfadhil@gmail.com, Mobile No. +964 770 610 2846).
Mousa M. Weis is a teaching staff member in Fuels & Energy Technical Eng. Dept., Kirkuk Technical College, Iraq.(em musamec@yahoo.com, Mobile No. +964 770 933 2089).

II. The model

The rock bed backed thermal storage unit under investigation shown schematically in Fig (1) with a model parameters illustrated in the Table (1) for a particular application of a group of processes involving air flow through a porous media. In this model the thermal performance and pressure drop are studies in two cases. The air is supplied in different temperatures variable with time to the thermal storage bed as shown in Figs (10 and 12). Starting from the initial time (*t*=0), the fluid is forced to flow in the porous bed through inlet section and the solid particles are at the same temperature. the bed contain the same mass and size of rock and had the same, uniform, cross sectional area. The assumptions of Schumann [6] have been employed to model rock beds. Schumann assumed that:

1. The fluid flowing through the bed was incompressible.
2. The temperature in the bed and in fluid was functions only of coordinate in the flow direction.
3. The Biot number of the rocks was sufficiently small so that the temperature distribution in the rocks was uniform.
4. The heat flow between the fluid and rock was proportional to the temperature difference between them.
5. The properties of the fluid and rock were constant.

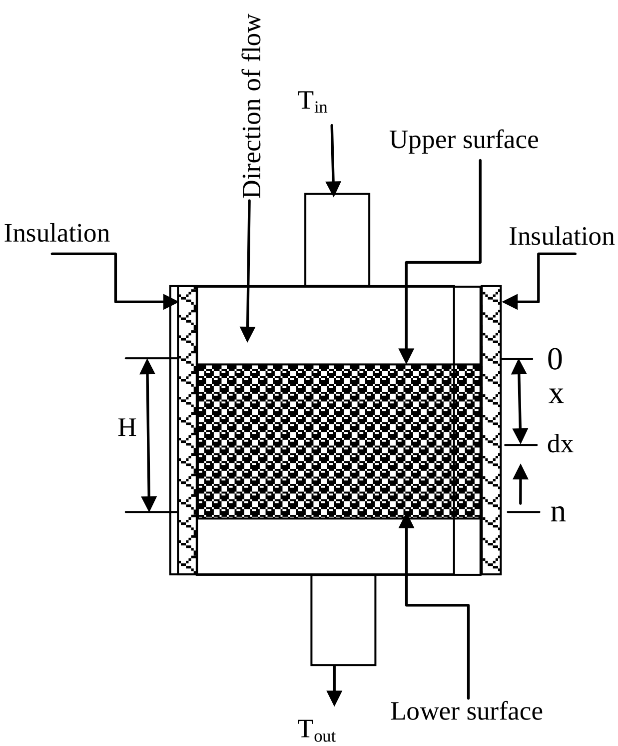

Fig (1) schematic of rock bed thermal storage

Table (1) System description

Area of the packed bed (A)	0.7854m^2
Specific heat of the rock (c_R)	837J/kg.^{o}C
Specific heat of the air (c_a)	1012J/kg.^{o}C
Density of the rock (ρ_R)	2400kg/m^3
Thermal conductivity of the rock (k_R)	0.45W/m.^{o}C
Diameter of the bed (D)	1m
Height of the bed (H)	1.5m
The void fraction (*f*)	0.45
Number of the nodes	9
Distance increment (Δx)	0.1666m
Time increment (Δt)	160 sec
Dynamic viscosity of the air μ	1.8463×10^{-5} kg/m.s

Table (2) Simulation parameters of two cases

Case1	G=1.018 kg/s.m^2	D_R (m)				
		0.01	0.025	0.038	0.05	
Case2	D_R= 0.01m	G(kg/s.m^2)				
		0.51	0.764	1.018	1.273	1.53

Consider a cylindrical storage rock bed along (x) axis. An elemental volume located between the abscissa x and x+dx is considered for heat transfer evaluation. The governing differential equation for the energy supplied by air to the rock bed through convection (q_v) into the elemental volume during *dt* is [5] :

$$q_v = h_v A(T_a - T_R)dx.dt \quad (1)$$

Where:

h_v: Volumetric convective heat transfer coefficient, W/m^3.^{o}C.

A: Cross section area of bed, m^2

T_a: Air temperature, ^{o}C.

T_R: Rock bed temperature,°C

x: Distance along the bed, m

t: Time, sec

The quantity of heat carried away by the air (q_a) is:

$$q_a = c_a GA\left(\frac{\partial T_a}{\partial x}\right)dx.dt \tag{2}$$

Where:

G: The mass flow rate of air per unit cross sectional area, kg/s.m^2

c_a : The heat capacity of the air, J/kg.°C

The heat loss to the surrounding (q_s) is:

$$q_s = UD\pi(T_a - T_\infty)dx.dt \tag{3}$$

U : Overall heat transfer coefficient, W/m^2.°C

T_∞ : Surrounding temperature, °C.

The energy balance for the air is obtained by summing up (1, 2 and 3):

$$q_v + q_a + q_s = \rho_a c_a Af\left(\frac{\partial T_a}{dt}\right)dx.dt \tag{4}$$

ρ_a: The air density, (kg/m$^{3)}$

f : The void fraction

The first energy balance differential equation is derived for air (gaseous phase):

$$\left(\frac{\partial T_a}{\partial t}\right)+\left(\frac{G}{\rho_a f}\right)\left(\frac{\partial T_a}{\partial x}\right)=\left(\frac{-h_v}{\rho_a c_a f}\right)(T_a - T_R) - \frac{\pi UD}{\rho_a c_a f}(T_a - T_\infty) \tag{5}$$

Heat balance for the rock bed (solid state) is similarity obtained from:

$$\frac{\partial T_R}{\partial t}=\frac{h_v}{\rho_R c_R(1-f)}(T_a - T_R) + \frac{k_R}{\rho_R c_R(1-f)}\left(\frac{\partial^2 R_R}{\partial x^2}\right) \tag{6}$$

ρ_R: The rock density, (kg/m^3)

c_R: Specific heat of the rock, J/kg.°C

k_R: Thermal conductivity of the rock, W/m.°C

The equations (5 and 6) are solved by finite difference method, the initial conditions are:

$$T_a(x,0)=T_a(x) \quad \text{and} \quad T_R(x,0)=T_R(x) \quad \text{at } t=0 \tag{7}$$

When:

$$T_a(x)=T_\infty \quad \text{and} \quad T_R(x,0)=T_\infty \tag{8}$$

And the boundary conditions are:

$$T_a(x,0) = T_\infty \quad and\ T_R(x,0) = T_\infty \quad at\ \ t = 0 \tag{9}$$

$$T_a(x,t)=T_{in}(t) \text{ When x=H and t>0} \tag{10}$$

Equations (5 and 6) can be written in terms of finite difference for nodes (n-1>x>1) as:

$$-W\cdot T_a(x-1,t+1)+H'\cdot T_a(x,t+1)+ W\cdot T_a(x+1,t+1)-T_R(x,t+1)=L\cdot T_a(x,t) + k_1 T_\infty \tag{11}$$

$$-C\cdot T_R(x-1,t+1)+F'\cdot T_R(x,t+1) -C\cdot T_R(x+1,t+1)-T_a(x,t+1) =E\cdot T_R(x,t) \tag{12}$$

For lower surface of the bed (x=0)

$$A'\cdot T_R(x,t+1)+B\cdot T_R(x+1,t+1) -C\cdot T_R(x+2,t+1)-T_a(x,t+1) =E\cdot T_R(x,t) \tag{13}$$

For upper surface of the bed (x=n)

$$A'\cdot T_R(x,t+1)+B\cdot T_R(x-1,t+1) -C\cdot T_R(x-2,t+1)-T_a(x,t+1) =E\cdot T_R(x,t) \tag{14}$$

Where:

$$W=\frac{1}{2\Delta x} \tag{15}$$

$$H'=1+k_1+\frac{k_1}{\Delta t} \tag{16}$$

$$L=\frac{k_3}{\Delta t} \tag{17}$$

$$A'=\frac{1}{\Delta t}+\left(1-\frac{k_2}{\Delta x^2}\right) \tag{18}$$

$$B=\frac{2k_2}{\Delta x^2} \tag{19}$$

$$E=\frac{1}{\Delta t} \tag{20}$$

$$F^{'} = \frac{1}{\Delta t} + \left(1 + \frac{2k_2}{\Delta x^2}\right) \quad (21)$$

$$k_1 = \frac{U}{Dh_v} \quad (22)$$

$$k_2 = \frac{h_v k_R}{G^2 c_a} \quad (23)$$

$$k_3 = \frac{\rho_a c_a f}{\rho_R c_R (1-f)} \quad (24)$$

Loof and Hawley gave the volumetric heat transfer coefficient as [6]:

$$h_v = 650 \times \left(\frac{G}{D_R}\right)^{0.7} \quad (25)$$

Where D_R the equivalent spherical rock diameter (m) is:

$$D_R = \sqrt[3]{\frac{6M}{\pi n \rho_R}} \quad (26)$$

Where:

M: Mass of rocks (kg)

n: Number of rocks

Δx: Distance increment, m

Δt: Time increment, sec

To estimate pressure drop across inlet and outlet flow channels of the packed bed thermal storage may be used (Ergun equation) [7] as follows:

$$\Delta P = F\left(\frac{H}{D_R}\right)\left(\frac{G^2}{\rho_a}\right)\left(\frac{1-f}{f^3}\right) \quad (27)$$

$$F = \frac{150(1-f)}{R_{ep}} + 1.75 \quad (28)$$

$$R_{ep} = \frac{GD_R}{\mu} \quad (29)$$

Where μ is viscosity of the air.

III. Resultant and discussion

This study considered two cases, the parameters of them illustrated in Table (2).In both cases the inlet air temperatures(T_{in}) are same at each time during 48 hr as input data. The results obtained are plotted to compares the performance of the rock bed storage. Figures (2, 3, 4, and 5) represent temperature distribution along the height of the rock bed at every two hours for equivalent diameters (0.01, 0.025, 0.038, and 0.05) m. respectively.

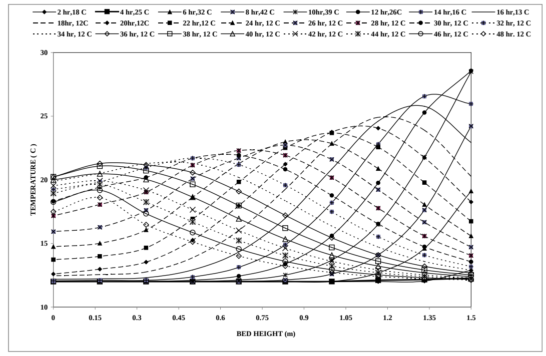

Fig (2) Temperature distribution in the rock bed during 48 hrs, for D_R=0.01m.

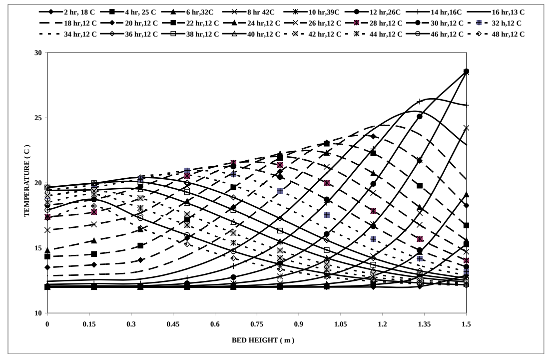

Fig (3) Temperature distribution in the rock bed during 48 hrs, for D_R=0.025m.

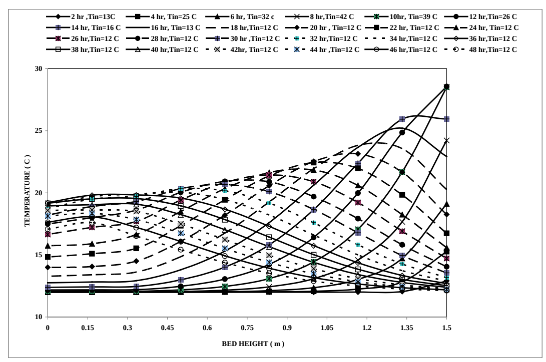

Fig (4) Temperature distribution in the rock bed during 48 hrs, for D_R=0.038m.

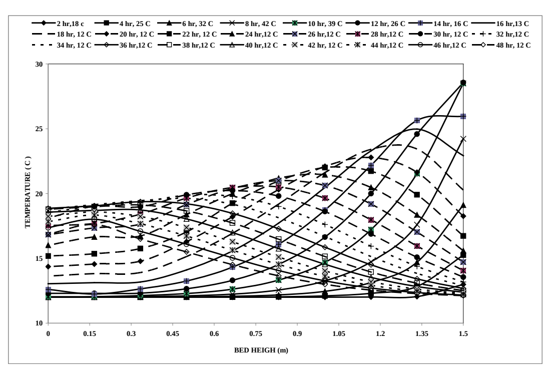

Fig (5) Temperature distribution in the rock bed during 48 hrs, for D_R=0.05m.

The sets of curves are divided in two parts with relative time; first part of them is a similar shape curves of temperature distribution from the starting time up to (16) hrs. , this mean that no effect of dimension of equivalent diameter on the temperature distribution in the rock bed at this limited time but later on the effect of dimension of equivalent diameter is very obvious, where the value of temperature at each node is greater than other dimensions of (D_R). Figures (6, 7, 8, and 9) represent the change of temperature at each node in the bed rock with respect of time for equivalent diameter (D_R) (0.01, 0.025, 0.038, and 0.05) m. respectively. The results obtained are putted in the Table (3). Which are represents the difference between the upper and the lower temperature. The results are indicate that the higher temperature differences are happen in the rock bed when (D_R =0.01m.).

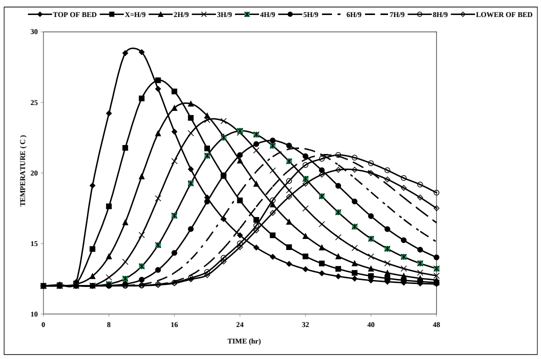

Fig (6) Node temperature change with respect of time for D_R=0.01m.

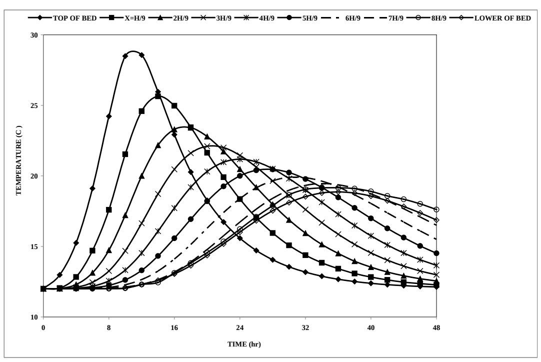

Fig (7) Node temperature change with respect of time for D_R=0.025m.

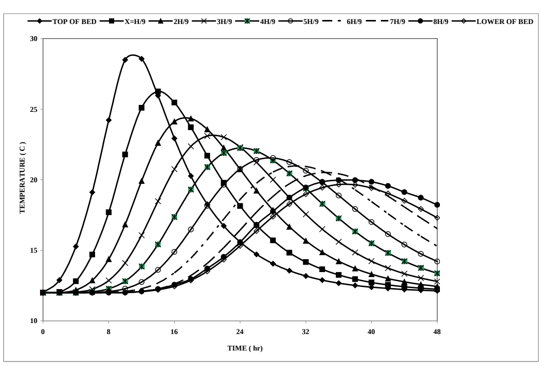

Fig (8) Node temperature change with respect of time for D_R=0.038m.

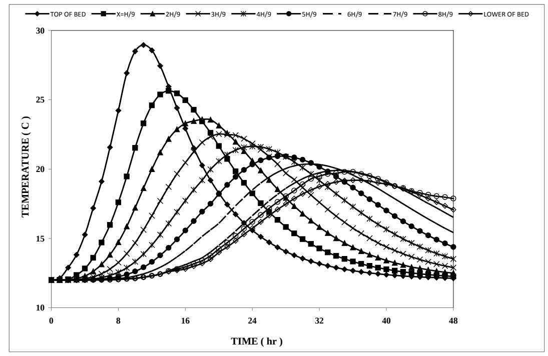

Fig (9) Node temperature change with respect of time for D_R=0.05m.

Table (3) Different between upper and bottom temperatures in each equivalent diameter at the same time

D_R (m)	Time (hr)							
	6	12	18	24	30	36	42	48
0.01	7.11	16.5	7.81	0.84	-4.75	-7.55	-7.25	-5.37
0.025	7.11	16.49	7.4	0.273	-4.72	-6.99	-6.72	-5.17
0.038	7.09	16.33	6.73	-0.16	-4.5	-6.5	-6.34	-4.95
0.05	7.07	16.27	6.63	0.43	-4.56	-6.19	-5.95	-4.65

Figure (10) shows the difference between inlet and outlet air temperatures through the rock bed system. It is indicated that the best outside temperature is found at (D_R= 0.01m).The second case the rock bed examined with variable mass flow rate per cross section area as shown in Table (2). The result obtained shown in Figure(11) which indicate a very low outside air temperature of the bed in condition of (G=0.51 kg/s.m^2), and by increasing the mass flow rate during the same interval of time (48 hrs).The outlet air temperatures are shown in Fable (4).

Figure (12) is representing the relation between pressure drop (Δp) and equivalent diameter (D_R) of the rocks in the case 1. From this relation the higher quantity of (Δp) is happen at (D_R= 0.01m), and it is reduce very quickly with increase in

(D_R) up to (D_R= 0.025m), and in a range of (D_R= 0.025m) up to (D_R= 0.05m) the change of (Δp) is small.

Figure (13) is shown the relation between (Δp) and mass flow rate per cross area (G) in the case 2. It indicated that the quantity of (Δp) is increase as the quantity of (G) is increase.

For reason of solution of the equations (5 and 6) by finite difference method more suitable for large of interval of time, but this condition in analytic solution unsuitable because the results are un real, in addition to this reason the sensitivity of the model is not obtain correctly by analytic solution.

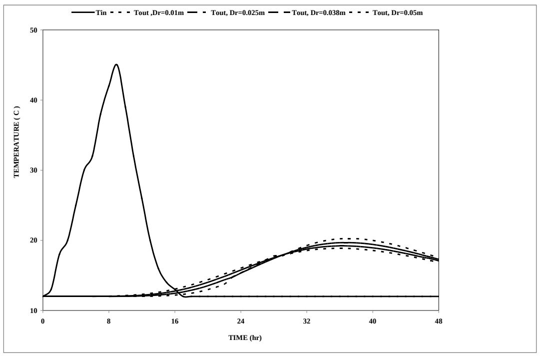

Fig (10) Change in temperatures between inlet and outlet air in case1

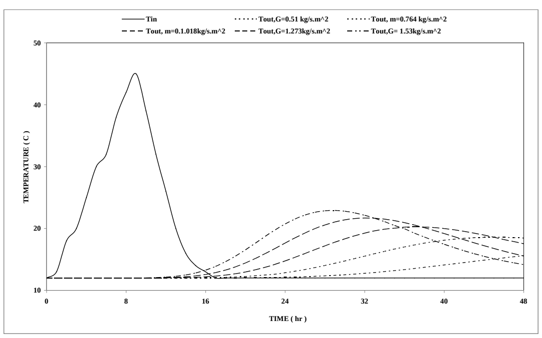

Fig (11) Change in temperatures between inlet and outlet air in case2

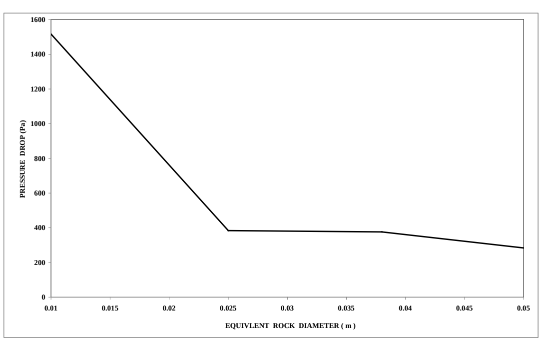

Fig (12) Pressure drop with respect of equivalent diameter in case1.

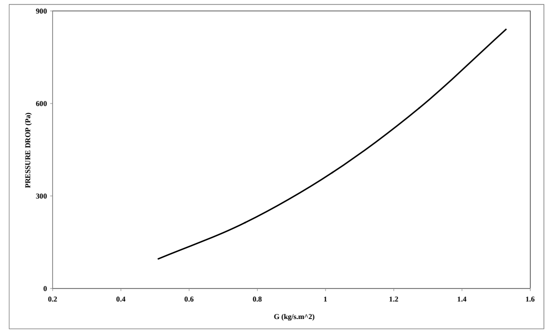

Fig (13) Pressure drop with respect of mass flow rate per cross section area in case2.

Table (4) Shown the outlet temperature from the rock bed at each mass flow rate per unit cross section area

G (kg/s.m^2)	Start time temperature ^oC	End time temperature ^oC	Max. temperature ^oC	Average temperature ^oC
0.51	12	15.6	15.6	12.8
0.764	12	18.44	18.59	14.32
1.018	12	17.53	20.26	15.52
1.273	12	15.55	21.7	16.13
1.53	12	14.16	22.91	16.4

IV. Conclusion

An analytical solution can be written for equations (5 and 6) with more boundary conditions of $T(0,t) = T(1,t)$ in the inlet air temperature. In this case, the solution is limited to relatively small values of the time. In order to extend solution to real case where an initial non-uniform spatial temperature distribution within the bed is considered at large time, initial boundary conditions are to be in corporate in the respected in the solution. The solution shows the response of the rock bed during the changing period (Energy recovery mode) and the profiles of air and rock bed temperatures with respect to time and length of the bed in the final equations (11,12,13,and 14), therefore, be expressed in finite difference form and solved by numerical method. Since the air is used as the heat transfer medium at low temperature, the effect of losses (heat loss, conduction through solid and heat capacity of fluid respectively) are found to be negligible in the solution of the case of air as a moving fluid. The best of heat recovery can be obtained at small equivalent diameter which controlled by the optimum head loss and this give suitable mass flow rate of air which can used in application of passive heating.

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Suad H. Danok holds a PhD in Mechanical Engineering from Seville University, 1993 (Spain) in the field of Renewable Energy. His main research interests include Renewable Energy, and Fluid mechanics. He has published more than 10 papers in peer-reviewed journals. He is also a reviewer local journal. Currently ***Suad*** is an Assistant Professor in the Refrigeration & Air Conditioning Technical Engineering Department in Kirkuk Technical College, Iraq. Email address: talebshebab@yahoo.com, Mobile No. +964 770 1261807.

Ehsan Fadhil Abbas holds a MSc in Mechanical Engineering Department from University of Technology (Iraq) in 1999, in the field of thermal power plants. His main research interests include Heat Transfer, Renewable Energy, and fluid mechanics. He has published more than 18 papers in peer-reviewed journals. He is also a reviewer local journal. Currently ***Ehsan*** is an Assistant Professor in the Refrigeration & Air Conditioning Technical Engineering Department in Kirkuk Technical College, Iraq. Email address: *ehsanfadhil@gmail.com*, Mobile No. +964 770 610 2846.

Mousa M. Weis holds a PhD in Mechanical Engineering from Baghdad University,2014 (Iraq) in the field of Fluid Mechanics and Heat Transfer. His main research interests include Heat Transfer, and Fluid mechanics. He has published about 3 papers in peer-reviewed journals. ***Musa*** is a lecturer in Fuels & Energy Technical Eng. Dept., Kirkuk Technical College, Iraq.(em musamec@yahoo.com, Mobile No. +964 770 933 2089).

The cost of large scale integration of sustainable power generation technologies in United Arab Emirates

Andreas Poullikkas

Abstract— In this work, a capacity expansion analysis is carried out in order to estimate the least cost power generation configuration with the integration of sustainable power generation technologies for the United Arab Emirates (UAE). Five scenarios using sustainable power generation technologies are investigated, including the integration of carbon capture and storage (CCS) technologies and solar-based power generation systems, and compared with the business as usual (BAU) scenario for different natural gas prices. Based on the input data and assumptions made, the results indicate that the BAU scenario is the least cost option. However, in the case UAE will move towards the use of sustainable power generation technologies, for the reduction of carbon dioxide emissions, the natural gas combined cycle technology integrated with CCS systems and the use of concentrated solar power systems with 24/7 operation are the most suitable alternative technologies.

Keywords— generation expansion planning, cost of electricity, energy not served, power system reliability, carbon capture and storage, renewable energy sources, power economics.

I. Introduction

ELECTRICITY demand and enhanced oil recovery are the main reasons behind the recent scarcity of natural gas in UAE. For example, between 2000 and 2010, UAE has witnessed a double increase in the electricity consumption [10]. Moreover, gas injection technology for UAE oil fields is primarily used because it is the most economical. That is about 30% of natural gas produced is re-injected into oil fields for enhanced oil recovery purposes [7]. As a consequence of electricity consumption growth and the continued use of conventional power generation technologies, carbon dioxide (CO_2) emissions in UAE are expected to increase significantly in the following years [2]. On individuals' level, UAE citizens produce CO_2 emissions twice as high as developed countries' citizens and ten times higher than the world's average CO_2 emissions per capita.

Therefore, UAE needs to investigate sustainable power generation solutions in order to satisfy future electricity demand and at the same time to reduce CO_2 emission rates. In other words UAE needs to focus on building a comprehensive CO_2 emissions reduction energy strategy [19]. Despite the above necessity, so far no specific action has been directed towards the building of such an energy policy. The integration of carbon capture and storage (CCS) technologies [12] into UAE power generation system and the use of solar-based renewable energy sources for power generation (RES-E), such as photovoltaic (PV) [17] and concentrated solar power (CSP) [18] systems, have not yet been investigated and therefore their capabilities as a significant means for reduction of CO_2 emissions have so far remained downgraded in UAE. As a first step in this direction, the new technical and economic status that the integration of such technologies will affect the UAE's long term strategic planning can be analyzed [13], [14].

In this work, a capacity expansion analysis is carried out in order to estimate the least cost power configuration with the integration of sustainable power generation technologies for the United Arab Emirates (UAE). As a test case the power generation system of the Emirate of Sharjah will be investigated. In particular, a range of candidate sustainable power technologies [16] are integrated within the existing power generation system of the Emirate of Sharjah and the total annual power generation cost is calculated. Five scenarios using sustainable power generation technologies are investigated, including the integration of carbon capture and storage (CCS) technologies and solar-based power generation systems, and compared with the business as usual (BAU) scenario for different natural gas prices. For the simulations, the WASP IV [23] software package is employed, which is a specialized simulation software used widely for the selection of the optimum expansion planning of a generation system. The electricity unit cost of the power generation system for the various investigated scenarios can then be calculated.

In section II, test case power generation system and the simulation software used are presented. In section III the data and assumptions used for the optimization analysis are discussed. In section IV the results obtained for the optimum expansion of the Emirate of Sharjah power generation system are presented in detailed. The conclusions are summarised in section V.

Parts of this work were undertaken while the author was a Visiting Professor in the Department of Mechanical Engineering, College of Engineering, American University of Sharjah, PO Box 26666, Sharjah, United Arab Emirates.

Andreas Poullikkas is with the Department of Electrical Engineering, Computer Engineering and Informatics, Cyprus University of Technology, Limassol, Cyprus (phone: +35725002014; fax: +35725002635; e-mail: anpdreas.poullikkas@cut.ac.cy).

II. Test Case Description and Optimization

In this investigation, the power generation expansion strategy, with sustainable technologies, for the Emirate of Sharjah is examined as a test case. The electricity sector in the Emirate of Sharjah is monopolistic and the owner and operator of the power stations is the state own company Sharjah Electricity and Water Authority (SEWA). There are seven power stations in the Emirate of Sharjah. The total installed capacity in the Emirate of Sharjah is 2576.5MWe with an annual electricity generation of approximately 10TWh [8].

The future generation system, of the Emirate of Sharjah power industry, is simulated using the Wien Automatic System Planning IV (WASP IV) package, which is widely used for automatic generation planning [23]. The WASP IV software package finds the optimal expansion plan for a given power generating system over a period of up to 30 years [18]. The foreseen seasonal load duration curves, the efficiency, the maintenance period and the forced outage rate of each generating plant are taken into account. The objective function, which shows the overall cost of the generation system (existing and candidate generating plants), is composed of several components. The components, related to the candidate generating units, are the capital cost and the salvage capital cost. The components, which are related to both the existing and candidate generating units are the fuel cost, the fixed operation and maintenance costs. The cost to the national economy of the energy not served (ENS) because of shortage of capacity or interruptions is, also, taken into consideration.

The WASP IV compares the total costs for the whole generation system for a number of candidate units. In the production simulation of WASP, a one-year period is divided into, at most, 12 sub-periods for each of which probabilistic simulation is applied. Equivalent load duration curves in the probabilistic simulation are approximated using Fourier series. The Fourier expansion makes it computationally simple to convolve and deconvolve generating units in the probabilistic simulation. The decision of the optimum expansion plan is made by the use of forward dynamic programming. The number of units for each candidate plant type that may be selected each year, in addition to other practical factors that may constrain the solution is specified. If the solution is limited by any such constraints, the input parameters can be adjusted and the model re-run. The dynamic programming optimization is repeated until the optimum solution is found.

The annual capacity reserve margin is determined as the level of additional standby power required being readily available during peak demand in order to cover, for example, the possibilities of a generator unit failure or a sudden surge in demand due to unusually high temperatures. In mathematical terms the capacity reserve margin is the measurement of the capacity to generate more power than the system generally requires at peak usage, or the amount of unused power available when the system is at peak usage. The annual capacity reserve margin, *CRM*, is defined as:

$$CRM = \frac{P_{in} - P_m}{P_m}, \qquad (1)$$

where P_{in} is the installed firm capacity (secure available capacity or dispatchable capacity) in MWe and P_m is the system peak load in MWe which can be either measured or projected. The installed firm capacity, P_{in}, can be determined by the addition of the installed capacity of all dispatchable (firm capacity) power generation units present in a power system. If an expansion plan contains system configurations for which the annual energy demand E_t, in kWh, is greater than the expected annual generation G_t, in kWh, of all units existing in the configuration for the corresponding year *t*, the total costs of the plan are penalized by the resulting cost of the ENS. This cost is a function of the amount of ENS, N_t, in kWh, which is calculated by:

$$N_t = E_t - G_t, \qquad (2)$$

Each possible sequence of power units added to the system (expansion plan) meeting the constraints is evaluated by means of a cost function (the objective function), which is composed of (a) capital investment costs, *I*, (b) salvage value of investment costs, *S*, (c) fuel costs, *F*, (d) non-fuel operation and maintenance costs, *M*, and (e) cost of ENS, Φ. Thus,

$$B_j = \sum_{t=1}^{T} \left[I_{jt} - S_{jt} + F_{jt} + M_{jt} + \Phi_{jt} \right], \qquad (3)$$

where, B_j is the objective function attached to the expansion plan *j*, *t* is the time in years (1, 2, …., *T*) and *T* is the length of the study period (total number of years) in US$. All costs are discounted to a reference date at a given discount rate. The optimum expansion plan is the minB_j among all *j*.

III. Data and Assumptions

In this capacity expansion analysis future sustainable generation technologies are integrated for future expansion within the existing power generation system of the Emirate of Sharjah. In particular two CCS technologies, namely post-combustion and pre-combustion CCS, integrated to the natural gas combined cycle technology [12] are investigated as well as two solar-based RES-E technologies, large PV parks [17] and parabolic trough CSP [18] systems. For the purposes of this work, the parabolic trough CSP technology is chosen mainly due to its technological maturity [22]. The study horizon covers a period of 30 years with a maximum annual capacity reserve margin of 20% and an assumed discount rate of 6%. For the simulations we employ WASP IV software package [23] with all costs updated to 2013 values.

In addition to the business as usual (BAU) scenario for the future expansion of the Emirate of Sharjah power generation system, which considers the natural gas turbine plants as the only candidate option, five more scenarios are examined in the analysis in order to assess the electricity unit cost of the future power generation system with the expected penetration of CCS integration and solar-based RES-E technologies. Therefore, all the scenarios examined in this work are listed below:

(a) Expansion with gas turbine technologies of 110MWe capacity using natural gas, which is considered as the BAU scenario,
(b) Expansion with natural gas combined cycle technologies of 250MWe capacity, integrated with a pre-combustion CCS systems,
(c) Expansion with natural gas combined cycle technologies of 250MWe capacity, integrated with a post-combustion CCS systems,
(d) Expansion with PV parks of 50MWp capacity,
(e) Expansion with parabolic trough CSP technologies of 50MWe capacity with no thermal storage,
(f)Expansion with parabolic trough CSP technologies of 50MWe capacity with 24/7 operation.

In order to examine the effect of natural gas price on the optimum generation planning, except form the base case natural gas price of 4US$/MMBtu, a sensitivity analysis has been, also, carried out with natural gas prices of 6US$/MMBtu, 8US$/MMBtu and 10US$/MMBtu.

For the purposes of this analysis a number of technical factors inherent in the processes CCS technology that contribute to overall plant efficiency penalization have been accounted for by the reduced efficiency used [20]. Also, the natural gas combined cycle plants with post-combustion CCS integration employ a monoethano-lamine based system. The CO_2 transport and geologic storage costs [6] are not examined in this study since these have not yet been determined in the case of the Emirate of Sharjah. Obviously the lack of concrete information that will help in the definition of these costs is of serious concern, because unless the exact storage and transportation cost is determined, decisions regarding the feasibility of CCS technologies cannot be fully justified [1].

In the case of the PV technology, with a capacity of 50MWp, a typical mono-Si solar PV module has been selected [3] with a capacity of 185W, efficiency 14.2% and area of 1.3m^2. As the solar potential varies with the orientation and the inclination of the solar PV panels [9] a south orientation at the yearly average optimum fixed angle of 24 degrees is assumed [13]. In the case of parabolic trough CSP technology, with a capacity of 50MW, we assume a typical solar to electricity efficiency of 15%. The effect of two-tank molten salt thermal storage integration is examined in this analysis in the case of scenario (f) that thermal storage of 24h/day (24/7 operation). This option is not currently available commercially [16], since the major obstacle to be overcome is the size, the operational issues and the cost of the necessary storage tanks required for thermal storage. Extensive research and development is currently underway using various storage mediums that can enable this technology to materialize in an economically viable way [5]. The integration of a thermal storage system has a direct effect on (a) capital cost (greater solar field is necessary), (b) land area (greater area to accommodate resulting solar field size is necessary) and (c) electricity production (power production is increased due to increased operating hours) [18].

IV. Discussion of the Results

As mentioned in section 2 the capacity reserve margin is a function of the installed firm capacity, P_{in}, which can be determined by the addition of the installed capacity of all dispatchable (firm capacity) power generation units present in a power system. The candidate options in this investigation of the gas turbine technology and the combined cycle technology integrated with CCS are both dispatchable technologies. On the contrary, depending on the type of RES-E technology dispatchability is marginal. However, CSP plants when integrated with thermal energy storage system can provide 100% firm capacity (secure available capacity). This is well justified and supported in the literature. CSP is unique among RES-E technologies in that is variable like solar and wind, but can easily be coupled with thermal energy storage system making it highly dispatchable [11]. In [4] it is stated that CSP integrated with thermal energy storage system is a very promising RES-E technology and has the potential to replace base load generation. Also, optimization models developed for the integration of RES-E in power systems indicated that a dispatchable CSP system utilises thermal energy storage system to provide firm (i.e., dispatchable) capacity [19]. CSP plants with thermal energy storage are dispatchable, thus the capacity value of the plant is equal to the capacity factor during the summer peak load period, which is essentially the nameplate capacity [21]. By careful sizing of CSP plant integrated with thermal energy storage system, it is feasible to build a power station of providing power throughout the day and night that is a 24/7 operation [16].

For interconnected systems energy regulatory bodies usually require to maintain a capacity reserve margin of 10%-20% as insurance against breakdowns in part of the system or sudden increases in energy demand. In the case of the Emirate of Sharjah a capacity reserve margin between the lower and upper limits of 10% and 20% is taken into consideration since interconnections exists with other Emirates within UAE. In the case of the dispatchable power generation technologies the capacity reserve margin is within the lower and upper limits justifying high reliability during the operation of the power system. When the candidate technologies for the expansion of the power system are either a CSP system with no thermal energy storage or a PV system the reliability is very low. The effect of low reliability on the economics of the power generation system, that is the cost of ENS, is examined below.

The expected annual electricity unit cost (excluding the cost of ENS) for the different natural gas prices are illustrated in Fig. 1 - Fig. 4. We observe that in all cases the least cost option is the BAU scenario followed by the combined cycle integrated with a pre-combustion CCS system scenario. Based on the optimum results third least cost option (excluding the cost of ENS) is the expansion of power generation system using PV systems followed by the combined cycle integrated with a post-combustion CCS system scenario and the CSP technology with 24/7 operation scenario. In order to examine the effect of dispatchability of each candidate technology the cost of ENS was also calculated within the optimisation procedure.

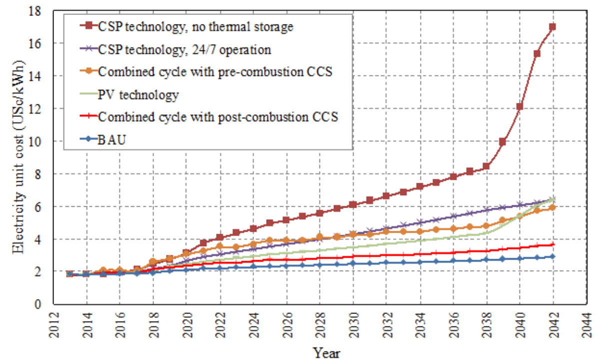

Fig. 1: Generation system annual electricity unit cost in real prices (base case scenario, natural gas price 4US$/MMBtu)

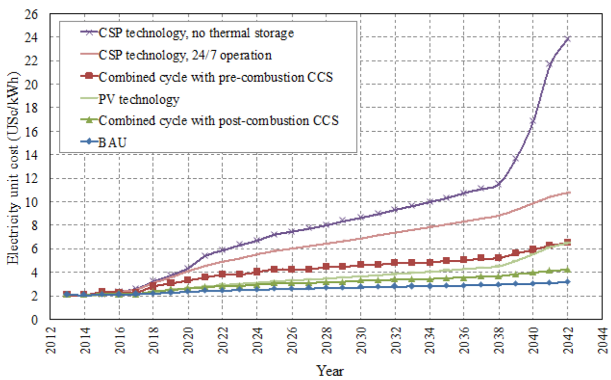

Fig. 2: Generation system annual electricity unit cost in real prices (sensitivity analysis for natural gas price of 6US$/MMBTU)

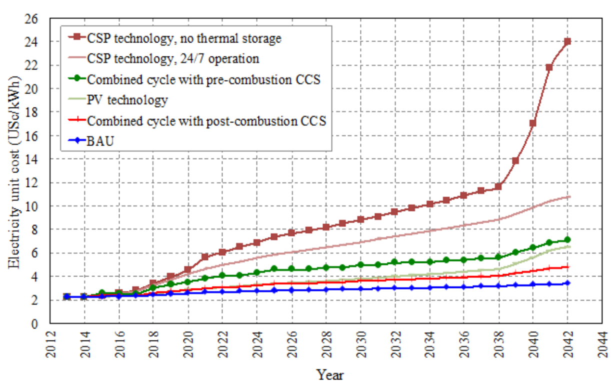

Fig. 3: Generation system annual electricity unit cost in real prices (sensitivity analysis for natural gas price of 8US$/MMBTU)

This is illustrated in Fig. 5 in the case of natural gas price of 4US$/MMBtu. However, the results are similar in the case of other variations of natural gas price since the cost of ENS is technology type dependent. We observe that in the case when the candidate technologies for the expansion of the power system is a CSP system with no thermal energy storage or in a PV system the cost of ENS increases considerably on a yearly basis as new capacity additions from those technologies are integrated within the power generation system.

Finally, a comparison of the overall results concerning the optimum total electricity unit cost (generation system electricity unit cost and cost of ENS) calculated for each scenario is presented in Table 1, in ranking order for all natural gas price variations investigated. We observe that by taking into account the cost of ENS on the total electricity unit cost of each configuration the ranking order is the same for all natural gas price variation.

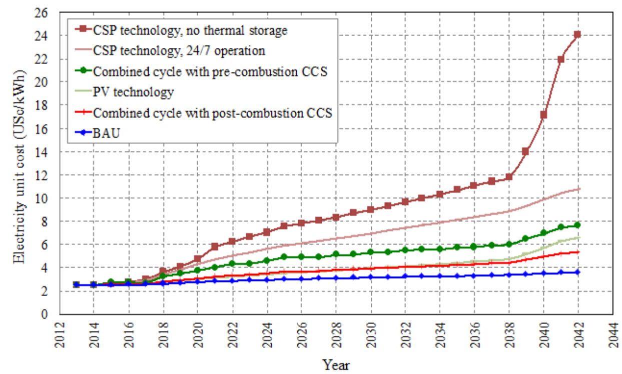

Fig. 4: Generation system annual electricity unit cost in real prices (sensitivity analysis for natural gas price of 10US$/MMBTU)

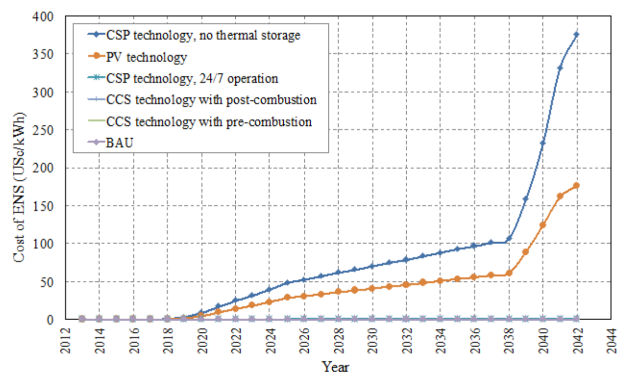

Fig. 5: Cost of ENS in real prices (base case scenario, natural gas price 4US$/MMBtu)

Table 1: Optimization results in real prices

Option no.	Candidate technology	Generation system electricity unit cost (USc/kWh)	Cost of ENS (USc/kWh)	Total electricity unit cost (Usc/kWh)
Natural gas price 4US$/MMBtu				
a	BAU	2.3546	0.0001	2.3547
c	Combined cycle with a post-combustion CCS	2.7360	0.0004	2.7364
b	Combined cycle with a pre-combustion CCS	3.8257	0.0001	3.8258
f	Parabolic trough CSP with 24/7 operation	3.9329	0.3554	4.2883
d	PV park	3.3753	41.4492	44.8245
e	Parabolic trough CSP with no thermal storage	6.0276	76.4829	82.5106
Natural gas price 6US$/MMBtu				
a	BAU	2.5796	0.0001	2.5797
c	Combined cycle with a post-combustion CCS	3.0646	0.0003	3.0649
b	Combined cycle with a pre-combustion CCS	4.1622	0.0004	4.1626
f	Parabolic trough CSP with 24/7 operation	6.1244	0.3960	6.5204
d	PV park	3.5314	41.4492	44.9806
e	Parabolic trough CSP with no thermal storage	8.3696	76.4829	84.8525
Natural gas price 8US$/MMBtu				
a	BAU	2.8047	0.0001	2.8048
c	Combined cycle with a post-combustion CCS	3.3932	0.0003	3.3935
b	Combined cycle with a pre-combustion CCS	4.4988	0.0004	4.4992
f	Parabolic trough CSP with 24/7 operation	6.2048	0.3960	6.6008
d	PV park	3.6874	41.4492	45.1366
e	Parabolic trough CSP with no thermal storage	8.5590	76.4829	85.0420
Natural gas price 10US$/MMBtu				
a	BAU	3.0294	0.0001	3.0295
c	Combined cycle with a post-combustion CCS	3.7214	0.0003	3.7217
b	Combined cycle with a pre-combustion CCS	4.8349	0.0004	4.8353
f	Parabolic trough CSP with 24/7 operation	6.2851	0.3960	6.6811
d	PV park	3.8433	41.4492	45.2925
e	Parabolic trough CSP with no thermal storage	8.7482	76.4829	85.2311

The most promising sustainable candidate technologies or a combination of these technologies are in ranking order the use of combined cycle integrated with a post-combustion CCS system, the use of combined cycle integrated with a pre-combustion CCS system and the use of parabolic trough CSP technology of with 24/7 operation. The rest of the candidate sustainable technologies reduce considerably the system reliability since their dispatchability is marginal leading to power interruptions and thus high cost of ENS.

V. Conclusions

In this work, a capacity expansion analysis was carried out in order to estimate the least cost power generation configuration using sustainable power generation technologies for UAE. Five alternative configurations of sustainable power generation systems, such as, the integration of carbon capture and storage (CCS) technologies and solar-based power generation systems were examined and compared with the business as usual (BAU) scenario for a range of natural gas price.

Based on the input data and assumptions made and taken into account the cost of energy not served, simulations indicated that the BAU scenario (i.e., expansion of the power system using conventional power generation technologies) is the least cost option. However, in the case UAE will move towards the use of sustainable power generation technologies, for the reduction of carbon dioxide emissions, the natural gas combined cycle technology integrated with CCS systems and the use of concentrated solar power systems with 24/7 operation are the most suitable alternative technologies.

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Dr. Andreas Poullikkas Dr. Andreas Poullikkas holds a Bachelor of Engineering (B.Eng.) degree in mechanical engineering, a Master of Phlosophy (M.Phil.) degree in nuclear safety and turbomachinery, a Doctor of Philosophy (Ph.D.) degree in numerical analysis and a Doctor of Technology (D.Tech.) higher doctorate degree in energy policy and energy systems

optimization from Loughborough University, U.K. He is a Chartered Scientist (CSci), Chartered Physicist (CPhys) and Member of The Institute of Physics (MInstP). His present employment is with the Cyprus University of Technology where he holds the post of Associate Professor of Power Systems and Chair of the Department of Electrical Engineering, Computer Engineering and Informatics. He is also, the Chairman of the Cyprus Energy Policy Council (appointment by the President of Cyprus) and a Member of the Board of Directors of the Natural Gas Public Company (DEFA), Cyprus (appointment by the Cyprus Government). In his professional career he has worked for the industry and for academic institutions such as a Visiting Faculty at the Harvard School of Public Health, Harvard University, USA and an Assistant Manager of the Electricity Authority of Cyprus (the founder and director of the Research and Development Department). He has over 25 years experience on research and development projects related to the numerical solution of partial differential equations, the mathematical analysis of fluid flows, the hydraulic design of turbomachines, the nuclear power safety, the analysis of power systems and power economics.

He is the Associate Editor of the Journal of Power Technologies and the author of various peer-reviewed publications in scientific journals, book chapters, conference proceedings and the author of four books. He is, also, a referee for various international journals, serves as a reviewer for the evaluation of research proposals related to the field of energy and a coordinator of various funded research projects. He is a member of various national and European committees related to energy policy issues. He is the developer of various algorithms and software for the technical, economic and environmental analysis of power generation technologies, desalination technologies and renewable energy systems.

The use of trend analysis for evaluating performance of horizontally integrated hospitals

Š. Papadaki, P. Staňková and Klímek P.

Abstract— This article is concerned with the use of trend analysis for evaluating performance of integrated hospitals. Taking into account that hospitals currently spend more than 50% of their budget on health care, we need to analyze their performance and how effectively they use their budgets. One solution to consider is to integrate hospitals into one unit, which should reduce expenses, increase the quality of health care and increase hospital effectiveness. This article evaluates 4 chosen indicators before and after integrating individual hospitals. Altogether, two holdings are analyzed, which were founded in 2009 and 2010.

Keywords— Efficiency, holding, hospital, integration, trend analysis

I. INTRODUCTION

Hospitals are one of the main organizations in the health service system. It has special importance in health economics, and imposes higher costs on the health system than other health system components [1, 2]. Hospitals are the main consumer of resources in the health sector. Improving their efficiency is the main way to decrease hospital costs [3].

Š.Papadaki is a assistant professor of the Department of Enterprise Economics of the Faculty of Management and Economics, Tomas Bata University in Zlín. In her research she is engaged in an issue of health care and costs control in health organisations. She was co-solver of the GACR project Utilization of Modern Costing Methods for Cost Optimization Purposes in Health Service registered under project number NT 12235-3/2011 and researcher of Internal Grant Agency of FaME TBU No. IGA/FaME/2012004 – „Project of Analysing of Economic-Managerial Methods and Tools Utilised in the Hospitals in the Czech Republic". Affiliation: Tomas Bata University in Zlin, nám. T.G.Masaryka 5555, 76001 Czech Republic. (e-mail:papadaki@fame.utb.cz)

P.Staňková is a assoc. professor and head of the Department of Management and Marketing of Faculty of the Management and Economics, Tomas Bata University in Zlín. She was a coordinator of Internal Grant Agency of FaME TBU No. IGA/FAME/2012/006: Research and application of marketing management tools in the healthcare management on account of healthcare reforms and collaborator of the OPVK project Partnership for competitiveness. Affiliation: Tomas Bata University in Zlin, nám. T.G.Masaryka 5555, 76001 Czech Republic. (e-mail:stankova@fame.utb.cz)

P. Klímek is a assoc. professor of the Department of Statistics and Quantitative Methods of the Faculty of Management and Economics, Tomas Bata University in Zlín. He is a guarantor of Econometrics and Applies Statistic. He took part in TAČR TD 010129 Power potential of workers 50+ and specific forms of human resource management of enterprise. He is an author or co-author of many publications from the statistics analysis field in the form of monograph, articles in journals, conference contributions and faculty textbooks. Affiliation: Tomas Bata University in Zlin, nám. T.G.Masaryka 5555, 76001 Czech Republic. (e-mail:klimek@fame.utb.cz)

Hospital efficiency has attracted much research in recent decades e.g. Barbetta, Prior, Parkin, Rosko, Steinmann, Staat [6-11]. For instance, Henke et al. assess the cost efficiency of German hospitals by comparing the average case cost of hospitals in different cities [12]. Swart et al. derive a ranking for 50 hospitals according to their length of stay [13]. Parkin and Hollingsworth examine the efficiency of a sample of acute care hospitals in Scotland through analyzing production relationships. [14] Linna & Häkkinen [38] analyzed the efficiency of Finnish hospitals, and Magnussen [39] analyzed Norwegian hospitals.

Greene [40] estimated the efficiency of national health care systems in 191 countries from an international perspective. The first technique to measure efficiency was developed by Farrell [41] when researching methods of evaluating efficiency of for-profit corporations in the U.S.A.

An analysis of Czech hospital efficiency has so far only been done by Dlouhý et al. [42]

II. THEORETICAL PART

We can observe the trend of integration in the hospital industry and also in services in that industry. In the USA, the number of hospital integrations has dramatically increased in the past 20 years [28, 29]. Integration in the USA typically refers to either horizontal integration of hospitals and physicians, or vertical integration of hospitals and physicians [30]. A similar trend has occurred in the Czech Republic during the past decades. When focusing on horizontal integration, two primary benefits can be seen: (1) increased market power and (2) greater efficiency [28, 31]

A number of foreign authors describe the benefits and risks of integration, e.g. Bazzoli, Baker, Clement, Lake, and Ackerman. [30-34]. The above authors state the following positive points for integration:

- Access to better resources due to collective purchasing
- Greater negotiating power
- Cost reduction and improvement of medical technology through greater information exchange
- Elimination of duplicating various services
- Ability to provide complex services
- Ability to share risks among multiple organizations
- Improved relationships with customers
- Improved quality of health care

On the other hand, several authors such as Halverson [35] or

Zuckerman [36] state the disadvantages of integration. Among other points they list the following:

- New costs are incurred from inter-organizational cooperation
- There is loss of autonomy and control

Every enterprise, even hospitals, needs to see how effective they are. According to Wagner, performance can be characterized as a concept which describes the manner in which a certain subject performs a duty, on the basis of comparing the examined and referenced phenomenon from the viewpoint of a pre-determined criterial scale. We operate with a pre-determined aim, which we try to approach. Wagner distinguishes two dimensions of performance:

a) Do the correct things – concerns performance in terms of choosing which duties to undertake. We see this as effectiveness.

b) Do things correctly – concerns performance in terms of efficient methods carrying out chosen duties. We see this as efficiency. [17]

According to Shaw, performance must be defined in relation to explicit goals that reflect the values of various stakeholders such as patients, professionals, insurers and regulators. This means that measurement systems focus on health outcomes valued by customers. Hospital performance is defined according to the achievement of specified targets, either clinical or administrative. Ultimately, the goal of health care is better health, but there are many intermediate targets concerning processes. Targets may relate to traditional hospital functions – such as diagnosis, treatment, health care and rehabilitation – as well as teaching and research [18, 19].

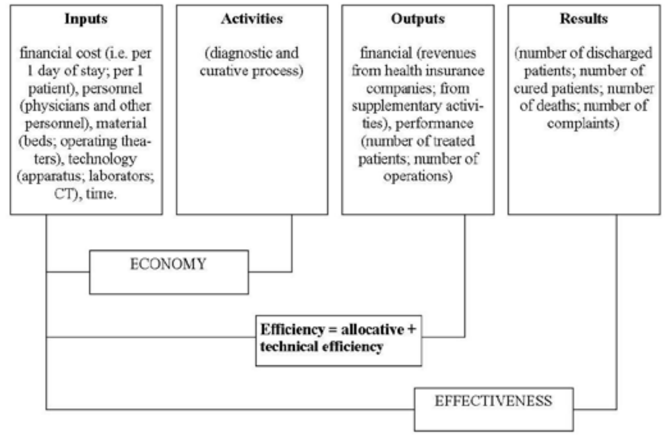
Otrusinova and Pastuzskova present 3 principles of public institution performance =”3Es” – Economy, Efficiency and Effectiveness. They express the basic principles of performance by using the following mathematical equations:

- Effectiveness = objectives
- Economy = objectives + minimum input
- Efficiency = objectives + minimum input + maximum output [20].

Efficiency is a term widely used in economics, commonly referring to the best use of resources in production. Hollingsworth and Peacock describe two types of efficiency in health and health care: technical efficiency and allocative efficiency [21]. Technical efficiency means reducing the employment of excess inputs. Allocative efficiency means selecting inputs that incur minimum costs [22].

Vaňková and Vrabková focus on measuring the efficiency of hospitals, see Figure 1. This model works with financial or non-financial parameters or with a combination of the two [25, 26, and 27]. People such as Mandl, Diery, and Ilzkovitz [24] deal with issues of hospital bed care efficiency measurement and evaluation.

Figure 1: The process-oriented Hospital Bed Care efficiency measuring Model [23]



Several mathematical techniques are usually considered to assess hospital efficiency and productivity – either parametric or non-parametric [4]. Non-parametric methods such as data envelopment analysis are the most popular [5].

Historically, the most common approach to measuring efficiency is collecting and analyzing descriptive statistics. This involves analyzing input and output such as full-time equivalents, beds, discharges, and operating expenses and then comparing these statistics of previous years to those of the current year or more-recent year. If a hospital's total discharges have increased over time at a greater rate than the rate of staff size increase and spending, then this could mean the hospital's efficiency might have been improved. [16]

In general, descriptive statistics are limited to measuring efficiency over a period of time. The fact that descriptive statistics alone do not account for many other factors that may confound their use as an efficiency indicator can be quite troubling. The most common confounder is variation of mixtures, which makes it difficult to compare the efficiency of one organization with that of another organization that uses only descriptive statistics. [16]

Much of the current research investigating single input or output variables uses regression analysis, or stochastic frontier analysis [15].

III. Analysis

There were 166 hospitals in the Czech Republic in 2013. This number includes holdings and other types of vertically integrated hospitals. Table 1 lists all these vertically integrated hospitals. The first holding – the health industry holding of the Královéhradecký region was founded in 2004 and contains four hospitals. Until now, a total of five holdings or other integrations have been created.

Table 1: Networked hospitals in the Czech Republic (own work)

Health holding of the Královéhradecký region founded in 2004	- Dvůr Králové nad Labem City Hospital - Jičín Regional Hospital - Náchod Regional Hospital - Rychnov nad Kněžnou Regional Hospital (since 2013 it has been part of the Náchod Regional Hospital) - Trutnov Regional Hospital
Hospitals of the Ústecký region founded September 1, 2007	- Děčín Hospital - Chomutov Hospital - Most Hospital - Teplice Hospital - Masaryk Hospital in Ústí nad Labem
Hospital holding of the Středočeský region founded September 18, 2009	- Rudolf and Stefanie Benešov Hospital - Kladno Regional Hospital - Kolín Regional Hospital - Mladá Boleslav Regional Hospital - Příbram Regional Hospital
Health holding of the Plzeň region Founded June 30, 2010	- Domažlice Hospital - Klatovy Hospital - Rokycanská Hospital - Stod Hospital - Horažďovice follow-up care hospitals - Svatá Anna hospitals of follow-up care
Hospitals of the Pardubický region founded January 1, 2015	- Pardubice Hospital - Chrudim Hospital - Svitavy Hospital - Litomyšl Hospital - Ústí nad Orlicí Hospital

Only two holdings were selected for further research – the Středočeský region hospital holding and the Plzeň region health holding. There is economic and non-economic information before and after integration only for these two hospitals. The remaining integrated health care holdings were excluded from research for the following reasons:

- The health holding of Královéhradecký region was founded more than 10 years ago and it is not possible to gain annual reports before and after integration

- The hospitals of the Ústecký region were founded by joining individual hospitals into one single unit which is organized into a single budget for all the hospitals. Is it not possible to analyze changes in each hospital before and after the integration

- The hospitals of the Pardubický region were founded this year and there can be no evaluation after integration.

For analysis, annual reports were used from each hospital from 2004 to 2013. Part of the annual reports included economic and also non-economic results which often needed to be included in order to complete various values in each annual report.

The research was conducted at the Faculty of Management and Economics, Tomas Bata University in Zlín, and the aim was to find answers to the following research question:

Does the networking of regional hospitals lead to improving hospital performance?

We will analyze selected indicators of selected hospitals.

The following indicators were chosen – two of which are financial and the other two are non-financial. These can be utilized to evaluate performance. These indicators are:

a) Economic indicators

- Economic outcome
- Current ratio

b) Non-economic indicators

- Average duration of stay
- bed occupancy

Indicators were analyzed from 2004 to 2013. A linear trend was used for evaluation by using a coefficient correlation and a t-test for statistical significance.

A. *The health holding of the Plzeň region*

1) *Economic outcome*

Figure 2 shows the average economic results of all hospitals in the holding of the Plzeň region. At the significance level of 0.10, the statistically significant linear trend increases in time. For the significance level of 0.05, this linear trend is not significant. This model can be used to describe and predict how the time series behaves for the significance level of 0.062 or less.

It is also important to mention that average economic results are in financial loss. It is though positive that this trend has a tendency to increase.

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Figure 2: Linear Trend Estimate for Economic Outcomes in the Plzeň Region (own work)

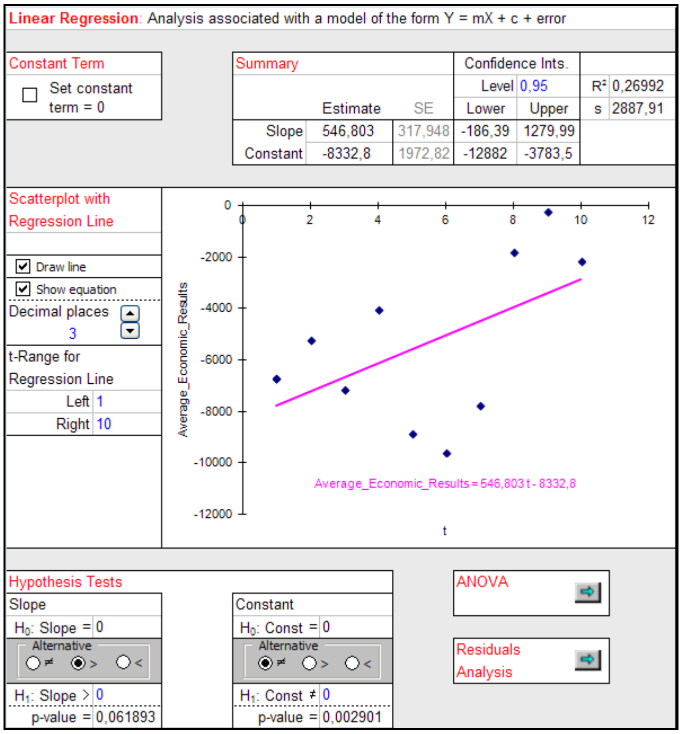
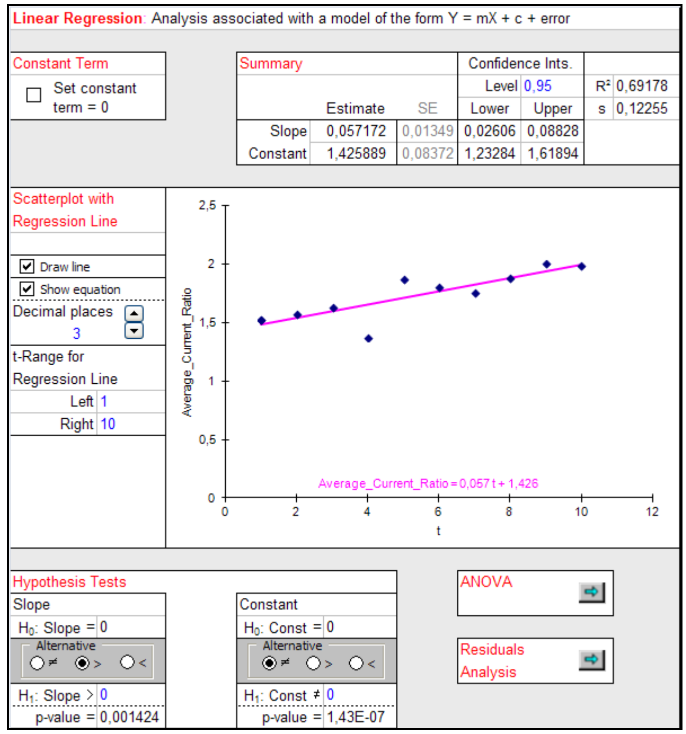


Figure 3: Linear Trend Estimate for Current Ratio in the Plzeň Region (own work)



2) *Current Ratio*

For all hospitals in the Plzeň holding, it was proven that the average current ratio at the significance level of 0.10 and also at the significance level of 0.05, increased in time for the statistically significant linear trend – see Figure 3. This model can be used to describe and predict the behavior of the time series for significance levels of 0.001 or less.

We recommend the range for general liquidity is between 1.8 and 2.5. We can see that the average for hospitals fluctuates within this range. Situations whereby values fall below the value of 1.0 would be problematic. This would mean that hospitals weren't able to cover the costs of their short-term obligations from circular activities, but rather from their long-term activities. Here for example, this means from the sale of possessions. This situation though is not indicated in the hospitals of the Plzeň region.

3) *Average Duration of Stay*

Concerning the average number of days' duration of stay for hospitals in Plzeň, it was estimated that the significance level of 0.10 had a statistically significant increasing linear trend in time, but the 0.05 level of significance was not proven as statistically significant – see Figure 4. This model can be used for describing and predicting the behavior over time for significance levels of 0.062 or less.

This trend is however, the opposite of the entire trend in the Czech Republic. In 2012 the average treatment time was 9 days and this has a long-term decreasing trend. On higher values, many hospitals have LDN and this has great influence in increasing the average values.

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Figure 4: Linear Trend Estimate for Average Duration of Stay in the Plzeň Region (own work)

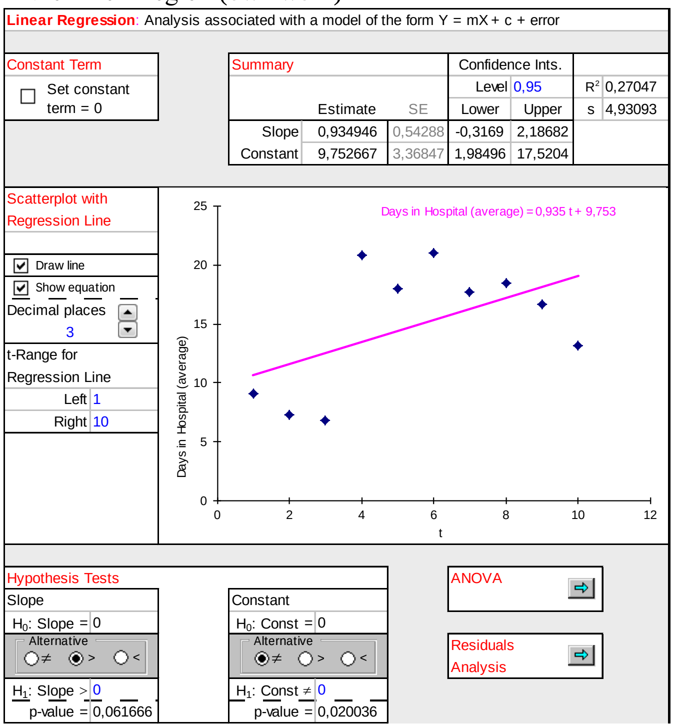
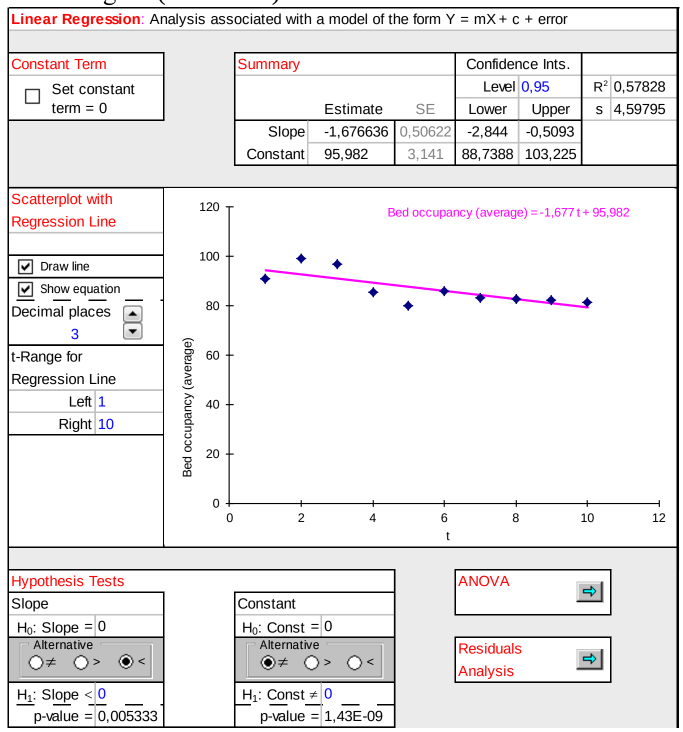


Figure 5: Linear Trend Estimate for Bed Occupancy in the Plzeň Region (own work)



4) Bed Occupancy

Concerning bed occupancy for hospitals in the Plzeň region, there was a statistically significant decreasing linear trend in time for the significance level of 0.10 as well as for the significance level of 0.05 – see Figure 5. This model can be used to describe and predict the behavior over time for significance levels of 0.005 or less.

B. The hospital holding in the Středočeský region

1) Economic outcome

As shown in Figure 6, the average economic result for all hospitals in the holding of the Středočeský region cannot be shown in a linear trend in time, neither for a significance level of 0.05 nor for a significance level of 0.10. This model cannot be used to describe and predict behavior over time, which is probably caused by the outlying observation in the fourth year (i.e. 2007).

The average economic result for the entire holding fluctuates in the negative and the whole trend was not proven as increasing. Here, the effect of integration on increasing economic results was not proven.

Figure 6: Linear Trend Estimate for Economic Outcome in the Středočeský region (own work)

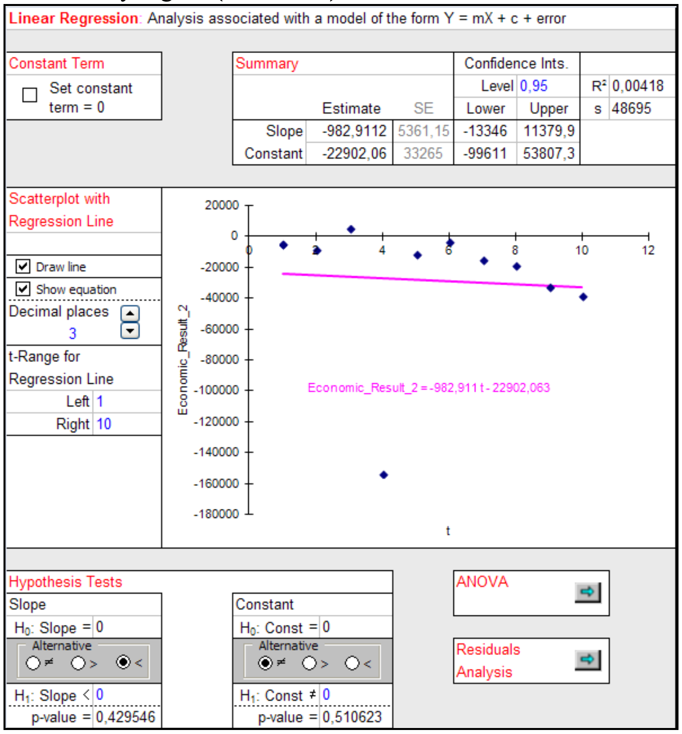
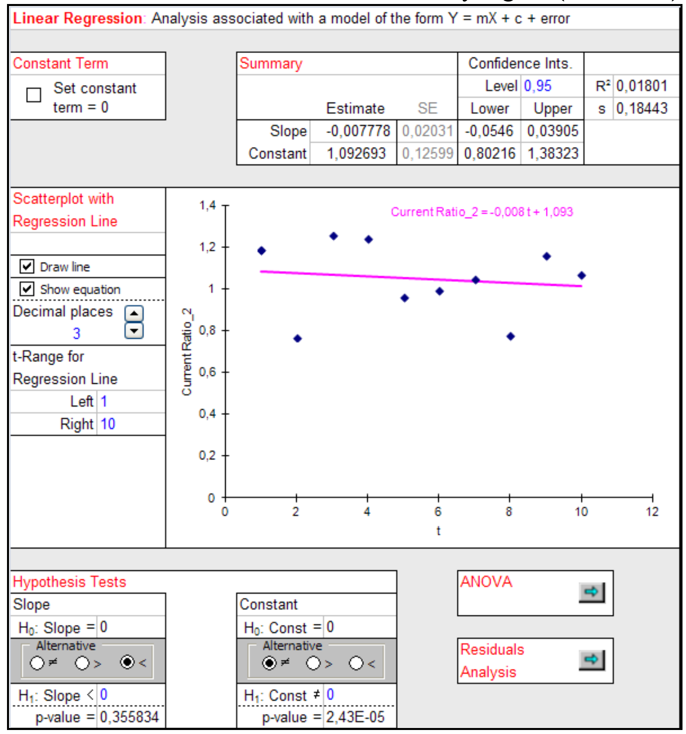


Figure 7: Linear Trend Estimate for Current Ratio in the Středočeský region (own work)



2) Current Ratio

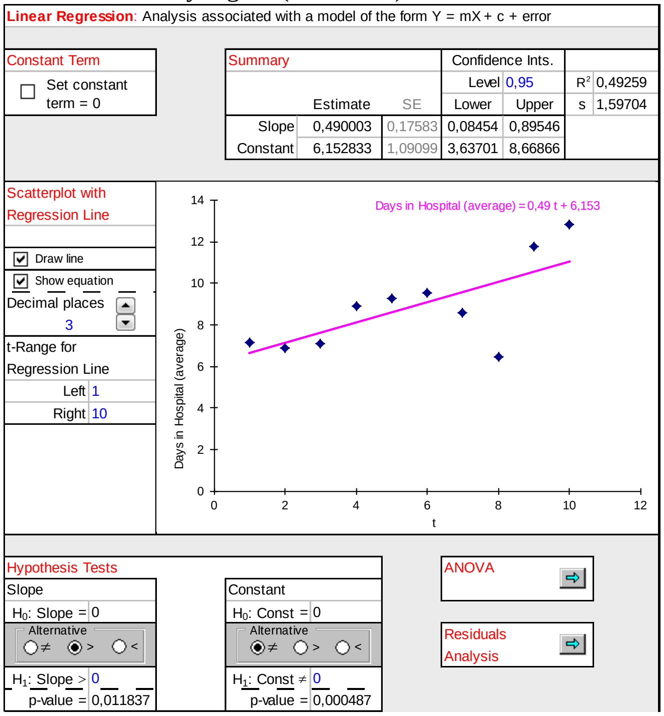
Concerning the average current ratio for hospitals in the holding of the Středočeský region, a statistically significant linear trend in time was not proven, not even for a significance level of 0.10 – see Figure 7. This model can be used for describing and predicting behavior over time. It is mainly caused by two distant amounts in observation numbers 2 and 8 (i.e. 2005 and 2011).

Concerning particular values, the average values do not fluctuate in the recommended ranges. The values are below the recommended value of 1.8, which is an unfavorable situation for hospitals and they are not capable of recouping their short-term commitments from their circular activities.

3) Average Duration of Stay

Regarding the average duration of stay for hospitals in the Středočeský holding, there is an estimated statistically significant increasing linear trend in time for the significance level of 0.10, and significance level of 0.05 – see Figure 8. This model can be used for describing and predicting behavior over time for the 0.012 significance level and lower.

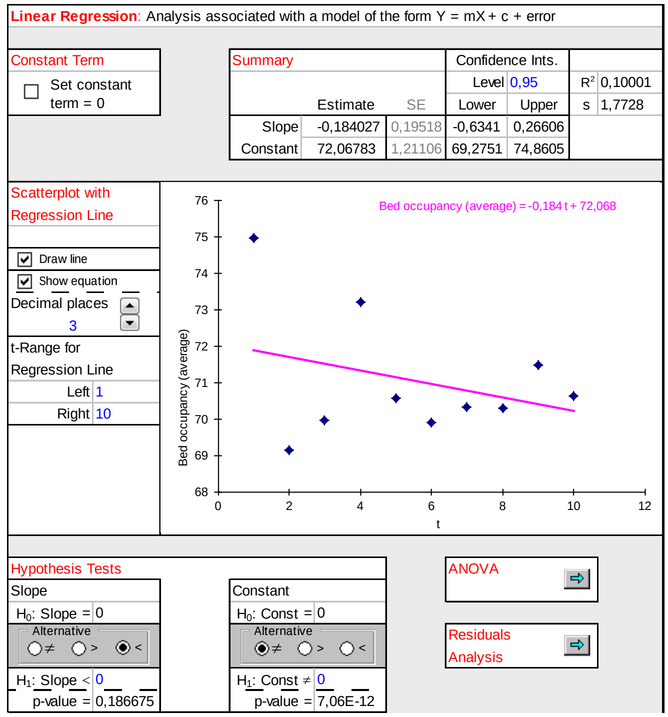
Figure 8: Linear Trend Estimate for Average Duration of Stay in the Středočeský region (own work)



4) Bed Occupancy

In the case of bed occupancy for all hospitals in the Středočeský region, there was not statistically significant decreasing linear trend in time neither for significance level of 0.05, nor for significance level of 0.05, see Figure 9. This model cannot be used to describe and predict the behavior of the time series. It is mainly caused by two outliers in observation number 1 and 4 (i.e. years 2004 and 2007).

Figure 9 Linear Trend Estimate for Bed Occupancy (Středočeský region) (own work)



IV. Conclusion

Using trend analysis, the research undertaken at the Faculty of Management and Economics at the Tomáš Baťa University in Zlín, based on samples from the health holding of Plzeň region and the hospital holding of Středočeský region has not clearly confirmed the premise that integrating holdings of Czech hospitals leads to greater efficiency – see Table 2.

In financial indicators, positive development was confirmed in the health holding of the Plzeň region, but this was to the contrary at the hospital holding in the Středočeský kraj – this positive trend was not evident. At first sight, the above-mentioned holding had better economic results and also better general liquidity, but the Středočeský kraj had opposite results.

The non-financial indicators evaluated the number of occupied beds and the average treatment period. These two indicators are closely associated. It is not possible to assess only one or the other indicator. The principle applies here that the shorter the hospital stay, the higher rate of turnover should be on each hospital bed. Both of these factors can be seen in analyzing hospitals. While in the Plzeň region holding we see some growth in increasing average bed stay length, on average there is no evident increase here. In the Středočeský region holding we see an increase in hospital stay length, but in bed occupancy there is no increase and might indeed be a decrease. The results of these evaluations is seen in table 2.

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Table 2 – Summary of research results (own work)

Evaluated Variable	Correlation coefficient	Slope	p-value	Significance (for $\alpha \leq 0{,}05$)	Significance (for $\alpha \leq 0{,}10$)
A. The health holding of Plzeň region					
Average Economic Outcome	0,519	546,803	0,062	NO	YES
Average Current Ratio	0,832	0,057	0,001	YES	YES
Average Duration of Stay	0,520	0,935	0,063	NO	YES
Average Bed Occupancy	−0,760	−1,677	0,005	YES	YES
A. The hospital holding of Středočeský region					
Average Economic Results	−0,065	−982,911	0,423	NO	NO
Average Current Ratio	−0,134	−0,008	0,356	NO	NO
Average Duration of Stay	0,702	0,490	0,012	YES	YES
Average Bed Occupancy	−0,316	−0,184	0,187	NO	NO

We can compare these results with foreign authors like Walston, Kimberly and Burns (1996). They unequivocally present benefits such as: lowering costs and eliminating unneeded services, economics of scale, increased market and negotiating power, profit and market share gains, better recruitment and longer retention of staff and also environmental acceptance. As was written above, these financial and non-financial benefits cannot be unequivocally confirmed. However, it is also essential to consider the limits of this research paper. The research was based on only two specific samples existing in the Czech Republic. Other holdings have either a very short or a very long period of being integrated and therefore it is very difficult to find specific comparable information. On the other hand, it is also essential to consider that integration is a long-term process. This process is continuously developing and searches new opportunities for improvement. Another aspect of development is also the politics of the health sector in each given nation. It is obvious that the Czech health sector has undergone and is still undergoing many changes which are reflected in individual indicators. Reforms in the Czech health sector are in constant flux and it is not easy to accommodate these changes. Despite these factors, we believe that long-term results will show that integrating hospitals is beneficial and this will install positive trends in further health care development.

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Flood damages in Slovakia

M. Zeleňáková and Z. Vranayová

***Abstract*—**Flood damages that arose on rivers, streams and hydraulic structures on the territory of Slovakia are huge. The highest flood risks are in Latorica, Bodrog and Hornad river catchments. Under the influence of long-lasting and intensive precipitations numerous flood arise. The water levels in many profiles on streams reached its historical maximums in the last years. Regular occurrence of floods in Slovakia is given primarily by total land water regime, where dominates very low absorptive power of heavy clay soils of flysch zone and also adverse condition of forests in eastern Slovakia.

***Keywords*—**Floods, damage, consequences, eastern Slovakia.

I. Introduction

Most countries in the world experience floods and flooding, even if such events are rare in some arid climates. As such they bring the risk of loss of life. Unlike other catastrophic natural events such as earthquakes, landslides, volcanic eruptions, avalanches, floods are much more widely distributed, and therefore there is a huge experience around the world of learning how to live with floods.

Flood events are caused and/or exacerbated by intense of long-lasting rainfall, snowmelt, and failure of a dam or embankment system, earthquakes, landslides, ice jams, high tides, storm surges and by human activities, including the operation of flood control systems.

Whereas the chief forcing factor generating a flood is the weather over the catchment, the weather itself is subject to long-term change due to the evolution and long-term variability of the climate [1], [2]. There are strong indications that the climate is changing [3], [4]. This leads to long-term modifications to precipitation over a catchment in terms of type pattern and frequency, and to the temperature and therefore the potential evapotranspiration. In addition, land use changes brought by human activity partly in response to climate changes can also be very significant [5], [6].

Floods have consequences for a wide range of structural, economic, social and environmental factors [7], [8]. We may be interested in the physics of flood generation and propagation, but the consequences of floods are what provide the primary incentive to study such phenomena. The intermittent, infrequent occurrence of major floods means that they are perceived as threats to society, and therefore have associated with them a number of risks. A comprehensive flood risk assessment is, however, extremely difficult.

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M. Zeleňáková and Z. Vranayova are with the Technical University of Košice, Faculty of Civil Engineering, Vysokoškolská 4, 042 00 Košice, Slovakia (corresponding author to provide phone: +421-55-602 4270; e-mail: martina.zelenakova@tuke.sk).

Between 2002 and 2013, for the 24 floods recorded the total direct costs were €790 million (damages available for all 24 floods). The average cost per flood was €33 million (based on those floods that are sufficient to exceed the threshold for inclusion in the EM-DAT database). Between 2002 and 2013, €63.8 million was invested in flood risk management measures, equivalent to €5.3 million per year on average. €3,800 million was from EU funds (but not all of this total may have been used for flood risk management).

In 2011 in Slovakia significant flood risk areas have been identified in 559 areas near water courses, with total length of 1,286.5 km. Out of the 559 geographic areas, 378 geographic areas have potential of a significant flood risk and in 181 geographic areas, the flood risk is likely to occur [9].

Slovakia, mainly its eastern part, is very vulnerable to floods. Floods cause huge damages – loss of life, human and animal suffering and material damage to property and environment [5], [10].

The paper analyzes the flood damages in Slovakia and in its regions.

II. Material and Methods

Water bodies in Slovakia are managed by Slovak Water Management Enterprise, s.e. (SWME, s.e.) – Figure 1.

Fig. 1. River basin in the eastern Slovakia

End of the last century brought to the region mainly in the eastern Slovakia a series of unpleasant surprises in the form of frequent occurrence of extreme flood events. They have not only resulted in extensive physical damage to property of citizens, as well as state property, but it also required a special loss of human life.

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The characterization of flood should interpret the major flood risks and the environmental significance of the findings. Graphs are one of the best analytical tools for describing flood risk analysis and relationships between investigated attributes, impacts etc.. Summary tables are an effective approach to display the most meaningful information in one condensed exhibit.

Data for analysis of consequences of floods in Slovakia are obtained from floods reports that are published at http://www.minzp.sk/sekcie/temy-oblasti/voda/ochrana-pred-povodnami/sprava-priebehu-nasledkoch-povodni-uzemi-sr-roku-2009-01-08-2010.html [11]. The reports were developed by Slovak Hydrometeorological Institute and Slovak Water Management Company and are published at web page of Ministry of Environment of the Slovak Republic..

III. Results and discussion

The present analysis include flood damages evaluation for the period from 1996 – 2013. The results present following graphs at Figures 2–5.

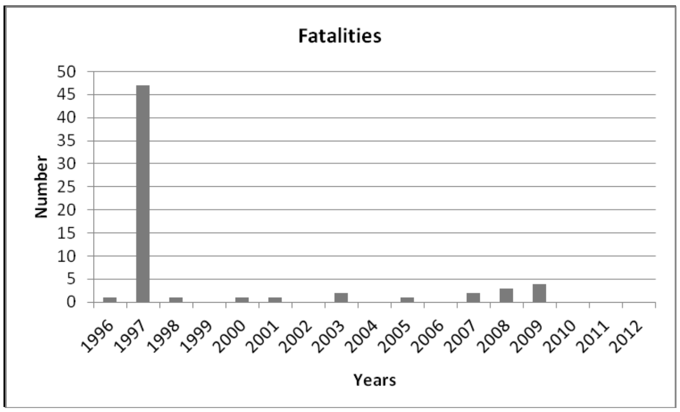

Fig. 2. Number of fatalities due to floods in Slovakia

The most fatalities were during the flood in 1997 – 46 people died during big flood in Jarovnice village.

In the following Figures the total damages at the property of inhabitants, municipalities, self-governing regions, state property and private companies were assessed.

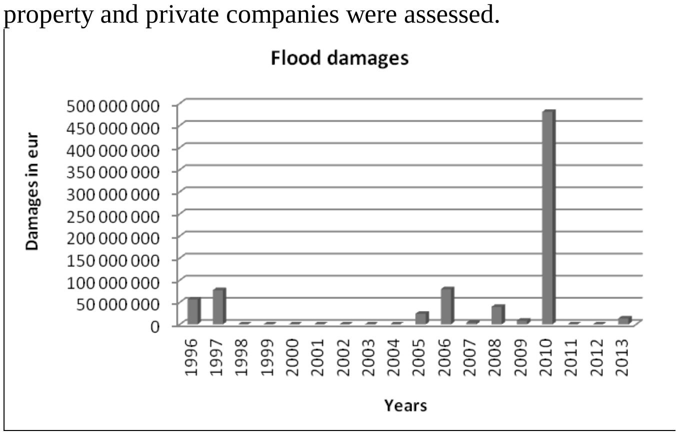

Fig. 3. Flood damages in eur

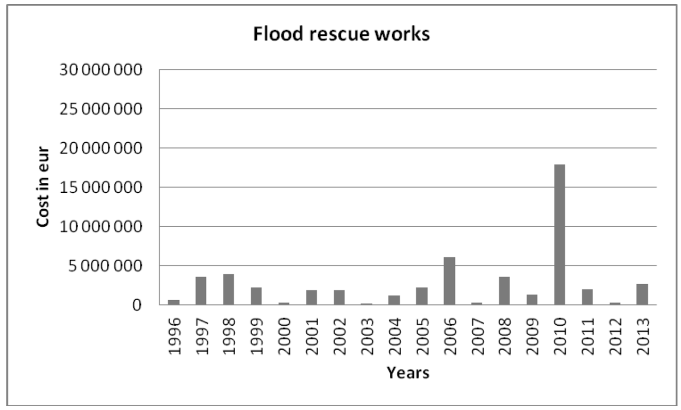

Fig. 4. Cost of flood rescue works in eur

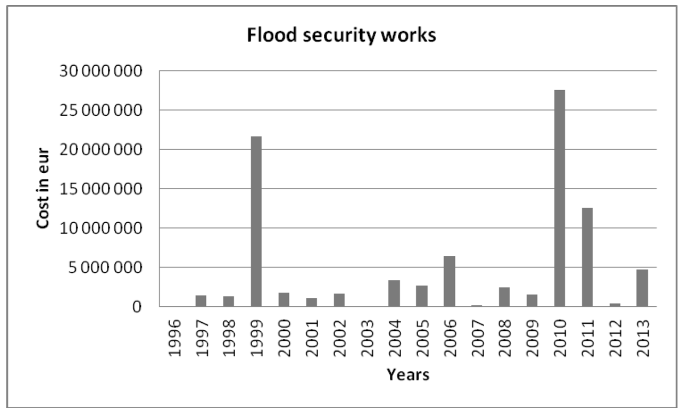

Fig. 5. Cost of flood security works in eur

The highest damages were during big floods in May and June 2010, especially in the eastern part of the country [5].

According the Slovak legislative – the Law on Flood protection 7/2010 Coll. Are flood rescue and security works defined as follows [12].

Flood rescue works are:

a) the flood warning service;

b) protection and rescue assets, including the possible early harvest at risk of flooding;

c) removal of hazardous substances from the likely impacts flooding areas;

d) temporary traffic access to the area which was hit by the flood, including the construction of temporal bridges or footbridges;

e) protection of water resources and drinking water systems, electricity, gas and telecommunications against damage;

f) evacuation;

g) disinfection of wells, cesspools, residential areas and transportation and disposal of animal carcasses and other wastes;

h) ensuring public order in the territory affected floods;

i) removing debris from houses and other buildings, public spaces and the communications;

j) ensuring damaged buildings to collapse or rehabilitation;

k) other work to save lives, health, property, cultural heritage and the environment made at the behest of the village, flood protection authority during 3rd degree of flood.

Flood security activities are:

a) carrying out patrol services;

b) the elimination of obstacles to the smooth run-off water;

c) the protection of the watercourse bed from damage water flow, water or objects drift by water;

d) removing ice floes, eroding and ice, ice breaking down roadblocks and ice constipation;

e) protection against heavy seas dams, seepage, effect erosion, seeps and protection against overflow crown dams and building of temporary access roads for this purpose;

f) special handling for water works;

g) closing levees, dams or flood lines;

h) discharging flood waters from the flooded area and the flooded buildings, structures and facilities;

i) removal or drainage of internal waters;

j) building secondary protective lines;

a) provisionally entered tubs of water flows;

l) the establishment of a provisional reimbursement is on the water works and the objects that are placed on the dams;

m) measures against backflow of water at the mouth sewage into the watercourse and culvert under roads and railways;

n) measures to prevent pollution of the watercourse hazardous substances in flooded areas;

o) activities of flood control and technical staffs

p) activities flood forecasting services;

q) special measurements to assess security stability and water works;

r) labeling and checking the level of the rivers, levees and flood lines during the flooding, including records of the time of measurement;

s) measurement of water flow in rivers and water works.

t) ground measurements, aircraft measurements and surveys concerning monitoring the development and acquisition of floods information for decisions on implementing measures including evacuation of the population, controlled flooding of the protected area and artificial levees or floodlines;

u) the creation of artificial hernias;

v) other work done at the behest of body protection floods and other work to prevent flood damage.

Figures 6–8 present the division of flood damage costs across the regions of Slovakia.

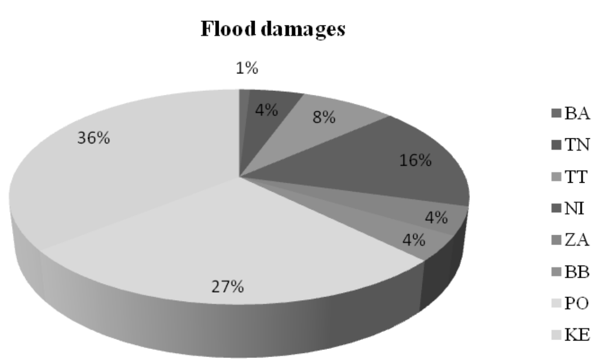

Fig. 10. Costs of flood damages

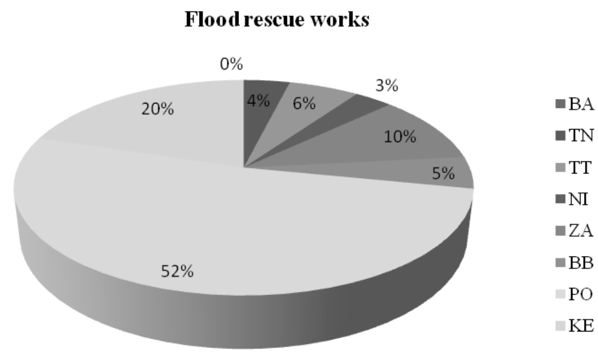

Fig. 11. Costs of flood rescue works

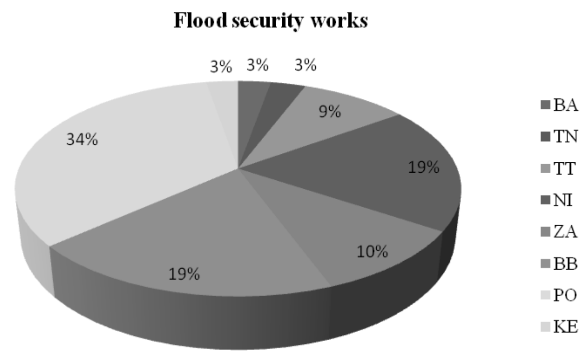

Fig. 12. Costs of flood security works

Bright colors present costs of flood damage and costs of rescue and security works in eastern Slovakia – Košice and Prešov region. Although this territory includes 1/3 of the whole territory of Slovakia the costs are more than one half of the total flood costs.

IV. Conclusion

Those floods implicated the loss of human lives, evacuation of inhabitants and economic losses in milliards eur. Flood damages that arose on watercourses and hydraulic structures on the territory of the Slovak Republic are huge. It is obvious that most affected is the eastern Slovakia, where is the most complex situation in Topľa, Ondava, Hornád, Torysa, Poprad and Laborec river basins in the recent years. Under the influence of long-lasting and intensive precipitations numerous flood waves, which are not fully controllable by manipulations on hydraulic structures, arise. The water levels in many profiles on watercourses reached historical maximums. The paper deals mostly with flood situations analyses that have occurred in eastern Slovakia.

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Martina Zeleňáková is associated professor at Institute of Environmental Engineering at Civil Engineering Faculty, Technical University of Košice. She is oriented on the field of water management and environmental risks in her scientific-research work. She publishes results of her work in journals and scientific proceedings from Slovak and abroad conferences.

Zuzana Vranayova is professor, head of Institute of Architectural Engineering at Civil Engineering Faculty, Technical University of Košice. She devoted her work in building facilities

Contributing to the aggregated expression of environmental damage by air pollution

Bohuslav Sekerka, Ilona Obršálová, Petra Lešáková

***Abstract* -** This article describes one of the possible approaches to the calculation of the pollution and its summary indicator. But, the suggested total indicator of pollution needs a correction according to the bias. This correction is described in this paper on chosen example.

The aim is to separate the total pollution into aggregates indicator of material and aggregates indicator of indicator of pollution per unit of quantity of emissions.

An indicator of pollution is possible to separate into two different aspects. It is possible to define pollution indices and the indices for quantity. The article presents the process and outcome on real data of air pollution in the Czech Republic.

***Keywords* -** Environmental damage, level of air pollution, price level, total value of pollution.
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I. THEORETICAL APPROACH

A. Value, Quantity, Unit Value

Let us consider a complex (total) phenomenon or process which consists of n partial disjoint parts i, i= 1, 2, …, n. The unification of all parts gives the total. [3],[12]. E.g. aggregate pollution consists of pollution caused by CO_2, SO_2, etc.[7], [8], [1].

Let us consider value of individual h_i for any part i. Let us assume that variables h_i are addable i.e. they have the same meaning and it is possible to sum them. We will call them values.

We state

$$H = \sum_{i=1}^{n} h_i \tag{1}$$

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Let us define variables q_i, which correspond quantity (amount) of an item i. The meaning of these variables can be various. So, their sum may not make sense. These variables will be called quantity.

So, for any item i we have two variables: value and quantity.

For any item i we define

$$p_i = \frac{h_i}{q_i}. \tag{2}$$

The variable p_i means the value of item i per unit of quantity i. If the value is expressed in monetary units, these variables represent prices. Generally, it may not be so, therefore, we will use term unit value.

For any h_i and positive q_i we obtain

$$h_i = \frac{h_i}{q_i} q_i \tag{3}$$

$$h_i = p_i \ q_i. \tag{4}$$

Values h_i , i=1,2, …, n form vector h.

Values q_i, i=1,2, …, n form vector q.

Values p_i, i=1,2, …, n form vector p.

Coordinates of these vectors correspond to the item i, i=1,2, …, n. The sum H is the total value in chosen time t or time period (t-1,t>

$$H = \sum_{i=1}^{n} h_i = \sum_{i=1}^{n} p_i \, q_i \ . \tag{5}$$

A question arises whether it is possible to define ~~set~~ numbers P and Q which correspond to vectors p and q so that

$$H = P\,Q\,. \tag{6}$$

P and Q represent scalar representatives of vectors p and q.

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B. Data Changes

In this paragraph we will consider continuous time and infinitesimal time interval < t, t + dt).

From relations written above it follows

$$dH = \sum_{i=1}^{n} dh_i = \sum_{i=1}^{n} \frac{dh_i}{h_i} h_i = \sum_{i=1}^{n} d(p_i q_i) = \sum_{i=1}^{n} (q_i\, dp_i + p_i\, dq_i) \tag{7}$$

$$\frac{dH}{H} = \sum_{i=1}^{n} \frac{dh_i}{H} = \sum_{i=1}^{n} \frac{dh_i}{h_i}\frac{h_i}{H} = \sum_{i=1}^{n} \frac{dh_i}{h_i} w_i \tag{8}$$

$$\frac{dH}{H} = = \sum_{i=1}^{n} \frac{d(p_i, q_i)}{p_i\ q_i} w_i = \sum_{i=1}^{n} \frac{q_i\, dp_i + p_i\, dq_i}{p_i\ q_i} w_i = \sum_{i=1}^{n} \left(\frac{dp_i}{p_i} + \frac{dq_i}{q_i}\right) w_i\ , \tag{9}$$

where weight w_i fulfils

$$w_i = \frac{h_i}{H}. \tag{10}$$

From it follows

$$\mathrm{d} \ln H = \sum_{i=1}^{n} (\mathrm{d} \ln p_i + \mathrm{d} \ln q_i)\ w_i \tag{11}$$

This relative change of the total value is equal to weighted sum of relative changes of the values for individual i.

Therefore, infinitesimal growth of value is equal to sum of weighted infinitesimal changes of unit value and quantity [6],[3].

In order to express infinitesimal growth we assume dependency of the variables on parameter (e.g. time) t which will be assigned as an index to considered variables. Therefore, we can write

$$H_{t+dt} = H_t + dH_t \tag{12}$$

$$\frac{H_{t+dt}}{H_t} = 1 + \frac{dH_t}{H_t} \tag{13}$$

It arises from here that the index reduced by a unit represents relative change of variable H.

$$\ln \frac{H_{t+dt}}{H_t} = \ln H_{t+dt} - \ln H_t = \sum_{i=1}^{n} w_i (\ln q_{it+dt} - \ln q_{it}) + \sum_{i=1}^{n} w_i\, (\ln p_{it+dt} - \ln p_{it}) \tag{14}$$

We assume that weights $w_i\ i = 1, 2, \dots, n$ do not depend on parameter t.

From which arises

$$\ln \frac{H_{t+dt}}{H_t} = \sum_{i=1}^{n} w_i \left(\ln \frac{q_{it+dt}}{q_{it}} + \ln \frac{p_{it+dt}}{p_{it}}\right) = \sum_{i=1}^{n} w_i\ \ln \frac{q_{it+dt}}{q_{it}}\ \frac{p_{it+dt}}{p_{it}} \tag{15}$$

$$\ln \frac{H_{t+dt}}{H_t} = \sum_{i=1}^{n} \ln \left(\frac{q_{it+dt}}{q_{it}}\right)^{w_i} \left(\frac{p_{it+dt}}{p_{it}}\right)^{w_i} \tag{16}$$

$$\ln \frac{H_{t+dt}}{H_t} = \ln \prod_{i=1}^{n} \left(\frac{q_{it+dt}}{q_{it}}\right)^{w_i} \left(\frac{p_{it+dt}}{p_{it}}\right)^{w_i} \tag{17}$$

$$\frac{H_{t+dt}}{H_t} = \prod_{i=1}^{n} \left(\frac{q_{it+dt}}{q_{it}}\right)^{w_i} \left(\frac{p_{it+dt}}{p_{it}}\right)^{w_i} \tag{18}$$

Let us define

$$Q_t = K_Q\, q_{1t}^{w_1}\ q_{2t}^{w_2} \dots q_{nt}^{w_n} \tag{19}$$

$$P_t = K_P\, p_{1t}^{w_1}\ p_{2t}^{w_2} \dots p_{n}^{w_n}\ , \tag{20}$$

where K_Q and K_P are positive constant such that

$$K_Q\, K_P = 1. \tag{21}$$

So, we can see

$$\frac{H_{t+dt}}{H_t} = \frac{Q_{t+dt}}{Q_t} \frac{P_{t+dt}}{P_t}. \tag{22}$$

For time t;

P_t may be considered as aggregate variable of unit values, i.e. as level of unit value;

Q_t may be considered as aggregate variable of value.

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II. EXAMPLE

A. Polution and its Clasification

Environmental data are available in the various classifications of pollution and other harmful effects [8], [11].

For the purposes of interpretation, it is sufficient to consider the information relating to one year and the types of pollution, which are in the following table.

Tab. 1 Selected air pollutants

(n)	Type of pollution	
1	PM_{10}	Particulate Matters
2	SO_2	Sulphur dioxide
3	NO_x	Oxides of nitrogen
4	CO_2	Carbon dioxide

Source [5]

We will use the selected data for the year 2011 in further analysis [5].

In general, you can assume n types of pollution.

B. Quantity of Polution

Default data are considered types of pollution emissions in tons per year (t/year) that are listed in the following table

Tab. 2 Emitted amount per year

(n)	q	kt/year
1	PM_{10}	48,4207345
2	SO_2	170,180470
3	NO_x	225,308640
4	CO_2	107 991,12

Sources: [10], authors, [11]

Costs of pollution per unit of quantity.

The amount of emissions we will mark the kind of q_i. These quantities are not possible to sum.

The next table shows data about the cost, which the issuer must incur pollution. Costs relating to the nature of the pollution and the unit of quantity (1 ton) we mark p_i. Their size is EUR per ton (€/t).

Tab. 3 Estimating of damage for pollutants unit

(n)	p	€/t
1	PM_{10}	11 000
2	SO_2	4 000
3	NO_x	4 000
4	CO_2	19 000

Source:[2]

The value of the pollution of the kind i we denoted by h_i. We get this value by using the relation

$$h_i = p_i \; q_i. \quad (23)$$

Dimension values h_i we determine the size of the values of p_i q_i. Applies

$$[€/Year] = [€/t] \; [t/ Year]]. \quad (24)$$

So, the values h_i are possible to sum for i = 1,2, ..., N.

Tab. 4 Damage for year in €

(n)	p * q	€/year
1	PM_{10}	532 628 079,5
2	SO_2	680 721 880,0
3	NO_x	901 234 560,0
4	CO_2	2 051 831 280 000,0
Sum		2 053 945 864 519,5

It is possible to define nonnegative weights prom the formulae

$$w_i = \frac{h_i}{H} \qquad i = 1,2,3,4 \quad (25)$$

So, we receive the table

Tab. 5 Weights calculation

n	Item	$h_i=p_i*q_i$ (€/Year)	w_i
1	PM_{10}	532 628 079,5	0,000259319
2	SO_2	680 721 880,0	0,000331422
3	NO_x	901 234 560,0	0,000438782
4	CO_2	2 051 831 280 000,0	0,998970477
Sum		2 053 945 864 519,5	1,000000

From relations

$$P = p_1^{w_1} \; p_2^{w_2} \; \dots \; p_n^{w_{nt}} \quad (26)$$

$$Q = q_1^{w_1} \; q_2^{w_2} \; \dots \; q_n^{w_n} \quad (27)$$

We determine the value of P and Q and their product.

In the calculation we use logarithms. Indeed

$$\ln(P) = \ln(p_1^{w_1}) + \ln(p_2^{w_2}) + \cdots + \ln(p_n^{w_n}) \quad (28)$$

$$\ln(P) = w_1 \ln(p_1) + w_2 \ln(p_2) + \cdots + w_n \ln(p_n) \quad (29)$$

$$\ln(Q) = \ln(q_1^{w_1}) + \ln(q_2^{w_2}) + \cdots + \ln(q_n^{w_n}) \quad (30)$$

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$$\ln(Q) = w_1 \ln(q_1) + w_2 \ln(q_2) + \cdots + w_n \ln(q_n) \quad (31)$$

We come out of table by the logarithms of the values

Tab. 6 Logarithms of the values

n	Item	$h_i=p_i*q_i$ (€/Year)	w_i
1	PM_{10}	532 628 079,5	0,000259319
2	SO_2	680 721 880,0	0,000331422
3	NO_x	901 234 560,0	0,000438782
4	CO_2	2 051 831 280 000,0	0,998970477
Σ		2 053 945 864 519,5	1,000000

Continue of Tab. 6

n	Item	$\ln(h_i)$	$w_i \ln(h_i)$	$w_i \ln(h_i)$ and Σ
1	PM_{10}	20,0933340	0,005210592	0,005210592
2	SO_2	20,3386644	0,006740671	0,006740671
3	NO_x	20,6192761	0,009047368	0,009047368
4	CO_2	28,3497538	28,32056709	28,32056709
Σ		28,3507839	28,35078387	28,34156573

Consider the aggregate numbers

Tab. 7 Aggregate numbers

n	It corresponds to		Exp(Σ)
1	$\Sigma_i w_i = 1$	28,3507839	2 053 945 864 520
2	$\Sigma_i w_i \ln(h_i)$	28,3415657	2 035 099 290 843

Let's calculate the values of P and Q. We proceed from tables

C. The values and weights

Tab. 8 Given values and weights

n	Item	p_i (€/t)	q_i (t/year)	$h_i=p_i*q_i$ (€/year)	w_i
1	PM_{10}	11 000	48 420,7345	532 628 079,5	0,000259319
2	SO_2	4 000	170 180,4700	680 721 880,0	0,000331422
3	NO_x	4 000	225 308,6400	901 234 560,0	0,000438782
4	CO_2	19 000	107 991 120,00	2 051 831 280 000,0	0,998970477
Σ		x	x	2 053 945 864 519,5	1,000000

Tab. 9 Logarithm of values

n	Item	$\ln(p_i)$	$\ln(q_i)$	$\ln(h_i)=$ $=\ln(p_i)+\ln(q_i)$
1	PM_{10}	9,30565055	10,78768	20,09333395
2	SO_2	8,29404964	12,04461	20,33866438
3	NO_x	8,29404964	12,32523	20,61927611
4	CO_2	9,85219426	18,49756	28,34975382

Tab. 10 Logarithm of the value multiplied by weights and the sum of its

n	Item	$w_i \ln(p_i)$	$w_i \ln(q_i)$	$w_i \ln(h_i)$ $w_i (\ln(p_i)+\ln(q_i))$
1	PM_{10}	0,002413	0,002797	0,005211
2	SO_2	0,002749	0,003992	0,006741
3	NOx	0,003639	0,005408	0,009047
4	CO_2	9,842051	18,478516	28,320567
Σ		9,850852	18,490713	28,341566
EXP(Σ)		18 975	107 254 308	2 035 099 290 843

Easy to see that it is

2 035 099 290 843 = 18 975*107 254 308

$$P\,Q = {}_wH \quad (32)$$

So,

value of **18 975** can express scalar values representative of p_i, which denoted P

value of **107 254 308** can express scalar values representative of Q_i, which we denote Q;

value **2 035 099 290 843** can express scalar representative h_i, which denote ${}_wH$

At the same applies

$$P\,Q = {}_wH \quad (33)$$

The problem is that the value ${}_wH$ does not match the

$$H = \sum_{i=1}^{n} h_i \,, \quad (34)$$

which is the default value for the weights.

Insert one of the options for addressing the problem. [9], [10]. Let us start from the definition of weights. For all *i* is valid

$$h_i = w_i\, H\,. \quad (35)$$

Therefore

$$\ln(h_i) = \ln(w_i) + \ln(H) \quad (36)$$

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$$w_i \ln(h_i) = \ w_i \ln(w_i) + w_i \ln(H)$$

(37)

Adding the obtained relationship over all i, we get

$$\ln(\,_wH) = \ \sum_{i=1}^{n} w_i \ln(w_i) + \ln(H) \sum_{i=1}^{n} w_i \,.$$

(38)

Since the sum of the weights is equal to one, we get

$$\ln(\,_wH) = \ \sum_{i=1}^{n} w_i \ln(w_i) + \ln(H) \sum_{i=1}^{n} w_i \,.$$

(39)

Hence

$$_wH = \ E \, H \,,$$

(40)

where

$$E = \exp\left[\sum_{i=1}^{n} w_i \ln(w_i)\right]$$

(41)

Hence

$$H = \frac{_wH}{E}.$$

(42)

Consideration is illustrated on the example

Tab. 11 Results of process

n	Item	$w_i \ln(p_i \, q_i)$	$w_i \ln(w_i)$	$w_i \ln(H)$
1	PM_{10}	0,005211	-0,00214	0,007351909
2	SO_2	0,006741	-0,00266	0,009396060
3	NO_x	0,009047	-0,00339	0,012439815
4	CO_2	28,320567	-0,00103	28,32159609
Σt		28,341566	-0,00922	28,35078387
EXP(Σ)		2 035 099 290 843	0,990824	2 053 945 864 520

Easy to see that

$$\mathbf{2\ 053\ 945\ 864\ 520} = \frac{\mathbf{2\ 035\ 099\ 290\ 843}}{\mathbf{0,990824}}$$

From the relation

$$H = \frac{_wH}{E}.$$

(43)

we get

$$H = \frac{P\,Q}{E}.$$

(44)

Since P is the proportion indicator, it is advisable to perform a correction for indicator Q. So get decomposition

$$H = \ P \ \frac{Q}{E}.$$

(45)

It can however be selected for the correction value P E_P correction value Q E_Q, so that it applies

$$E = \ E_P \ E_Q \,.$$

(46)

The numerical value is obtained for P=18 975
and Q=107 254 308.

If P is not corrected, the corrected Q is equal to 108 247 565,04 as is true

$$\mathbf{2\ 053\ 945\ 864\ 520} = \mathbf{18\ 975} * \ \frac{\mathbf{107\ 254\ 308}}{\mathbf{0,990824}}$$

(47)

$$\mathbf{2\ 053\ 945\ 864\ 520} = \mathbf{18\ 975} * \ \mathbf{108\ 247\ 565,04}\,.$$

(48)

III. CONCLUSION

The article indicated one of the possible methods of obtaining overall characteristics. Commonly used features are analyzed in terms of their explanatory power and in terms of accuracy. On this issue article implicitly points.

Generally, when examining structured variables, it is necessary to examine the influence of factors weighing on aggregate variables. This must include in the survey and related analyzes.

Next viewpoints should be considered concern the sensitivity to changes, and the characteristics of the variables that determine them

Formulas used in the description and definition of the characteristics might be expressing by different way e.g. d ln(x) or statements dx / x have the same meaning.

This article draws attention to other aspects of description and quantification of phenomena and processes. The result should be considered a rough estimate with advantages and disadvantages of aggregate indicator.

These possibilities are illustrated on the example of problematic quantification of environmental damage. This procedure could help to improve the quality and acceleration of data for decision-making processes

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Prof. Ing. Bohuslav Sekerka, CSc. is professor of the Financial Mathematics at the Institute of Economics.

Assoc.Prof. Ing. Ilona Obršálová, CSc. is engaged in the field of Environmental Economics at the Institute of Administrative and Social Sciences.

Ing. Petra Lešáková is PhD. student at the Institute of Administrative and Social Sciences.

All are employed at the University of Pardubice, Faculty of Economics and Administration. http://www.upce.cz/english/fea/index.html

Economic Allocation of Hybrid Thermal/Electrical Energy Storage for Concentrated Solar Power Plant

Ahmed Rahouma[1, 2 *], Rasha El-Azab[1, 2], Mohamed Daowd[1, 2], Amr M. A. Amin[1, 2]
[1]Academy of Scientific Research and Technology (ASRT), Cairo – Egypt.
[2]Helwan University (HU), Faculty of Engineering, Cairo – Egypt.
Ahmed_rahouma@h-eng.helwan.edu.eg

***Abstract*—**Integrating Concentrated Solar Power (CSP) as a Variable Renewable Energy Source (VRES) with electric grids is increased during the last decades, and achieve many technical, economic and environmental targets. Also, integrating VRESs, such as wind and solar power, are prominent on the Smart Grid horizon.

Unexpected behavior of solar based systems rises a need of using hybrid storage system. This paper will propose hybrid storage system that consists of both of TESS and EESS. The hybrid storage system aims to have advantages of both systems. CSP plants provided with this hybrid storage system will have better performance and be able to handle sun variations and weather conditions smoothly in normal operation and transient performance. An optimal allocation model for thermal and electrical energy storage system is defined to maintain the system stability with minimum cost.

***Keywords*—** BESS, Integrating CSP, Spinning Reserve, TESS, VRES.

I. Introduction

INTEGRATING Variable Renewable Energy Sources (VRESs) with electric grids becomes a national target for many countries. VRESs are growing components of electricity grids around the world due to its contributions to energy system decarbonization, long term energy security, and expansion of energy access to new energy consumers in the developing world.

Despite of huge benefits of integrating VRESs, they have two main attributes; variability and uncertainty. Variability is generation changes according to the availability of the primary fuel, e.g. global solar radiation in case of Solar Photovoltaic Generation (SPVG) plant resulting in swings of the plant output. And uncertainty is magnitude and time of the generation output is unpredictable.

This variable nature poses challenges to the conventional Power systems and Power Systems Operators. Conventional electric grids have traditionally been powered by generating resources that are relatively stable and controllable.

In contrast, the output of VRES plants is intermittent and dependent on uncertain factors such as weather conditions. Among VRESs, solar thermal power, also known as Concentrated Solar Power (CSP) has a great potential in the renewable energy sector.

The rest of the paper is structured as follows: Section II presents concentrated solar power technologies. In section III defines spinning reserve and its effect on system stability. Section IV, introduces energy storage systems specifically TESS and Battery Energy Storage System (BESS).

Section V shows studied case of CSP plant during the period of cloudy weather and its reflect on the system stability. Section VI presents economic allocation of hybrid storage system consists of BESS and TESS. Finally, the main conclusion and contributions of the paper are highlighted in Section VII.

II. II. CONCENTRATED SOLAR POWER

Concentrating solar thermal power technologies are based on the concept of using mirrors to concentrate sunlight onto a receiver, which collects and transfers the solar energy to a heat transfer fluid (HTF) used to generate electricity through conventional steam turbines. Large CSP plants can be equipped with a heat storage system to allow electricity generation at night or when the sky is cloudy.

There are four main CSP technology families which differ depending on the design, configuration of mirrors and receivers, heat transfer fluid used and whether or not heat storage is involved. They can be classified according to focusing sun’s rays configuration and the receiver technology

The concentrating solar thermal power market continued to advance in 2013 after record growth in 2012 as shown in Fig. 1. Total global capacity increased by nearly 0.9 GW, up 36%, to more than 3.4 GW5 [1].

These CSP technologies are currently in medium to large-scale operation and mostly located in Spain and in the USA as shown in Fig. 1. Although parabolic trough collector technology is the most mature CSP design, solar tower technology occupies the second place and is of increasing importance as a result of its advantages.

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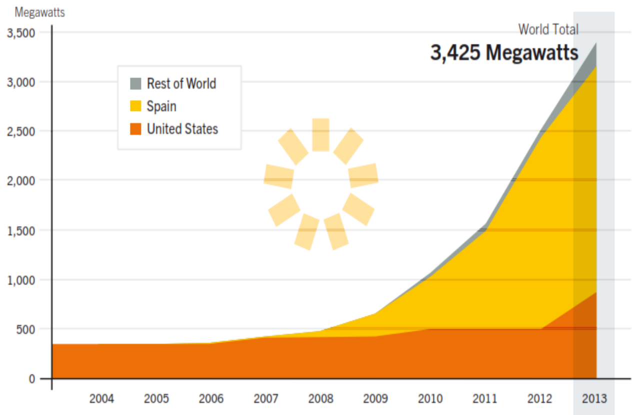


Fig. 1. CSP Global Capacity, by Country or Region, 2004–2013 [1].

III. SPINNING RESERVE

The spinning reserve can be defined as the unused capacity which can be activated on decision of the system operator and which is provided by devices which are synchronized to the network and able to affect the active power. [2].

System operators normally have access to a range of operating reserves that control active and reactive power through the grid. Spinning reserve can be classified as follows:

1) Positive spinning reserve is the on-line reserve capacity that is synchronized to the grid system and ready to meet electric demand within acceptable predefined time frame.

2) Negative Spinning Reserve is the capacity that can be switched off quickly to compensate a dip in generated energy (e.g. Load Shedding).

The frequency fluctuates when there is a change in the production of, or in the demand for energy. If a generator trips, the frequency will decline. Depending on the prime mover and spinning reserve, the frequency will eventually go back to its desired value, see Fig. 2.

If the loss of generation is greater than the spinning reserve, the frequency could eventually stabilize at a new value lower than the desired one, as shown in Fig. 3.

The comparison between Fig. 2 and Fig. 3 shows that sufficient spinning reserve is considered as a defense line for electrical grids from severe damages or blackouts.

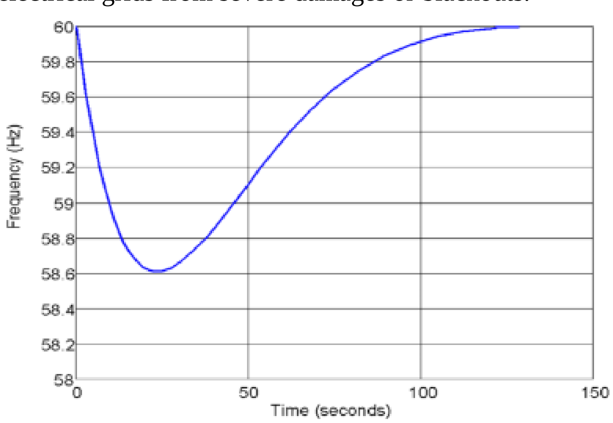


Fig. 2. Frequency changes with sufficient spinning reserve [3]

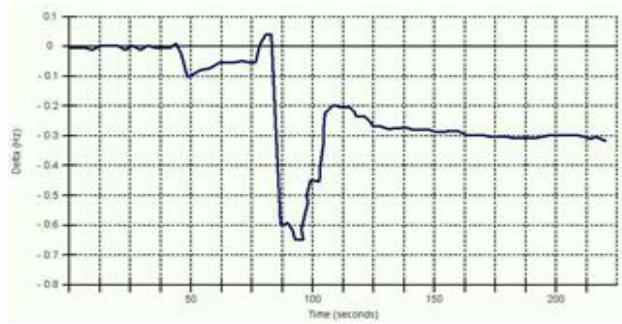


Fig. 3. Frequency oscillation with insufficient spinning reserve [3]

IV. ENERGY STORAGE SYSTEMS

Energy Storage Systems (EES) technologies can be classified according to many factors, such as, their functions, response time, and suitable storage durations. [4].

Integrating large scale Electrical Energy Storage Systems (EESS) with electric grids achieves many benefits as follow:

1) Enabling time-shift of energy delivery,
2) Supplying capacity credit,
3) Providing grid operational support,
4) Providing transmission and distribution support,
5) Maintaining power quality and reliability, and
6) Allowing integration of intermittent renewables generation.

CSP plants experience short term variations on cloudy days and cannot provide energy during night hours unless incorporating Thermal Energy Storage System TESS and/or backup systems such as Battery Energy Storage System to operate continuously. TESS and BESS will be discussed in the following sections.

A. *Thermal Energy Storage System*

An advantage of CSP over non-dispatchable renewables is that it can be built with TESS, which can be used to shift generation to periods without solar resource and to provide backup energy during periods with reduced sunlight caused by cloud cover [5].

The response time of TESS, each TESS configuration has different response time, will be in order of minutes. In [6], the controller of TESS aims to keep the HTF outlet temperature (steam generator feed temperature) at the desired set point. It takes about 17 minutes until the HTF outlet temperatures settle at the set point. TESS is considered in concept phase.

TESS cost varies dramatically form type to another. In [7], TESS cost range is estimated from 29.7 to 52.7 $ for each thermal KWhr.

B. *Battery Energy Storage Systems*

Among different types of BESS, EESS currently consist of large installations of lead-acid batteries as the standard technology. The primary function of grid support is to provide spinning reserve. Lead acid batteries are considered attractive alternatives both because of technological maturity and availability as well as low relative cost.

Lead acid batteries can be used for grid applications, such as angular stability, grid voltage stability, grid frequency excursion suppression, short and long duration power quality, as well as several combinations of functions [8].

Notable improvements to lead acid battery technology led to advanced lead acid. Advanced lead acid technology reduces maintenance requirements, extends life expectancy, and improves cell uniformity which increases both battery life expectancy and cost.

In [9], BESS deployment time varies from 3 to 5 m sec, which can be neglected according to the studied time frame. According to [9], BESS cost will decrease dramatically from 100 €/ kWh to 250 €/ kWh currently to 50 €/ kWh to 80 €/ kWh in 2030.

V. STUDIED CASE

CSP plants have significant impacts on the operation and stability of electric power systems. Weather conditions, such as clouds, have an impact on CSP plant operations, but less other solar energy technologies. During clouds, the input thermal power delivered to the power block, which produced by the solar field, will be influenced.

To examine the frequency behavior and response of CSP integrated with complicated power systems during severe solar radiation conditions. A single machine system is tested by using MatLab/Simulink program, as shown in Fig.4.

In [10], a typical severe case of sun radiation is described. The sun radiation is decreased by about 80% of its normal value for more than an hour. The following assumptions are made for the detailed analysis:

- The effects of automatic voltage regulator are taken in consideration because of their fast response.
- All loads connected to the network are of constant power type with 0.85 p.f.
- Sudden decrease in mechanical power of the synchronous machine by about 80% after one second of normal operation.

Fig. 5 shows the response of CSP's power block components due to DNI variations. As mechanical generator input power decreases, the instantaneous electric output power, generated by power block, is greatly affected. The stored kinetic energy in power block is released to compensate the shortage in input mechanical power, leading to frequency decaying.

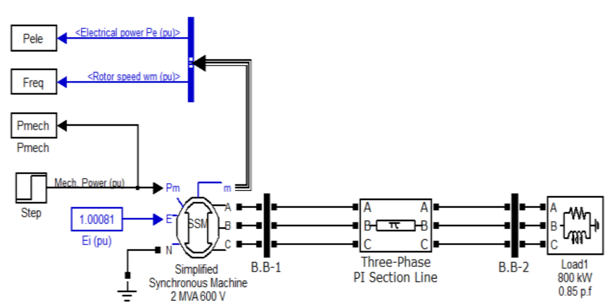
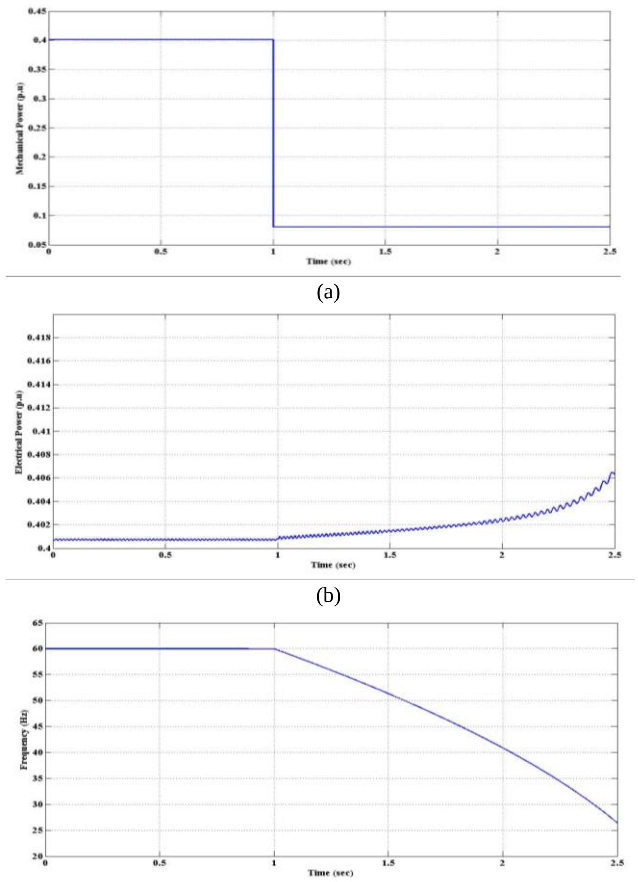


Fig. 4. Single machine system



(c)

Fig. 5. Response of CSP's due to severe DNI variations, (a) generator's input power, (b) synchronous generator's output power, and (c) frequency.

According to the studied case, with such large decrease in solar radiation, the protection system will disconnect the CSP plant within 1 second. With high sharing of CSP, cascading outage of solar plant will occur which may lead to frequency collapse or blackout. Adequate energy storage schemes are an urgent need in high sharing of CSP grid integration to prevent or decrease the danger of blackout.

VI. HYBRID ENERGY STORAGE SYSTEM

The hybrid storage system aims to have advantages of both systems. CSP plants provided with this hybrid storage system will have better performance and be able to handle sun variations and weather conditions smoothly in normal operation and transient performance.

In [11], an innovative equation is suggested for sizing ESS, as follows:

$$E_{storage} = N_{dip} * KE_{reco} / fch \qquad (1)$$

Where

$E_{storage}$: recommended battery energy,

f_{ch} : available discharge percentage , (assumed = 0.7),

N_{dip} : number of expected dips in solar power,

KE_{reco} : stored energy needed to damp the frequency behavior to controllable one.

ESS will respond to detection of critical frequency (59.3 Hz for electric grids have nominal frequency of 60 Hz), and recovers system's frequency to acceptable limits. According to the previous equation, the studied system needs ESS equals 915 KWh.

Due to the previous mentioned factors, BESS can be integrated with CSP plant to maintain stable and constant output power and frequency. BESS will discharge and provide the required power to compensate the released kinetic energy from power block during transient operation.

BESS allows a more flexible generation strategy to be pursued in order to maximize the value of the electricity generated. During normal operation, BESS should operate in startup period of TESS.

An economic analysis will determine the optimum size of both BESS and TESS. In this study, different assumptions are taken in cost formulation, as follows:

- BESS average cost is 175 $/ kWh, while TESS average cost is 41.2 $ for each KWh thermal.
- BESS start up time is neglected, while TESS start up time is 17 min.
- BESS initial cost is 160,390 $, while TESS initial cost is 307,200 $.
- Thermal to electrical efficiency equals 40%.

Capital cost of BESSs and TESSs is presented according to [12], [13]. Capital cost of BESS mainly consists of the cost of storage units and the cost of power conversion system.

A linear cost formula for BESS and TESS are estimated as follows:

$$Cost_{BESS}\ (\$) = 175 * E_{storage,ele} + 160{,}390\ \$/\ kWh_{ele}, \qquad (2)$$

$$Cost_{TESS}\ (\$) = 41.2 * E_{storage,th} + 307{,}200\ \$/\ kWh_{th}, \text{ and} \qquad (3)$$

$$= 103 * E_{storage,ele} + 307{,}200\ \$/\ kWh_{ele}. \qquad (4)$$

From Fig. 8, TESSs are cheaper than BESS for stored energy more than 10 MWh, while BESS should designed to cover transient operation, TESS start up time and for stored system less than 10MWh.

By using previous equations for the studied case, the required energy (915 KWh) from ESS will be divided to two parts; 260 KWh for the first 17 min., and 655 KWh for the remaining 43 min. BESS only will discharge during the first period. So, BESS's cost for this period will be 205,890 $.

During the remaining period, 43 min., TESS of 655 KWh will cost 374,665 $. But, BESS of 655 KWh will cost 275,015 $. Hence, BESS is cheaper than TESS. It is economic to use BESS as EESS.

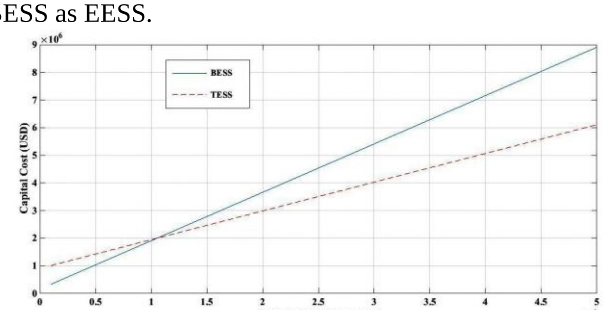


Fig. 8 Capital cost of BESSs and TESSs

VII. CONCLUSION

Integrating VRESs with electric grids has many technical problems such as frequency instability due to their variability and uncertainty features. CSP plants usually have TESS to increase energy production and capacity factor.

A single machine system behavior is studied to simulate the effect of solar radiation dips. According to this study, TESS's response for weather variations is very slow, which effects on electrical output power of CSP plant. Incorporating BESS will enhance CSP plant's performance, and stabilize the output power.

Hybrid energy storage system consists of BESS and TESS will give CSP plants better performance because of BESS and TESS advantages such as BESS's fast response and low prices of TESS.

An empirical form of capital costs for both BESS and TESS are estimated. An optimal allocation model for thermal and electrical energy storage system is defined to maintain the system stability with minimum cost.

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Ahmed Rahouma is a master student in electrical power and machines engineering department at Helwan University. A. Rahouma received the B.Sc. degree in electrical engineering from Helwan University, Cairo, in 2010. His research interests include PMU applications, smart grid, and power system integration with renewable energy resources, load shedding and transient stability. His programs interests include Matlab/Simulink, PSAT, DigSilent and ETAP

Rasha El Azab is a lecturer at the Faculty of Engineering at Helwan University R. M. Elazab received the B.Sc. and M.Sc. degrees in electrical engineering from Helwan University, Cairo, in 1999 and 2005 respectively. She is granted double PhD degrees, in electrical power engineering, from Vrije University Brussels, Belgium and Helwan University, Egypt in 2012. She is a member of several EU projects; STS-Med, EuroSunMed, IEEE society. Her research interests include wide-area protection and control systems, PMU applications, smart grid, and power system integration with renewable energy resources, load shedding and transient stability.

Dr. Eng. Mohamed Daowd
Faculty of Engineering, Helwan University.
Born in Giza-Egypt. BSc, MSc graduation "Electrical Machines and Power Engineering" from Helwan University Cairo-Egypt in 1999 and 2006 respectively. He obtained his Ph.D. in Electrical Vehicles from Vrije University Brussel, Belgium in 2013. Currently he is assistant professor, Faculty of Engineering, Helwan University. Egypt. Furthermore, he is a member of several EU projects; STS-Med, EuroSunMed, IEEE society. Research interests include solar base renewable energy, batteries. Email: m_a_daowd@yahoo.com, m.a.daowd@ieee.org.

Amr M. Amin is a Professor and Dean of the High Technological Institute, 10th Of Ramadan Egypt. He participated and managed many national and multinational funded projects. These projects are in the areas of energy optimization, renewable energy, solar desalination, and educational developments. He is currently working on a project entitled 'Multipurpose Applications by Thermodynamic Solar (MATS)", EC Frame Work Programme 7, FP7, 22 M Euro and STS-MED Small scale thermal district units for Mediterranean communities, 5 M euro, EU-ENPI program. He was a member of the study group organized by EASAC (the European Academies Science Advisory Council). He is serving as an evaluator for many EC funding schemes, FP7, TEMPUS, ENPI, and ERASMUS MUNDS. On the National level he is an evaluator for the Industrial Modernization Council IMC, Ministry of Industry and Commerce and the Research Development and Innovation RDI, Ministry of Scientific Research. He also serves as referee for many international and national journals and conferences.

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Comparative studies between wind turbine active/reactive power control

Azzeddine Dekhane , Abdallah Abderrezak
Department of Electrical Engineering
Badji Mokhtar-Annaba University P.O. Box 12, 23000 Annaba, Algeria
abdallah.abderrezak@univ-annaba.dz

Abstract: - Wind turbines are controlled to provide constant active and reactive power during a certain period for contributing to the service system. In this paper, we present three types separate control of active and reactive power for horizontal axis wind turbine in order to compare their performance: the direct method with a PI and a Fuzzy Logic controller, and also the indirect method control with powers feedback. We aim to obtain the maximum of performance and reducing the controllers number, with taking into consideration the particular wind speed in Algeria. We present also the model of the system to be controlled. A series of simulation results obtained by Matlab / Simulink software are compared and analyzed.

***Keywords*—Wind Turbine, power, modeling, control, simulation, fuzzy, Algeria**

I. INTRODUCTION

Fossil fuel dependency in the global economy and the environmental concerns hold attention for an alternative to current electricity generation methods. However, wind energy has proven the most promising sustainable energy resources [1]. Indeed, progress in wind technology is leading to lower costs compared to conventional methods [2]. In Algeria, more than 80% of the country has a wind speed greater than or equal to 4 m / s [3].

As known, in wind turbine installations, the generator mode of the doubly-fed induction machine (DFIM) attracts particular interest [4]. The wind turbine conversion system based on the doubly-fed induction generator (DFIG) is presented in Figure 1. The stator is directly connected to the grid (fig. 1); it operates synchronously at grid frequency, although the rotor is connected via a static converter that controls the active and reactive power of the generator.

The recent growth in wind power generation has reached a level where the influence of wind turbine dynamics can no longer be neglected. Regulations require normalization to make all stakeholders contribute to service system: control of active power, frequency, reactive power, voltage and tolerance of fault mode [5]. Control of the power quality is required then to reduce the adverse effects on the of WECS integration into the network. Thus, active control has an immediate impact on the cost of wind energy. Moreover, high performance and reliable controllers are essential to enhance the competitiveness of wind technology.

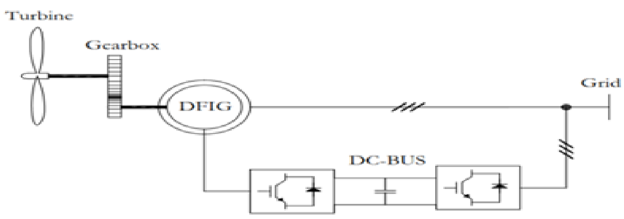

Fig. 1 Chain of conversion

Several active and reactive power control strategies have been the subject of many researches. In the high wind speed range, the pitch control seems more relevant for controlling power margin [6]. To this end, the turbines incorporate either electromechanical or hydraulic devices to rotate the blades, and while in Algeria the low wind speed range makes this type of setting useless viewpoint price /additional needless inertia. The direct and indirect power control method presented in [7] seems to be more effective. The simulation results shown that the indirect control is more efficient than the direct one in terms of dynamics and responses to reactive power levels, but this method is more complicated due to the necessary regulator number and its very high cost.

This paper aims to improve the performance of direct control. To do this, we replace the conventional PI correctors by fuzzy logic controllers. Since the fuzzy logic approach is based on linguistic rules [8], the controller design doesn't require machine parameter to perform adjustment. In terms of robustness, this controller possesses a high robustness [9]. The simulation results obtained by the latter are compared with both direct and indirect methods to analyze the studied system dynamics. In the next section, we briefly describe the mathematical model of wind turbine essential elements.

II. MODELING OF VARIABLE SPEED WIND TURBINE

A. *Energy efficiency of a "wind sensor"*

We can be found throughout the literature several models for power production capability of wind turbines that have been developed. Power in a wind turbine is proportional to the cube of the wind speed and may be expressed as [10]:

$$P_e = \frac{1}{2}\rho A \quad (1)$$

Where ρ is air density, A is the area swept by blades and V is wind speed. A wind turbine can only extract part of the power from the wind, which is limited by the Betz limit (maximum 59%). This fraction is described by the performance coefficient of the turbine C_p, which is a function of the blade pitch angle and the tip speed ratio.

Therefore the mechanical power of the wind turbine extracted from the wind is:

$$P_m = \frac{1}{2} c_p(\lambda, \beta) \rho \pi R^2 V^3 \quad (2)$$

The performance coefficient depends on both the pitch angle (β) and the tip speed ratio (λ). The tip speed ratio is calculated by using blade tip speed and wind speed upstream of the rotor, as in the following formula [11]:

$$\lambda = \frac{R\Omega}{V} \quad (3)$$

The relationship between performance coefficient (c_p), pitch angle (β) and tip speed ratio (λ) is established by the $c_p - \lambda$ approximation (3) for different blade pitch angle, as shows the simulation result obtained by MATLAB / SIMULINK software.

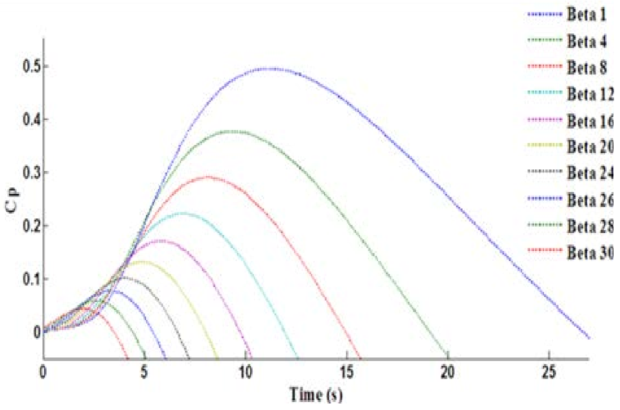

Fig. 2 performance coefficient (c_p)

B. *Model of the wind*

The model of the wind is essential to obtain realistic simulations for the wind turbines power control. The model includes wind turbulence. But to exploit this energy, we must consider the following constraints [12]:

- The wind speed may fluctuate by ± 25% over a several minutes period.

-The regularity of the wind direction and speed depends on the site. To determine the best wind resource, we must conduct surveys of speed and wind direction over a period of at least one year.

The measurement of wind speed is generally carried out at 10 meters above the ground. However, it is often useful to be able to measure at interest altitudes such as the heights of wind turbines.

Several empirical formulas allowing the vertical extrapolation of wind speed [4,13]. Speed v_1 is extrapolated from an altitude above sea level to a $z_1 z_2$, according to the formula (4)

$$V_2 = V_1 \left[\frac{Z_2}{Z_1}\right]^{\alpha_1} \quad (4)$$

With

$$\alpha_1 = \frac{1}{In\frac{Z}{Z_0}} - \left\{\frac{0.0881}{1 - 0.0881\ In\frac{Z_1}{10}}\right\} In\left(\frac{V_1}{6}\right) \quad (5)$$

Where

$$Z = \exp[\mathrm{In}(Z_1) + \mathrm{In}(Z_2)]/2 \quad (6)$$

Z: the roughness of the ground.

Wind speeds, the roughness of the place is available, were extrapolated at 10 meters height, and at 25 meters altitude. Table 1, defines the values of and according several surfaces type [14].

TABLE I

VALUES OF Z_0 AND A_1 ACCORDING SEVERAL SURFACES TYPE

Surface type	Z0 (mm)	α1
sand	0.2 to 0.3	0.10
mown grass	1 to 10	0.13
high grass	40 to 100	0.19
suburb	1000 to 2000	0.32

Figure 3 shows a realistic sample of variable wind speed simulated in 100s.

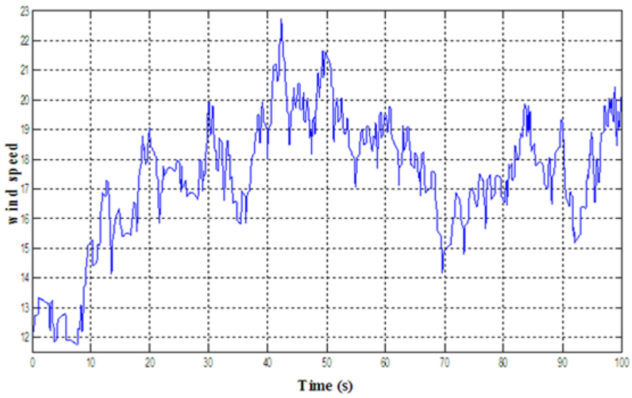

Fig. 3 Wind speed sample (100s)

C. *DFIG Modeling*

As cited before, we use in this study the DFIG, nowadays, most of the installed wind turbines are based on a doubly fed induction generator (DFIG), sharing the place with the wound rotor synchronous generators (WRSGs) and the permanent magnet synchronous generators (PMSGs) [15]. These generator choices allow variable speed generation.

The DFIG is operable as a motor or generator independently from the rotation speed [16]. It allows access to the rotor voltages and currents [17]. The rotor voltages control gives the machine the ability to operate in super or sub synchronism of both motor and generator mode [18].

The general equations of the DFIG can be written in a three-phase landmark as a result [19] [20].The generalized reduced order machine model was developed based on conditions and assumptions cited in [19].

$$\begin{bmatrix}[V_s]\\ [V_r]\end{bmatrix} = \begin{bmatrix}[R_S][I_S]\\ [R_R][I_r]\end{bmatrix} + \frac{d}{dt}\begin{bmatrix}[\phi_s]\\ [\phi_r]\end{bmatrix} \quad (7)$$

And the flux ;

$$\begin{cases}[\phi_s] = L_s[I_s] + M[I_r]\\ [\phi_r] = M[I_s] + L_r[I_r]\end{cases} \quad (8)$$

$$L_s = I_s - M_s;\ L_r = I_r - M_r\ ;\ M = \frac{3M_{sr}}{2} \quad (9)$$

Taking into account (8), Park transformations applied to (7) provide:

$$\begin{cases}V_{sd} = R_s I_{sd} + \frac{d\phi_{sd}}{dt} - \dot{\theta}_s \phi_{sq}\\ V_{sq} = R_s I_{sq} + \frac{d\phi_{sq}}{dt} - \dot{\theta}_s \phi_{sd}\\ V_{rd} = R_r I_{rd} + \frac{d\phi_{rd}}{dt} - \dot{\theta}_r \phi_{rq}\\ V_{rq} = R_r I_{rq} + \frac{d\phi_{rq}}{dt} - \dot{\theta}_r \phi_{rd}\end{cases} \quad (4)$$

$$\begin{cases}\phi_{sd} = L_s I_{sd} + M\, I_{rq}\\ \phi_{sq} = L_s I_{sq} + M\, I_{rq}\\ \phi_{rd} = L_r I_{rd} + M\, I_{sd}\\ \phi_{rq} = L_r I_{rq} + M\, I_{sq}\end{cases} \quad (10)$$

Power expression can be rewritten as follows:

$$\begin{cases}P = -V_s \frac{M}{L_s} I_{rq}\\ Q = -V_s \frac{M}{L_s} I_{rd} + \frac{{V_s}^2}{L_s \omega_s}\end{cases} \quad (11)$$

Figure 4, presents the block diagram of DFIG used in simulation. The input are rotor voltages (V_{rd} and V_{rq}) however, the outputs are the stator active and reactive power (P_s and Q_s).

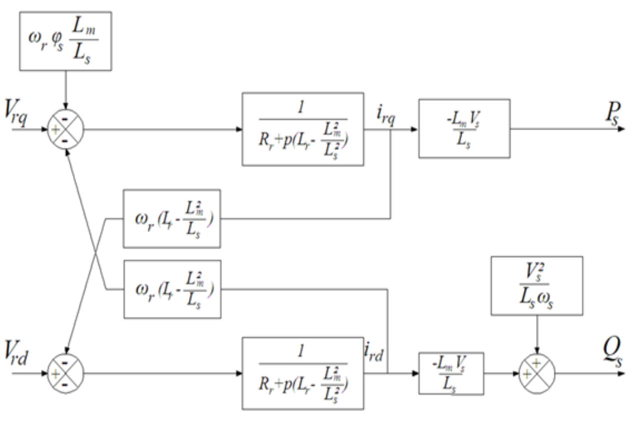

Fig. 4 DFIG bock diagram

Table 2, shows the main parameters of the induction generator which is used in this study.

TABLE II

DFIG PARAMETERS

Components	**Rating Values**
R_s	*0.455 Ω*
L_S	*0.07 H*
R_r	*0.19 Ω*
L_r	*0.0213 H*
M	*0.034 H*
P	*2 Pole pair*

III. METHODS PRESENTATION

In this section, first, we describe two existed types for separate control of both active and reactive power: Direct/Indirect control methods using PI controllers, then in the end we present our proposed combined method by using FL-controller with a proper Fuzzy rules Inputs and outputs. In real installation, these methods are implemented to control the rotor/generator side converter as described in figure.1.

A. *Direct control with PI*

Considering the block diagram of the system to be controlled "Fig. 5 ". Taking into account the relation between the rotor currents and stator powers, we see the appearance of the $\frac{MV_s}{L_s}$ term. Since the wind turbine is considered connected to a high power and stable network, this term is constant and therefore there is no necessary regulator between the rotor currents and powers is needed. But we provide a control loop for each power with an independent regulator by compensating the perturbation terms shown in the block diagram "Fig. 5, [21] [22] [23].

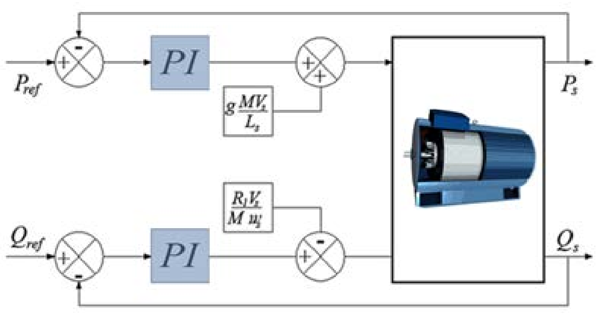

Fig. 5 Direct control block diagram

As shown it is clear that this method simple to implement

B. *Indirect control with power-loop*

The basic principle of the indirect method is to replicate the block diagram of the control system in the opposite direction [25] [26]. We reach a block diagram to express voltages according powers. Indirect control will therefore contain all the elements in the DFIG block diagram.

To enhance indirect control, we insert an additional power loop to eliminate the static error while preserving the system dynamics. Thus, we obtain the block diagram shown in "Fig. 6 ", we distinguish the two control loops for each axis, one to control the current and another one for the power.

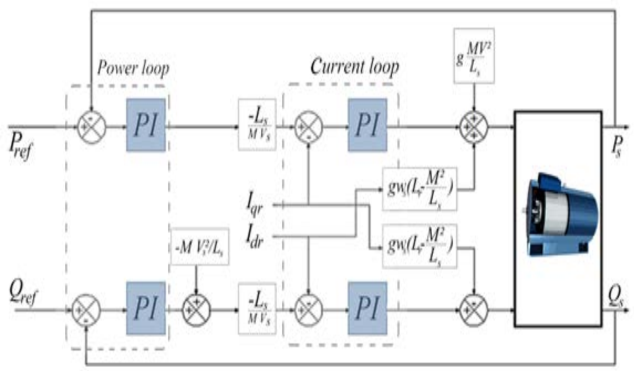

Fig. 6 Indirect control with the power-loop

C. *Direct Control With Fuzzy Logic Controller*

As explained in the fuzzy control block diagram "Fig. 7 ", have two inputs (the error (e), and its derivatives (de)) and an output (of the order (cde)).

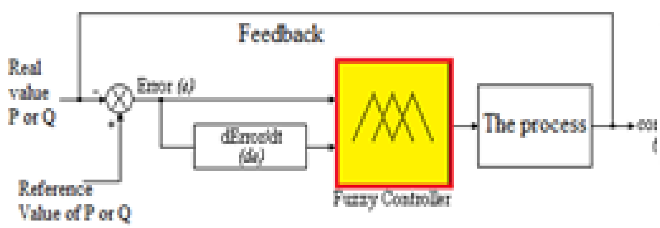

Fig. 7 Fuzzy Control Synoptic Schema

The fuzzy controller inputs are the active and reactive power errors, the error rate of change in a time interval. Linguistic variables and terms are shown in Table 3.

As described in Figure 6 , this paper focuses on fuzzy logic control based on mamdani's system[24]. This system has four main parts. First, using input membership functions, inputs are fuzzified then based on rule bases and inference system, outputs are produced and finally the fuzzy outputs are defuzzified and applied to the main control system. The membership functions used for the input and output variables are shown in fig8 and fig9.

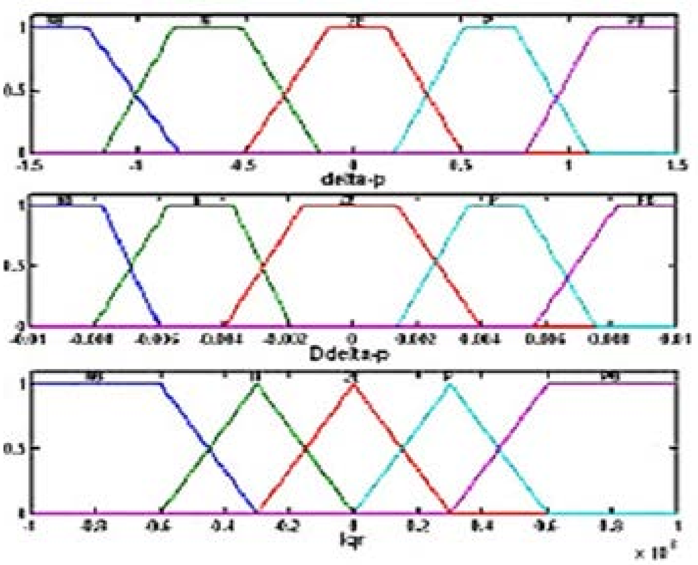

Fig. 8 Inputs and outputs of the active power controller

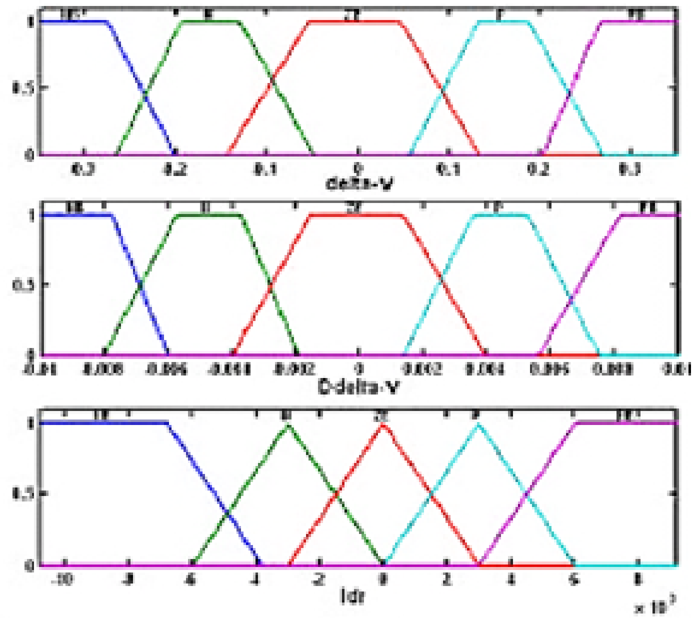

Fig. 9 Input and output of the reactive power controller.

TABLE III

FUZZY RULES

Errour (e)	**Error derivative (de)**				
	NB	**N**	**ZE**	**P**	**PB**
NB	NB	NB	N	N	ZE
N	NB	N	N	ZE	P
ZE	N	N	ZE	P	P
P	N	ZE	P	P	PB
PB	ZE	P	P	PB	PB

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IV. Simulation and Discussion

Direct control with PI and fuzzy correctors and indirect control with the power loop were implemented in MATLAB / SIMULINK software for testing. We applied to the system levels of active and reactive power in order to observe the control behavior.

"Fig. 10 ", presents the results of simulations with the direct control of PI.

There is a reactive power error when active power is low. By cons, it shows a static error at the active and reactive power mainly due to the methodology of this regulation. There is only one current-loop, and powers are thus remained in open loops.

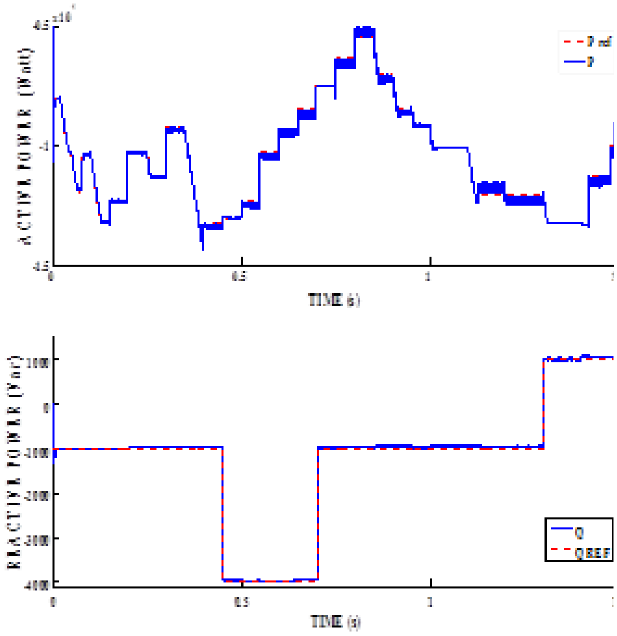
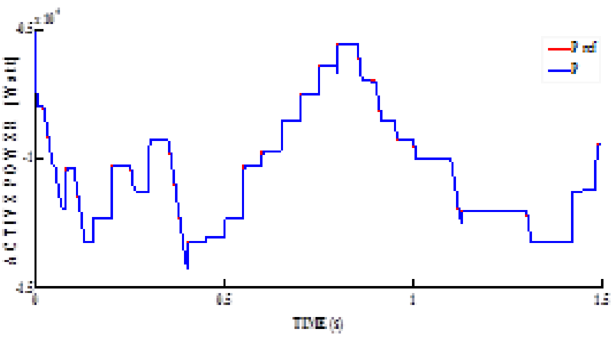


Fig. 10 Active and reactive power control (direct PI)

"Fig. 11 ", presents the simulation results of the direct control with fuzzy regulators.



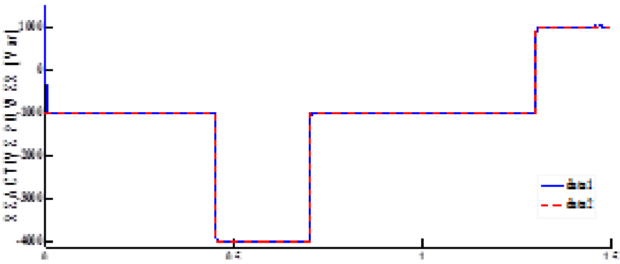


Fig. 11 Active and reactive power control (Fuzzy regulators).

We notice that the system has a satisfactory dynamic and null static error. For both active and reactive powers, there is a dynamic that reacts quickly and without overshoot. Levels are properly monitored and there are no more power errors. The coupling between the two powers is very small and hardly noticeable. It should not be a problem for the future machine model operation.

"Fig. 12 ", presents the results of simulations of indirect control with the power loop.

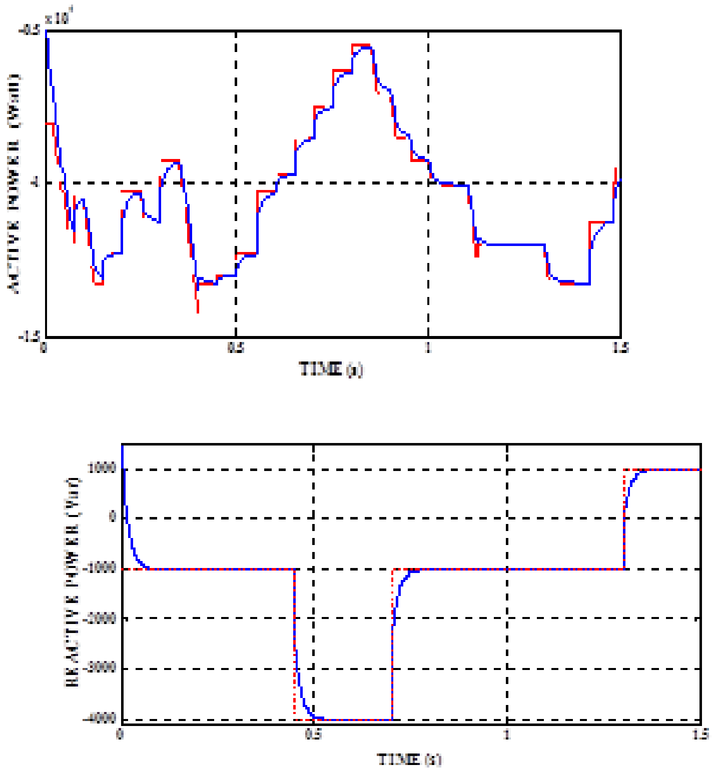


Fig. 12 Active and reactive power (Indirect Control with feedback).

Simulation results of indirect control with the closure of the powers really shows a null static error but a little big response time, which makes this control slow, and this is mainly due to the incorporation of two control loops, one of the currents and the other of the powers.

It is clearly that the proposed method very easy to implement and present a very satisfaction performance comparing to the Indirect control with power-loop method.

V. Conclusion

Simulation results already presented have shown that the indirect control with the power loop gives a better performance than the direct method using the power loop. This eliminates the static error, there's a outstanding time response (0.08s) however the control with a power loop is complicated to implement regarding the required regulators, that's why the use of fuzzy regulators, which seem difficult to adjust, is less complex than the four regulators and therefore the cost will be lower. We have proven by the presented simulation results that the static error is zero and that the response time is faster. The FLC, offer a very satisfactory performance without the need of a detailed mathematical model of our system, we just by incorporating the experts' knowledge into fuzzy rules. In addition, it has inherent abilities to deal with imprecise or noisy data; thus, it is able to extend its control capability even to those operating conditions where linear control techniques fail (i.e., large parameter variations) which it is a future perspective of this work.

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An offer of information technology companies on the e-commerce market

B. Skowron-Grabowska, T. Szczepanik

Abstract—The article presents the issues related to the Information Technologies as well as Information and Communication Technologies. The e-commerce issue, in which operate information companies offering customers e-service through websites, move, was presented. The most commonly used devices for e-commerce, the most common method of payment for purchases on websites, the most convenient method of delivery and receipt, and the reasons not to buy online, were introduced..

Keywords— e-commerce, e-services, IT and ICT technologies.

I. Introduction

GLOBALIZATION and the increasing demand, both for luxury goods and cheap substitutes, contributed to the diversification of market offers, as well as ways of signing sale and purchase transactions. Diverse forms of trade exchanges is inseparably linked with the achievements of IT and ICT, thanks to which, the use of computers with Internet access is also common among companies and households. IT and ICT enterprises sectors are developing rapidly, showing the latest trends in the field of technology, equipment, storage and transmission of information [1]. The importance of innovation in these areas has the key importance to the sectors benefiting from the development of these technologies. The modern economy is characterized by increasing competition on the market of goods and services, increasingly shorter product life and the increasing pace of change. The globalization of the market and increase competitiveness meant that the intensification of activities aimed on customer acquisition has become a necessity. With the result that seeks to meet the needs in a faster and more efficiently, maximizing customer satisfaction by using computer technology, improving various areas of life [2].

II. The use of IT and ICT technology in information enterprises

The second half of the twentieth century was characterized by the emergence of a new type of social solution commonly referred to, as the Information Society, which main feature is the rapid development of information and communication technologies [3]. Such phenomena as, access to a computer, mobile telephony and Internet enabling communication and access to information are realized on an unprecedented and a very large scale [4]. It can be argued that the world has entered the same in the era, where the most valuable asset is information. The information society can be defined as: "The society characterized by the preparation and the ability to use information systems, computerized and using telecommunication services to transfer and remote processing of information" [5]. On this basis, we can characterize an information enterprise as enterprise using technological development, enabling processing, gathering and transmission of information in any form so that it can offer new opportunities, amenities, changing the way we live and work. This company presents a lot of activity in the field of exploration and innovation [6]. These companies are based on the use of Information Technology as well as Information and Communication Technology which importance and use has considerably increased over the years.

IT (Information Technology) is a set of measures, devices such as computers and computer networks and tools (including software), as well as other technologies which serve the use of comprehensive information. IT includes: information, computers, computing and communication [7]. IT is based on the use of modern technology, including a computer to acquire, transmit and share information.

ICT - Information and Communication Technologies are technologies dealing with collection, processing and transmission of electronic information [8]. In the circle of information and communication technologies primarily occurs the Internet, growing by leaps and bounds, wireless networks, fixed and mobile telephony and electronic media, which include radio and satellite TV [9].

ICTs include a wide range of IT solutions and complex IT systems allowing the use of this information. There are two distinctive groups of seven basic industries, which more or less are related to IT and ICT: [10]

- The group of communication equipment include:
  - computer hardware;
  - communication equipment;
  - the network equipment and data transmission equipment;
  - office equipment.
- The group of services include:
  - software;

B. Skowron-Grabowska is with Czestochowa University of Technology, Management Faculty, 42-201 Czestochowa, Poland (corresponding author, telephone 48 34 3250309; e-mail: beatas@ zim.pcz.pl).

T. Szczepanik is with Czestochowa University of Technology, Management Faculty, 42-201 Czestochowa, Poland (e-mail: tomeksz@zim.pcz.pl).

- telecommunication services;
- IT services.

The development of information and communication technologies is very fast, and the possibility of using in enterprises very wide. The Information Management System is "the part of information enterprise management system, which is supported by information technology" [11]. ICT technology from hardware facilities provides the use of advanced web services, e-economy, e-commerce, security of networks and systems, mobile access to the Internet. For businesses, this means the ability to accelerate the exchange of information, having a virtual database of organizations, access to Internet services or network marketing [12]. For households, this means the freedom to connect with the world through social media, and the use of a range of e-services such as e-clinic, e-learning or e-commerce [13].

III. Preferences of the customers of information enterprises on the e-commerce market

E-commerce includes the transactions carried out by the network, based on IP and other computer networks [14]. The payment and final delivery of the goods or services ordered by the network can be made both in the network and beyond it. Transactions in the context of e-commerce can be made with or between different entities: businesses, individuals, government agencies and other public and private organizations.

One of the most common forms of electronic commerce are now online stores, which are increasingly offering much more attractive and varied range than in the traditional form [15]. In a large and constant rate widens the range of various e-services [16]. As a result, the industry which began to support online purchasing processes (e-procurement1) through the use of modern technology to ensure better communication between buyers and suppliers, started to develop.

Customizing offers to customers' needs, is one of the elements of e-commerce and it is an important factor for companies operating on the e-commerce market determining the effective fight for customers. Facilities offered by the use of IT and ICT can attract and keep customers. In electronic commerce important is the speed in decision making, the ability to immediate payment for goods which results its immediate dispatch to the customer.

Table 1 devices used in e-commerce

Type of device	% of respondents
portable computer (laptop)	86
desktop computer	69
mobile phone / smartphone	35
tablet	19
e-book reader	4
other	1

[1] This is the area of e-business on the electronic integration and management of all activities related to electronic procurement and sourcing process. It allows you to streamline business processes and gain savings from cheaper purchases of materials and services.

Source: based on "E-commerce in Poland 2014" Gemius for e-Commerce Poland, Electronic Chamber of e-Commerce Poland 2014.

The most commonly used devices to do online purchases are portable devices such as laptop - 86% or mobile phone (35%), but equally popular is the use, for this purpose, your desktop computer - 69%.

Companies must also adapt the offer of payment, so that the customer can choose the most suitable method of payment for chosen goods. Table 2 shows the most common method of payment for purchases on websites.

Table 2.The most frequent methods of payment for purchases on internet services

Method of payment	**% of respondents**
By the service payment: Allegro, Dotpay, PayPal, Przelewy24	**37**
online bank transfer	**28**
Cash on delivery from the courier	**21**
credit card / e-card	**7**
text message	**1**
cash at the seller's premises	**1**
deferred payment	**1**
the mobile payment (via QR codes, etc ..)	**0**
payment by installments	**0**
other	**2**
I do not know / hard to say	**1**

Source: based on "E-commerce in Poland 2014" Gemius for e-Commerce Poland, Electronic Chamber of e-Commerce Poland 2014

For shopping on websites, customers usually make payments via payments services e.g. PayU, Dotpay, PayPal, Transfers24 - 37%. 28% of respondents as a form of payment choose online bank transfer, while 21% decide to pay in cash to the courier upon receipt. This shows the popularity of e-payment among customers, but a large part of them still choose cash transactions, to see them more secure.

In Table 3 there are presented the most convenient forms of delivery and reception of purchased through websites goods.

Table 3 The most convenient method of delivery and reception

Delivery Method	**% of respondents**
delivery by courier	**69**
easyPacks	**15**
delivery by post	**10**
Personal pickup	**4**

receive the package in a kiosk (Service Pack on the Move)	**1**
Other	**1**
I do not know / hard to say	**0**

Source: based on "E-commerce in Poland 2014" Gemius for e-Commerce Poland, Electronic Chamber of e-Commerce Poland 2014

Delivery by courier has been recognized as the most convenient way of delivery / reception of goods by 69% of respondents. 15% indicated easyPack, 10% delivery by mail, while only 4% of respondents indicated personal pickup. Most buyers choose more convenient form of delivery directly into the hands of their own, which makes at every stage of e-commerce, there is no need to leave the house. This e-commerce offer directed to the clients allows to find the product on the network, to make the choice of the product, to pay for it online, and then to expect delivery of purchased goods.

However, despite the advantages of e-commerce, it is also worth to look at the reasons for not buying online, which are presented in Table 4

Table 4 Reasons for not buying online

Reasons	**% of respondents**
I prefer to see the product before buying it	**55**
I'm afraid of problems with the guarantee of the product purchased on the Internet	**34**
I'm used to buying in traditional stores and I do not need to change it	**32**
I fear for the safety of payment	**30**
I'm afraid of problems with delivery	**28**
delivery costs are too high	**25**
I prefer to talk with the seller before buying any product.	**21**
buying online is too complicated	**11**
I cannot find, on the internet, products which I am interested in.	**9**
I do not have time to buy on the Internet	**7**
buying online is too expensive	**6**
Other	**7**
I do not know / hard to say	**21**

Source: based on "E-commerce in Poland 2014" Gemius for e-Commerce Poland, Electronic Chamber of e-Commerce Poland 2014

The elderly and less educated people dominated among no buyers. There is an overrepresentation of rural residents, and people who describe their financial situation as bad. There are also Internet users who are less engaged in activities on the network. Their potential for e-commerce is worth noting - almost half of the network is looking for products or compare their prices. People who have no experience in shopping online (54% of all Internet users) as the main reason for his skepticism indicate the need for physical familiarize themselves with interesting products - this motive shows 55% [17]. This was followed by the security concerns, delivery and after-sales service. It is worth emphasizing that one third of respondents declare simply a habit to traditional trade. Very interesting answers gave the youngest on-line no buyers, because they largely declared the need to familiarize themselves with products, as well as frequently express concerns about transactions safety and problems with delivery. For e-commerce skeptics, low price is the most important argument in favor of using the e-commerce solutions..

IV. Conclusion

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Regardless of the type of business e-commerce market will develop dynamically, and the prognosis for Poland is particularly optimistic. While creating a company, it is certainly worth taking into consideration e-business development. The Convenience and intuitiveness of use, permanent availability, easy and fast contact with customers, new ways of promotion and advertising, and the relatively low cost of setting up this type, are only a few of the most important factors determining the rapidly growing popularity of e-commerce and advantage over traditional trade. E-shopping is not still very common among Polish Internet shoppers, however, it is clear that this kind of purchases is becoming more and more popular by greater use of mobile devices such as a smartphone or tablet. To a lesser extent they also pay in cash, more willingly paying for purchased on the network products by bank transfer or through payment services. Shopping on the websites brings the majority of Internet users benefits in terms of saving time, abilities to compare products. These factors determine customers satisfaction, which results in the use of a wide range of e-services on e-commerce market.

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Pressure Control with Minimal Power Consumption of a Pumping Station

V. Vodovozov and Z. Raud

Abstract— The paper introduces a novel energy-saving pressure control algorithm based on the vector-matrix estimation of working point suitable for programmable logical controllers (PLC). Focus is on the variable speed driven (VSD) parallel connected centrifugal pumps broadly used in industry. The study is aiming to arrange the accurate pressure regulation at minimal power consumption.

Keywords— Pumps, energy saving, pressure control, variable speed drives, power consumption, microcontrollers.

I. Introduction

CENTRIFUGAL pumps represent the most popular type of pumping equipment used in different areas and providing from 80 to 90 % of full water treatment [1], [2]. Commonly, their control is directed to the pressure regulation to prevent cavitations, to compensate unintentional leakages, or to make up the volume variations in the district networks and the building water circulation systems [3]. To supply the pumping stations, the variable speed drives (VSD) are commonly used that, besides the pressure adjustment, provide a wide range of functionalities including the speed adjustment, technology management as well as the power quality improvement. Programmable logical controllers (PLC) remarkably enhance their abilities.

This paper concentrates on improvements in the design of the multi-pump systems that support the required pressure level in the pipeline at minimal consumed power.

A lot of researches in the field of pumping management have been published in recent years.

The first their group concerns the pressure adjustment. In [4] the model-based pressure monitoring was suggested aiming to detect and partially isolate some faulty working conditions. In [5] the feed-forward fuzzy immune algorithm has been proposed aiming to tune controllers in the time-varying nonlinear pressure loops. The proportional pressure control in the multi-valve heating system with a solo VSD pump was discussed in [6]. A constant pressure supply water station, which adopts embedded PLC-based fuzzy controller, was described in [7]. Using a new PLC built-in fuzzy PID controller suggested in [8], the collecting pressure performance could be improved. Under invariant control presented in [9], the steam pressure overshoots were decreased in comparison with the traditional feedback control methods.

Several studies were focused on energy saving [10], [11]. In [12], a novel hybrid estimation method for the centrifugal pump operational state was established basing on the process identification by reading the flow rate and head estimates obtained from the manufacturers' characteristics. In most of the above investigations the efficiency was assigned as a major quality index.

The second group of researches focuses on the multi-pump installations. Particularly, in [13] the deep study of the multi-pump system performance in the best efficiency region has been represented. In [14], an optimal control of a water boosting system built with multiple parallel-connected VSDs was discussed.

A method of the pressure control with minimal power consumption of the multi-pump stations proposed in this work is based on such a peculiarity of the PLC architecture like fast operation with pre-defined tabularized data under the limited number of sensors and actuators. The paper is organized as follows. The first part concentrates on the mathematical model of the pumping process. Then, the vector-matrix model of a pumping station is offered. Specific attention is paid to the consumed power estimates in solo and multi-pump stations. After that, a PLC pump control system is described..

II. Mathematical Model Of Pumping Process

Among the variables described the pumping process the most important are the flow rate Q, head H, and brake power Pshaft on the pump shaft. Their relationship is usually described by the performance and power characteristics (QH and QP curves) supplied with the manufacturer's documentation for the rated rotational speed. Examples of such characteristics can be found in [15] and [16].

When the pressure adjustment is of the primary concern, the pressure in the pipeline can be found from the Bernoulli's equation [17] as follows:

$$p = g\rho\left(H - \frac{v^2}{2g} - z\right), \quad (1)$$

where

p – fluid pressure, N/m^2

$g\rho H$ – initial pressure at the intake, N/m^2

$g\rho z$ – pressure at the measuring point, N/m^2

V. Vodovozov is with Tallinn University of Technology, 19086 ESTONIA (e-mail: valery.vodovozov@ttu.ee).

Z. Raud is with Tallinn University of Technology, 19086 ESTONIA (phone: +372-56665916; e-mail: zoja.raud@ttu.ee).

$p_0 = g\rho(H - z)$ – static pressure, N/m^2

$\rho\frac{v^2}{2}$ – dynamic pressure, N/m^2

$v = \frac{Q}{A}$ – fluid velocity in a pipeline, m/s

A – cross-sectional area of the pipeline, m^2

ρ – fluid density, kg/m^3

g – acceleration due to gravity, m/s^2

z – elevation of the point above the reference plane, m

At the changing pump speed n, the relationships between the above process variables of the hydraulic system are governed by the affinity laws [10], [18]:

$$\frac{Q_1}{Q_2} = \frac{n_1}{n_2}, \tag{2}$$

$$\frac{H_1}{H_2} = \frac{p_1}{p_2} = \left(\frac{n_1}{n_2}\right)^2, \tag{3}$$

$$\frac{P_{1shaft}}{P_{2shaft}} = \left(\frac{n_1}{n_2}\right)^3. \tag{4}$$

Index 1 here denotes the initial states and index 2 – the final states of the variables. Using (2) – (4), the performance and power characteristics obtained from the manufacturer's documentation for the rated speed may be recalculated to the families of performance and power characteristics at different speeds. An example of such a family for the pump Ebara CDX 120/12 [15] is shown in Fig. 1 with the solid traces that display the flow-pressure performance characteristics of a sole pump at the speed range from 2800 to 1000 rpm.

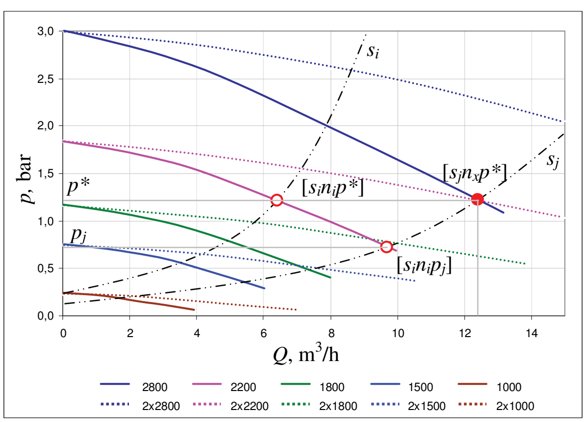

Fig. 1. A family of flow-pressure curves for the sole (solid lines) and paired (dotted lines) pumps Ebara CDX 120/12 crossed by the system traces.

Every pumping station overcomes some particular resistance of the pipeline defined by a specific consumer's design [10]. The model of such a resistance known as a system characteristic is as follows:

$$p_s = p_0 + k_p Q^2 \tag{5}$$

where k_p is the pressure loss coefficient. In contrast to the performance characteristics, the system characteristics cannot be provided by manufacturers because they depend on the pipeline topology. Variations of the liquid consumption affect the system traces that tend left as the resistance increases and tend right when the resistance falls. Particularly, at the closed discharge valve the pump pressure is at its maximum and the flow rate approaches almost zero.

Every intersection of a pump performance characteristic with a system curve represents some process working point. As an example, in Fig. 1 the family of performance characteristics is superimposed by a pair of system characteristics produced at different cross-sectional areas of a discharge valve. An obtained set of working points discretely describes the pumping processes at various pipeline states.

III. Vector-Matrix Model of a Pumping Station

Let every pump may operate at N discrete speed levels n_k ($k \in N$) supporting N respective performance characteristics that cross some of the M discrete pressure levels p_k ($k \in M$). Assume further that the station services different states described by L system characteristics s_k ($k \in L$). Enumerate the points of intersections of the performance and system characteristics as [snp] where n is the speed and p is the nearest pressure level following an intersection point on s_k characteristic. Every [snp]-working point specifies a definite consumed power P_{sup}. These powers can be pre-calculated and stored in a lookup table of the control PLC.

In this way, every possible working state of a pumping process specified by its consumed power P_{sup} is represented as a 3-dimensional [snp]-vector (Fig. 2).

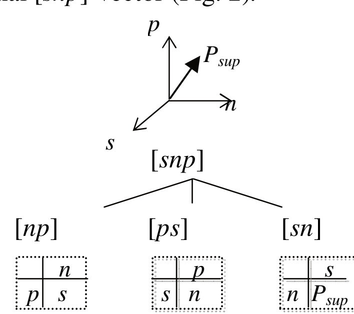

Fig. 2. Vector-matrix model of a pumping station.

Each [np]-sub-vector can be described as an NM-size matrix of the particular system characteristic at different pressure levels for the respective speeds. Each [ps]-sub-vector can be described as an ML-size matrix of the particular speed for different system characteristics at the respective pressure levels. Each [sn]-sub-vector can be described as an LN-size matrix of the supply power P_{sup} at different speed levels for the respective system characteristics.

Let a multi-pump station consists of R pumps. When r identical pumps operate in parallel ($r \in R$), their common flow rate is r times higher than a separate pump has. As an example, a set of dotted lines in Fig. 1 represents the performance characteristics of a pair of parallel-connected pumps. An appropriate model of R parallel connected identical pumps is represented by R similar vectors P_{sup} those flow rates for every r pumps are r times higher than in the separate pump model. The number of system characteristics L can now be increased.

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To estimate the consumed power in the station working points, the following algorithm can be proposed.

From the manufacturer documentation, first, obtain the diagram of the flow rate versus brake power P_{shaft} given along with the performance characteristic for the rated speed. Next, basing on this power characteristic and using the affinity law (4), estimate the brake power at every n_k speed. As well, the mechanical torques T on the pump motor shaft can be also estimated as follows [19], [20]:

$$T = \frac{30 P_{shaft}}{\pi n} \tag{6}$$

After that, address to the drive manufacturers' documentation, for example [21], [22], where the motor and power converter losses ΔP_{MC} are usually presented for their part-torque operation at different speeds. Now, the consumed powers in the station working points can be estimated as follows:

$$P_{sup} = P_{shaft} + \Delta P_{MC} \tag{7}$$

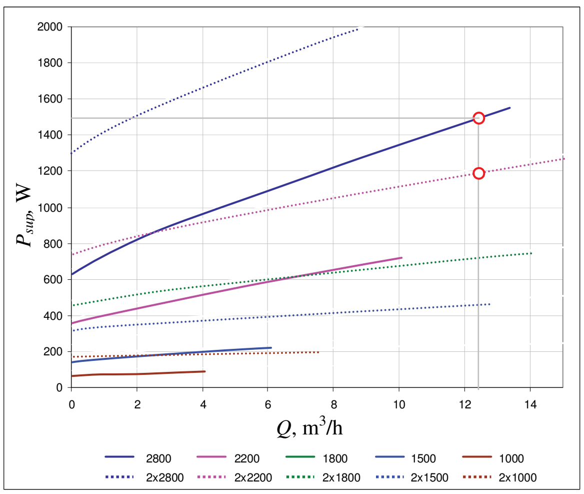

Fig. 3. A family of flow-power characteristics of the sole (solid lines) and paired (dotted lines) pumps Ebara CDX 120/12 driven by ACQ810 VSDs.

For example, in Fig. 3 a family of the flow rate versus supply power P_{sup} curves developed for the sole Ebara CDX 120/12 are drawn with solid lines. To build them, the nominal pump brake power characteristic was acquired from [15] and recalculated with (4) for every performance characteristic in Fig. 1. To find the drive losses, the data of ACQ810 VSDs were obtained with the help of [22].

In the case of r pumps, their common brake power and drive losses increase r times compared to the separate one. In Fig. 3 a recalculated family of flow-power characteristics for the pair of parallel-connected pumps Ebara CDX 120/12 is drawn with dotted lines.

IV. PLC Pump Control

Multiple control algorithms may be offered using the above model which helps the designer to maintain and explore all the model variables.

Let the system equipped with speed and pressure sensors aims is to stabilize some reference pressure at variable system states and to perform it with minimal power consumption. To solve this problem, it is reasonably to use only R [np]-matrixes where, at the intersections of p^* rows and n columns, the consumed powers P_{sup} are stored. The following control algorithm can be proposed.

Let initially the pumping station is in i^{th} working point [$s_i n_i p^*$] shown in Fig. 1. It means that a pump rotating at n_i speed supports a reference pressure p^* at the system state s_i. Assume that, under an influence of a disturbance, the pressure has been changed to p_j. This calls the transition of the working point to a new system state s_j at the same speed n_i. The control task is to shift the working point to the new position [$s_j n_x p^*$] of the system characteristic s_j targeting to support the reference pressure level p^*. For this purpose, once the sensor detects the new pressure p_j, the PLC must search all the possible numbers of pumps r and their speeds n_k for the reference pressure level p^*.

The first speed under the question can be calculated using the affinity law (3) as follows:

$$n_k = n_i \sqrt{\frac{p^*}{p_j}} \tag{9}$$

Call the PLC to search the appropriate consumed power P_{sup} at the intersections of p^* rows and n_k columns in all R [np]-matrixes. Next, these powers have to be compared and to choose the variant with the minimal one. Once the solution found, the required pumps are running, their reference pressures assigned, and the pressure control executed.

The functional diagram in Fig. 4 represents an experimentally tested system built on Ebara CDX 120/12 pumps driven by ACQ810 VSDs. Here, a multi-pump station consists of the common PLC connected to R VSDs one of those is shown. The PLC implements the control algorithm, and runs the pumps. A motor M connected to the pump is supplied with a power electronic converter. The direct torque control (DTC) system converts the sensing motor currents I and voltages U and, basing on the reference speed n^*, identifies the required supply voltages U^* for the power converter and runs the pump.

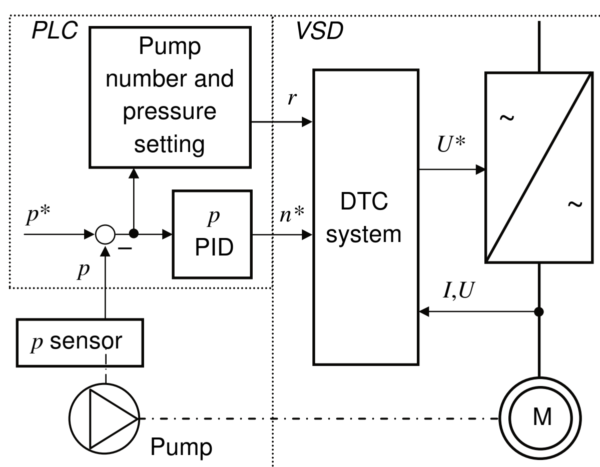

Fig. 4. Functional diagram of PLC-based pressure control.

The reference speed of the VSD is received from the output of the proportional-integral-differential (PID) pressure regulator which estimates, restricts, and converts the difference of the reference p^* and actually measured p pressures.

Any time when the pressure changes, the PLC runs the above algorithm aiming to find the best choice from the viewpoint of the consumed power, is it a single pump rotating at some recommended speed or several pumps working at lower speeds. After that, the required pumps are running and the pressure PID control executed.

For example, let the target working point is $[s_j n_x p^*]$ in Fig. 1 where two variants of control are possible: one pump operated at the speed of 2800 rpm or two pumps operated at 1200 rpm each. As follows from Fig. 3, in the former case the consumed power is about 1500 W whereas in the latter case the common consumed power is about 1200 W. Hence, from the economy point of view, two pumps operated at lower speeds better suit the optimum criteria.

V. Conclusion

The new pressure control algorithm based on vector-matrix working point estimation with the PLC has been proposed and verified. Besides the effective pressure regulation it provides the system operation at the minimal power consumption.

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Introducing Dynamic Project Management in a Novel Adsorbent Production/Application Scheme for Oil Spill Response in Aquatic Environments

Dimitrios Sidiras, Dimitrios Batzias, Christina Siontorou, Leonidas Kamarinopoulos, Yiannis Pollalis, Fragiskos Batzias

Abstract — This work deals with introducing dynamic project management in the development/production/application of a novel adsorbent aiming at water pollution response, especially when the pollutant is a mixture of hydrocarbons, like in the case of an oil spill. Initially, we analyze the top-down and bottom-up approaches in dynamic programming and present the difficulties in total cost minimization when it is used within an optimization procedure based on the tradeoff between indirect and direct cost for performing each activity/stage of the program. An environmental project management network has been designed/developed to overcome these difficulties including (i) stages/activities in series/parallel and (ii) decision nodes considering alternatives. Subsequently, this network is implemented in the case of production of a novel adsorbent within an international R&D program supported by the EU. Emphasis is given on the cooperation with (i) laboratories, which cover the technological dimension, (ii) information technology experts, who cover the systems analysis dimension, and (iii) environmental investment evaluators, who cover the economic dimension, in order to achieve a multi-disciplinary approach and fulfill the 'complementarity', which is a *sine qua non* condition for undertaking an R&D program subsidized by the EU. Finally, sensitivity analysis is carried out in relation with the decision nodes performance and the results are discussed.

Keywords — dynamic programming, environmental management, oil spill response, optimization, water pollution.

I Introductory Analysis

Dynamic Project Management (DPM) is an applied version of dynamic programming, where the Bellman's Principle of Optimality dominates either under the form of the 'Bellman equation' in case of solving discrete-time optimization problems or under the form of the 'Hamilton – Jacobi – Bellman equation' in case of solving continuous-time optimization problems. Ideally, there are two approaches to deal with such problems within a computer programming environment; top-down by deduction and bottom-up by induction. The first of them is a direct/straightforward decomposition of the recursive formulation of the problem under consideration. If (i) the solving procedure can be structured recursively, using the sub-procedure adopted/adapted to each sub-problem, and (ii) the formalism of at least certain sub-problems is repeated, then we may store the solutions corresponding to each sub-problem in a table serving as a check list. In case that we have to solve a new problem, we decompose it to sub-problems following the same formalism we have previously used; subsequently, we check weather some of these sub-problems are included in the table mentioned above. If corresponding successful solutions have been included, we apply them *mutatis mutandis*; if either there are not such solutions or the applied ones are proved unsuccessful, we try to solve these sub-problems through a new procedure. On the other hand, the bottom-up approach is based on reformulating the problem in such a way that the solved sub-problems can be easily recomposed to give the original problem as well as more general problems of the same kind. Proper algorithmic procedures can be found in [1]-[3].

Optimization in DPM may be based on cost minimization of certain stages, which belong to the critical path that determines the project Completion Time (CT), denoted by D. These stages are the sub-problems that obey to the same formalism, according to which the cost $C(D)=C_1(D)+C_2(D)$ is the dependent variable, while $C_1(D)$ and $C_2(D)$ are the partial costs, representing indirect and direct cost, respectively. The first of these partial costs is an increasing function of D with an increasing rate (i.e., $dC_1/dD>0$, $d^2C_1/dD^2>0$), since the penalty clauses included in agreements (usually under the form of a legal document) determine disproportionally higher fine, for breaking an enchaining rule, in the region of higher D-values. The second of these partial costs is a decreasing function of D with an increasing algebraic or a decreasing absolute rate (i.e., $dC_2/dD<0$, $d^2C_2/dD^2>0$ or $d|dC_2/dD|/dD<0$) because of the validity of the Law of

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F. A. Batzias is with the Dep. Industrial Management & Technology, Univ. Piraeus, 80 Karaoli & Dimitriou, GR18534 Piraeus, Greece (corresponding author phone: +30-210-4142360; fax: +30-210-4142392; e-mail: fbatzi@unipi.gr).

D. K. Sidiras, D. F. Batzias, L. Kamarinopoulos and C. G. Siontorou are with the Dep. Industrial Management & Technology, Univ. Piraeus, 80 Karaoli & Dimitriou, GR18534 Piraeus, Greece (e-mail: sidiras@unipi.gr, dbatzias@unipi.gr, lkamarin@unipi.gr, csiontor@unipi.gr.

Y. Pollalis is with the Dep. Economic Science, Univ. Piraeus, 80 Karaoli & Dimitriou, GR18534 Piraeus, Greece (e-mail: yannis@unipi.gr).

Diminishing (differential or marginal) Returns (LDR): the higher the time compression of a stage (i.e., intensification of the corresponding operation by spending more resources/human efforts) the higher the respective costs, following a non-linear pattern. Evidently, D_{opt} is determined as the abscissa of the C_{min} point, which represents the equilibrium in the tradeoff between the conflict variables C_1 and C_2; at this point, $MC_1=MC_2$, where $MC_1=dC_1/dD$ and $MC_2=\left|dC_2/dD\right|$ are the marginal values of C_1 and C_2, respectively.

In case of an interest rate decrease, the C_1-curve moves downwards becoming more flat, because the indirect cost decrease is expected to be more expressed in the region of higher D-values, since the interest rate decrease implies less expenses, as well as lower economic penalty in case of breaking agreed clauses in the long run; as a result, D_{opt} is shifting to D'_{opt}, where $D'_{opt}>D_{opt}$, as shown in Fig.1a. In case of introducing a better knowledge management approach, through an Expert System (ES), and interconnection with laboratories providing relevant data, the C_2-curve is expected to move downwards becoming also more flat, since the cost decrease will be more expressed in the region of lower D-values, where cost was already high due to the excessive expenditure required to compress stage duration; as a result, D_{opt} is shifting to D''_{opt}, where $D''_{opt}<D_{opt}$, as shown in Fig.1b. It is worthwhile noting that in both cases C_{min} decreases while the vectors ($D'_{opt}-D_{opt}$) and ($D''_{opt}-D_{opt}$) have opposite direction, which means that the final D_{opt} placement (i.e., to the left or right of its original position) is depended on the form of the partial cost functions and their parameter values.

The movement of the C_1-curve in the first of the two cases analyzed above seems to depend on an exogenous factor (i.e., the interest rate) while the second of them seems to depend on an endogenous factor (i.e., the adopted/adapted knowledge exploitation/exploration method). Nevertheless, since interest rate forecasting is performed within the DPM framework, the first factor is endogenously introduced as regards its quantitative expression. Similarly, the effectiveness of the second factor depends on the knowledge introduced exogenously through the Intelligent Agent (IA) in charge to transfer knowledge from external Knowledge Bases (KBs). Consequently, both factors are not purely exogenous or endogenous, but are rather a mixture as regards their origin. Since these mixtures depend on the kind of project under consideration for applying DPM, there is a difficulty in formulating sub-problems allowing for similar algorithmic solution procedures, a basic condition characterizing dynamic programming, especially in its mathematical/computerized version [4]-[6]. This difficulty is higher in the case of an environmental project, where parameter values in most stages frequently change over time, especially when R&D is included, for introducing a novel material to combat water pollution in large scale, as it is the case in the present work.

Moreover, distinct/simple top-down and bottom-up approaches cannot apply, since setting *a priori* conditions/assumptions and making *a posteriori* reformulations usually take place interactively within the same stage, making the design/development of pure recursive functions almost impossible or impractical for common use.

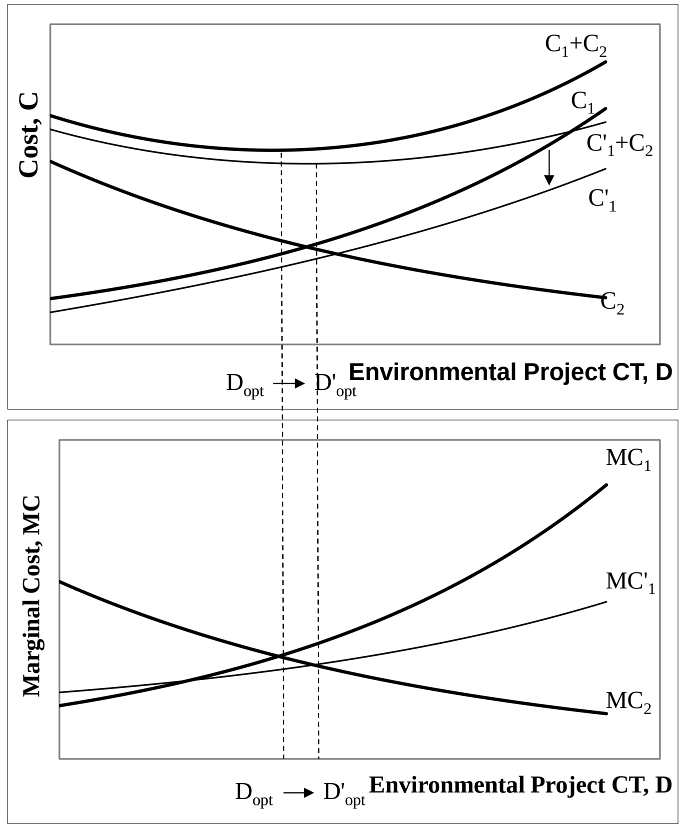

Fig. 1a. Dependence of indirect and direct costs C_1 and C_2, respectively, on environmental project Completion Time D, and shifting of the optimal value D_{opt} in case of an interest rate decrease in the time course.

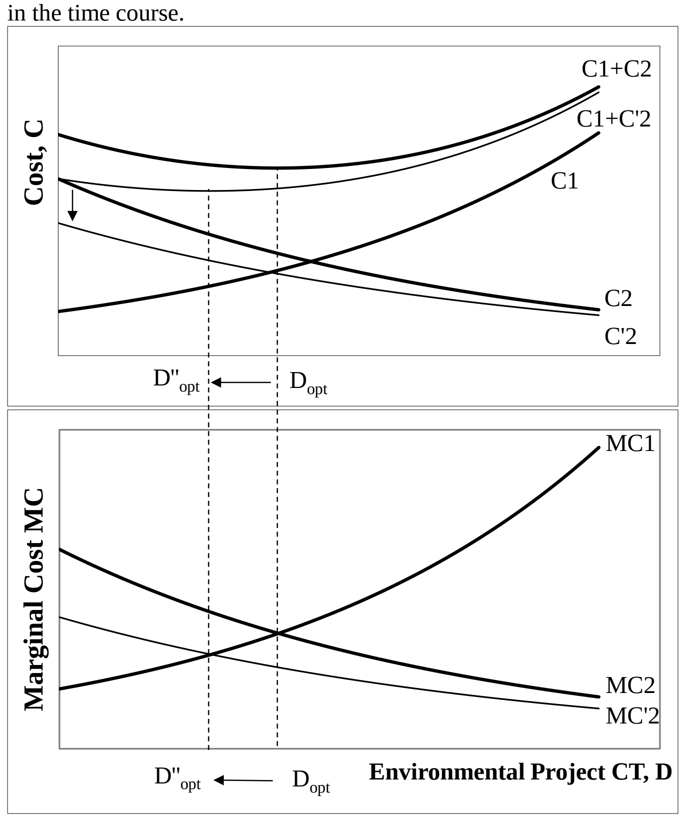

Fig. 1b. Dependence of indirect and direct costs C_1 and C_2, respectively, on environmental project Completion Time D, and shifting of the optimal value D_{opt} in case of introducing a better knowledge management approach, through an expert system.

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II METHODOLOGY

In order to cope with the difficulties quoted above, we have developed a DPM approach methodology, properly designed to meet the needs of an environmental project, concerning the 'Development of New Material from Waste Biomass for Hydrocarbons Adsorption in Aquatic Environments' (Research Program co-financed by the European Union and Greek national funds). The interconnection of the subsequently described necessary activities/stages is shown in the flowchart of Fig. 2, where the arrow (network) diagram representation has been adopted. In such representations, the precedence relationship between activities is denoted by using events. An event represents a point in the time domain, signifying the completion of certain activities and the beginning of other ones. Therefore, the start and end points of an activity are defined by two events, named 'tail' and 'head' of the corresponding arrow, the length of which need not be proportional to the duration of the activity nor does it have to be depicted as a straight line.

(0,1) Assessment of spatiotemporal distribution of agricultural land (per cultivar, with reference to the yield per acre) and mapping data in the corresponding layers of a Geographic Information System (GIS).

(1,3) Evaluation of lignocellulosic residues remaining in fields and mapping of data in the GIS layers.

(3,5) Sample survey to record the intention of farmers (i) to collect and lay (on own means) lignocellulosic residues near the fields to be transported for further processing (Willingness To Supply - WTS) or (ii) to pay jointly an undertaker for doing the same job (Willingness To Pay - WTP) or (iii) to accept the exploitation of agricultural remains on a small fee (Willingness To Accept - WTA).

(5,7) Mapping the road (including the rural) networks in GIS.

(7,9) Optimal choice of accessible points (preferably by large trucks, in order to benefit from scale economies) for the trans-shipment.

(0,2) Assessment of spatiotemporal distribution of forested land (by type of forest flora, with reference to the increase of forest capital and type of operation) and mapping of data in the corresponding GIS layers.

(2,4) Evaluation of lignocellulosic residues at forestrated areas and mapping of data in GIS layers.

(4,6) Sample survey to record the intention of the forest stakeholders (including residents of nearby communities engaged in logging) to collect and lay (on own means) lignocellulosic residues near the fields for transfer to Biomass Processing Units (BPUs) for further processing (Willingness To Supply - WTS).

(6,8) Mapping the road (including the forest) networks in GIS.

(8,10) Optimal choice of accessible points (preferably by large trucks, in order to benefit from scale economies) for the trans-shipment.

(13,14) Selection and study of the available pollution countermeasures.

(14,15) Determination of methods/practices for the implementation of adsorbents in inland waters (rivers, lakes, wetlands) and shallow bays (near the shoreline).

(13,15) Cooperation agreements with local authorities/ agencies.

(15,16) Selection of a method for disposal/further utilization of lignocellulosic materials after adsorption (e.g., landfilling or incineration to benefit from the increased calorific value).

(0,11) Mapping of existing waste water receivers in GIS.

(11,12) Mapping of present and expected (accidental and systematic) pollution in separate GIS layers.

(12,13) Recording of information on potential pollution sources and short-term forecasting, using interval analysis to count for uncertainty, taking into account the most optimistic and the most pessimistic scenarios (best/worst case approach) as extreme cases.

(16,17) Determination of spatiotemporal supply and demand for pollution abatement services, taking seasonality into account.

(17,20) Preliminary environmental impact assessment (including approximate cost-benefit analysis).

(9,13) Solving the location problem of the trans-shipment points, taking into account the estimated availability of the vehicle fleet during the harvest periods, so that the lignocellulosic material will not remain at the trans-shipment stations for a long time risking its quality (mainly due to enzymatic hydrolysis and biodegradation, which is accelerated by micro-climatic factors such as increased temperature and humidity).

(10,13) Solving the problem of forest residues trans-shipment, likewise to (9,13) for agricultural wastes.

(0,18) Pre-feasibility study for a prototype BPU, including quality control in the design phase, with emphasis on the methodology for testing product reliability.

(18,19) Sensitivity analysis (under uncertainty) of the first break-even point which is determined by quantifying the environmental benefit (cost-benefit analysis under uncertainty).

(19,20) Assessment of the scale economies expected to be achieved.

(A,21) Further data collection/processing.

(B,23) Preliminary placement of BPUs and determination of their optimal production capacity.

(23,24) Environmental impact assessment of the operation of the BPUs, taking into account that the product contributes significantly to the protection/restoration of the aquatic environment, thus a clear preponderance of positive impacts is expected, and the proposed BPUs are of low disturbance whereas the additives that will be used for biomass modification will derive from by-products/wastes of other industrial units, a synergy that provides an additional environmental benefit within the Industrial Ecology framework.

(24,25) Resolving ownership problems that may result from the placement of the BPUs and their supporting network.

(25,26) Final placement of BPUs by solving the location/allocation problem while also solving any other problems related to trans-shipment and/or optimization of the production/storing capacity.

(26,27) Simulation of the operation (including quality control, emphasizing on product reliability, under the expected conditions of supply of wasted/recyclable raw material and demand of the novel adsorbent produced).

(27,28) Optimization of each activity duration through time compression.

(28,29) Final cost-benefit analysis, after the determination of capital cost through depreciation.

(29,30) SWOT analysis, to assess the viability and profitability of the project.

(C,31) Corrective interventions, in accordance with the SWOT results.

(C,32) Compilation of the business plan, in accordance with legislation and other provisions for licensing either with State participation in the initial investment or with granting for a long-term loan at significantly reduced interest rate.

(D,34) Writing of a report on the expenditures that the subsidy may cover.

(E,33) Subsidy increase by taking advantage of this margin.

(33,34) Writing of a report on conditions/prerequisites that may permit subsidies extension.

(34,35) Internal KB updating/enrichment/restructuring [7].

(35,36) Design/developed of an Inference Engine (IE), mainly by using Case Based Reasoning (CBR), for searching within the internal KB [8]-[11].

(36,37) Adoption/Adaption of an IA properly modified to provide the internal KB with necessary information extracted from external KBs, as described in [12].

(A) Are the already available data (within the internal KB) adequate for such an environmental impact assessment?

(B) Are the already available data/information adequate for taking into account synergies and externalities expected to occur, creating an Industrial Ecology framework, in candidate places of BPU installation?

(C) Is the knowledge acquired so far capable (i) to make reliable estimations of the present situation parameters and (ii) to forecast trends in the medium/long run?

(D) Is the subsidy and the rest financial tools sufficient to support the investment satisfactorily?

(E) Is there a margin permitting subsidy increase as a result of including externalities (after externalizing/ quantifying non-marketable benefits) in the cost-benefit analysis performed by the State?

The SWOT analysis (denoting Strengths, Weaknesses, Opportunities, Threads), quoted in stages (29,30) and (C,31),

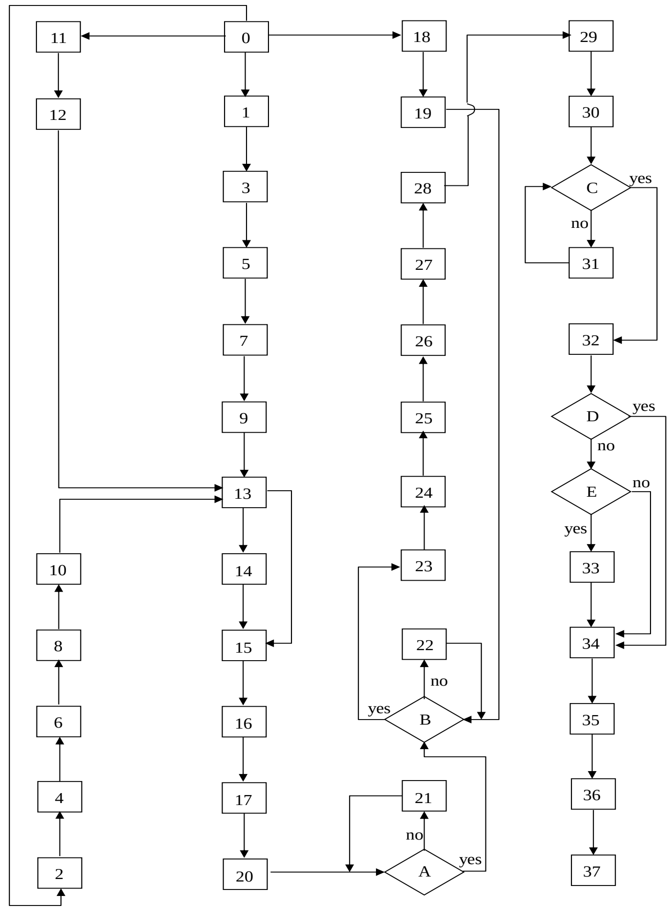

Fig. 2. Dynamic network analysis of the environmental project, under the form of a flowchart, with stages/activities in series/parallel and decision making (DM) nodes, depicted as arrows and rhombi, respectively.

includes a closed forecasting/backcasting loop, putting emphasis on the backcasting module, which is responsible for any scheduling revision that should be made within a DPM framework.

III IMPLEMENTATION

The methodology described above has been illustrated numerically in the case of a Greek island of the E. Aegean Sea located nearby the route that oil transporting tankers follow in their way from Russia initially to S. Aegean and then either to Suez Canal or Gibraltar. For the assignment of duration values on activities, three evaluators were used, giving fuzzy numbers in triangular LR form to count for uncertainty. The technique of consensus in input was used for defuzzification by means of the centroid method and the corresponding results are shown as crisp numbers in Table I. Activities with zero duration before or after a Decision Making (DM) node serve as dummy ones to indicate interdependence and precedence relationships among entering and leaving (to/from that node) activities. Nevertheless, such dummy activities may turn to real ones, even forming part of either an already established critical path or a new one, depending on the result/output of a DM node.

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Table I. Numerical data for duration per activity in hours (crisp numbers, after defuzzification) corresponding to DPM simulation for a Greek island of the Eastern Aegean Sea.

Activity	Duration
(0,1)	3,6
(1,3)	1,5
(3,5)	5,7
(5,7)	4,8
(7,9)	2,9
(9,13)	11,2
(0,2)	3,6
(2,4)	1,1
(4,6)	7,3
(6,8)	5,4
(8,1)	3,7
(10,13)	4,4
(0,11)	0,9
(11,12)	4,1
(12,13)	1,8
(13,14)	21,1
(14,15)	10,2
(13,15)	2,3
(15,16)	4,9
(16,17)	5,1
(17,20)	14,3
(20,A)	-
(A,21)	8,3
(21,A)	-
(A,B)	-
(B,22)	31,7
(22,B)	-
(B,23)	17,4
(23,24)	7,3
(24,25)	21,8
(25,26)	62,4
(26,27)	2,9
(27,28)	34,1
(28,29)	19,7
(29,30)	42,2
(30,C)	-
(C,31)	3,8
(31,C)	-
(C,32)	16,3
(32,D)	-
(D,34)	4,1
(D,E)	-
(E,33)	10,5
(E,34)	-
(33,34)	6,3
(34,35)	7,6
(35,36)	9,3
(36,37)	7,9
(0,18)	51,1
(18,19)	3,3
(19,B)	4,6

The corresponding critical path, with total duration 338.3 hours, is shown in Fig. 3, where the respective activities are quoted in grey, in case that the Boolean output of all DM nodes is 'yes'. A significant change of the critical path may take place, if at least one of these Boolean outputs changes, provided that the implied numerical difference is adequate to make longer the partial duration of another path, arranged in parallel. Such an example is given in Fig. 4, where the output from the DM node B is 'no'. In this case, the parallel partial path (0,18), (18,19), (19,B), (B,22) is activated, becoming part of the new critical one. The new total duration is 343.7 hours (i.e., 5.4 hours higher compared to the previous critical path, depicted in Fig. 3).

Sensitivity analysis can be performed by examining the impact of the change of the duration assigned to a certain activity onto the project total duration. Such an example is shown in Fig. 5, where the duration of the (A,21) activity is arbitrarily set to 28.3 hours (i.e., 20 hours more than the 8.3 value quoted in Table I). Evidently, the critical path is initially the one depicted in Fig.3, including the (A,21) activity, on

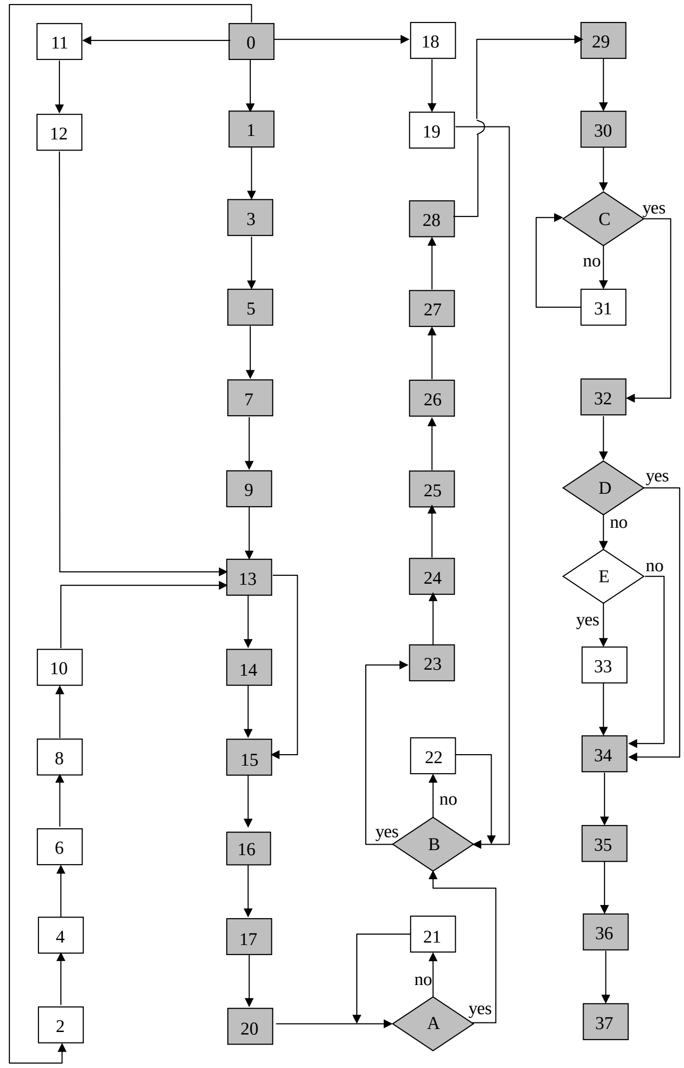

Fig. 3. DPM implementation based on the numerical data of table I, in case that the output of all DM nodes is 'yes'; the path quoted in gray is the critical one, giving total time of 338.3 hours.

condition that both the Boolean outputs from DM nodes are 'no' (the rest model outputs maintained to the 'yes' option); by decreasing the (A,21) duration through the intensification of this activity (see the Discussion Section subsequently), the total project duration decreases, until this decrease becomes 358.3 – 343,7 = 14.6 hours, when the critical path changes. It is worthwhile noting that the initial total project duration of 338.3 hours is not taken into account herein, since it was estimated for 'yes' output from the DM node A.

The intensification mentioned above can be realized by consuming more resources, thus increasing the direct cost, as represented by $C_2(D)$ in Fig. 1. Nevertheless, there is a limit, called 'crush time', beyond which no further reduction in the duration can be effected. In practice, the non linear curve $C_2(D)$ can be approximated by a piecewise linear curve, when the respective activity can be broken down into a small number of sub-activities, each corresponding to one of the line segments, where the local slop dC_2/dD is constant.

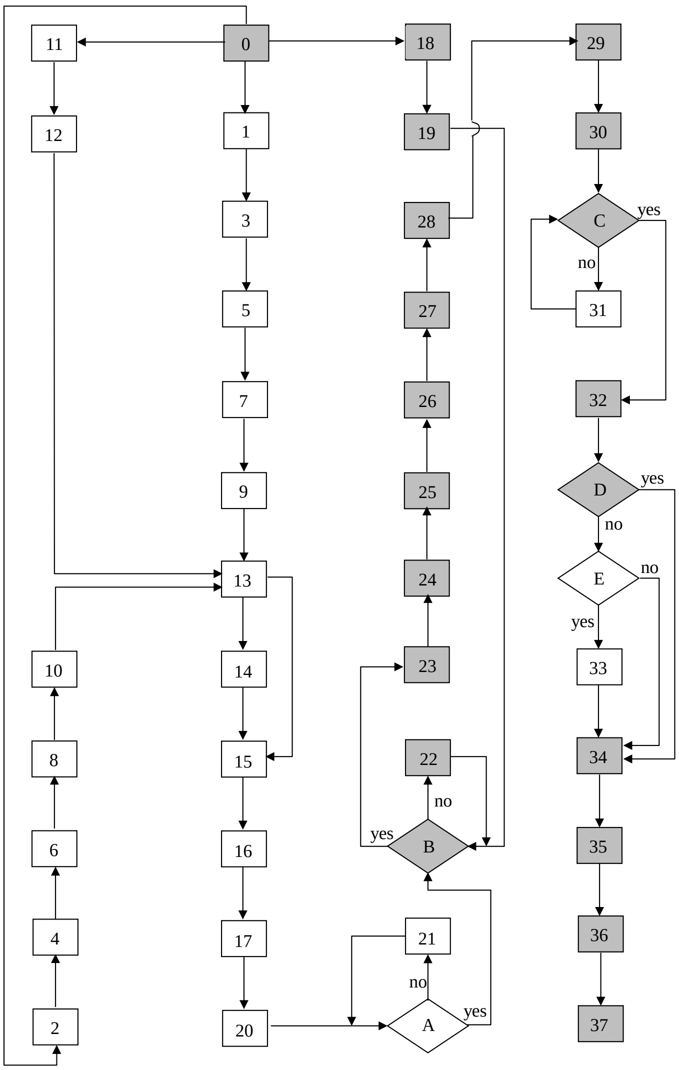

Fig. 4. DPM implementation based on the numerical data of table I, in case that the output of all DM nodes (with the exception of *B*) is 'yes'; the new path quoted in gray is now the critical one, giving total time of 343.7 hours (i.e., 5.4 hours higher compared to the previous critical path, depicted in Fig. 3).

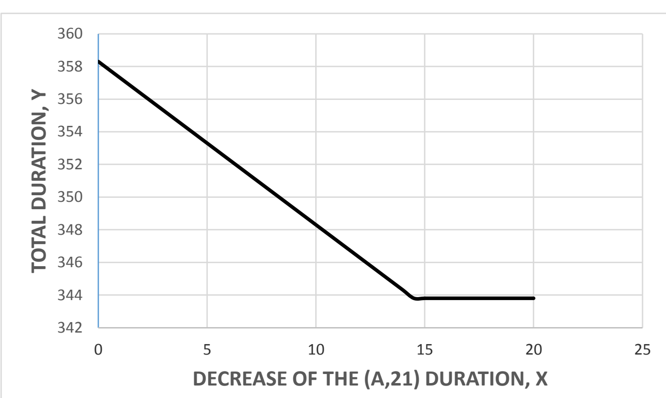

Fig. 5. Dependence of the total project duration on the decrease of the (A,21) activity duration (both expressed in hours), representing a monoparametric sensitivity analysis approach; the intersection point signifies the critical path change.

IV DISCUSSION

The optimum number of Decision Making (DM) Nodes, N_{opt}, can be determined as the abscissa of the maximum of the network technoeconomic Efficiency P_{max} (including operational characteristics, like Performance/Functionality), $P(N)_{max}=[P_1(N)+P_2(N)]_{max}$, where the conflict variables $P_1(N)$ and $P_2(N)$ depend mainly on the acquired knowledge objectivity and the expenditure (including capital and operation cost) to obtain/process/store/update the required information at proper granularity level, respectively. The first partial efficiency variable P_1 is an increasing function of N (i.e., $dP_1/dN>0$), since conceptual merging of certain questions into a unique node by using experts' opinion, increases subjectivity, thus decreases network objectivity. This increasing function has a decreasing rate (i.e., $d^2P_1/dN^2<0$), as a result of network being less flexible (characterized by fewer degrees of freedom) and more sensitive locally. The second partial efficiency variable P_2 is a decreasing function of N (i.e., $dP_2/dN<0$), since expenditure increases (economic efficiency decreases) with N; the same function exhibits a decreasing algebraic or an increasing absolute rate (i.e., $d^2P_2/dN^2<0$ or $d|dP_2/dN|/dN>0$), since efficiency is an increasing function of capital cost, because of the validity of the LDR. Evidently, (N_{opt}, P_{max}) is the equilibrium point in the tradeoff between P_1 and P_2 at $dP/dN=0$ or $d(P_1+P_2)/dN=0$ or $MP_1=MP_2$, where

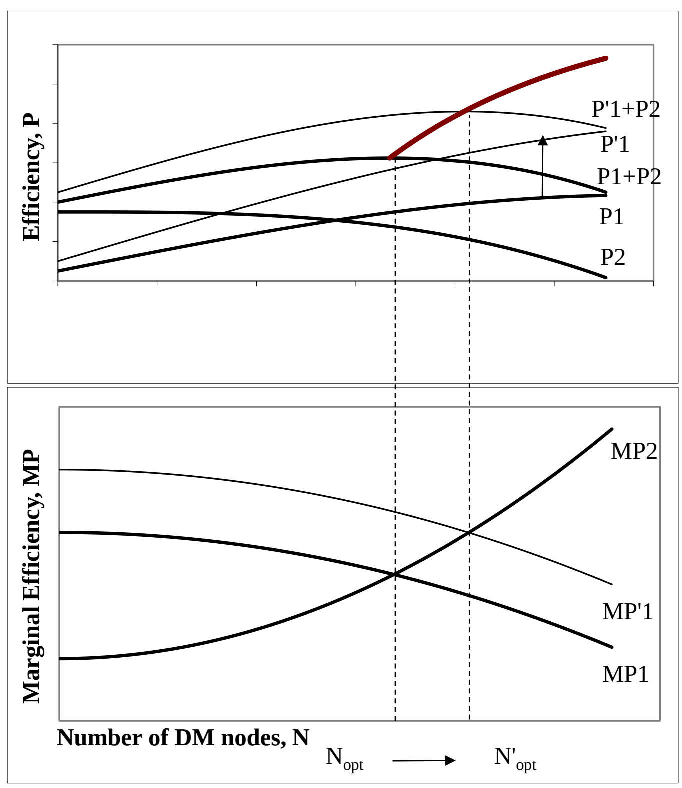

Fig. 6a. Dependence of partial efficiencies P_1 and P_2 on the number of DM Nodes N, represented as continuous curves, and shifting of the optimal value in case of introducing a computer aided processing of information, to reduce the optimal duration of stages already on the critical path; the thick curve in the upper diagram is the locus of the P_{max}-points.

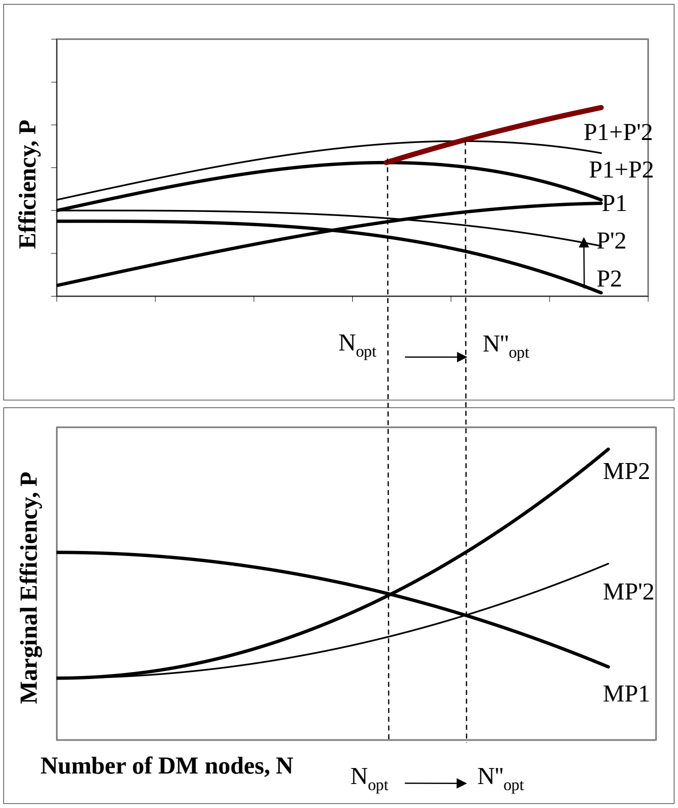

Fig. 6b. Dependence of partial efficiencies P_1 and P_2 on the number of DM Nodes N, represented as continuous curves, and shifting of the optimal value, if the same computer aided processing contributes to improvement of cooperation between network activities, thus decreasing the necessity for information at higher granularity level; the thick curve in the upper diagram is the locus of the P_{max}-points.

$MP_1=dP_1/dN$ and $MP_2=|dP_2/dN|$ are the marginal values of the opposing (to each other) partial dependent variables P_1 and P_2 at N_{opt}.

In case of introducing a computer aided processing of information to reduce the optimal duration of stages already on the critical path, the P_1-curve will move upwards, becoming also steeper, since the difference is expected to be more expressed in the region of higher N-values, where the situation is complicated and the necessity for fast combinations calls for computerized solutions; as a result, the N_{opt} will shift to N'_{opt}, where $N'_{opt}>N_{opt}$, as shown in Fig. 6a. If this computer aided processing contributes to improvement of cooperation between network activities, thus decreasing the necessity for information at higher granularity level, where the operating cost is disproportionally higher, then the P_2 curve is expected to move upwards becoming more flat, since the difference is expected to be more expressed in the region of higher N-values, where the cost for knowledge acquisition is already high and the corresponding economic margin wider; as a result, the Nopt will shift to N''_{opt}, where $N''_{opt}>N_{opt}$, as shown in Fig. 6b. It is worthwhile noting that in both cases P_{max} increases; moreover, the vectors ($N'_{opt}-N_{opt}$) and ($N''_{opt}-N_{opt}$) have the same direction, which means that the final N_{opt}-value is N_f , where $N_f = (N'_{opt}-N_{opt}) + (N''_{opt}-N_{opt})$.

In the medium/long run, accumulated experience will have the same implications that introducing computer aided processing of information is expected to have. This means that the analysis presented graphically in Fig. 6a and Fig. 6b will hold even when no computerized system is used, although the combination of human and machine expertise is expected to have a very significant synergistic effect, starting from 'learning by doing' and reaching to Cybernetics of 2nd order. More specifically, implicit/subjective knowledge can be externalized, thus becoming more objective, through a SECI mechanism, as described by Nonaka et al. in [13]-[15], including four stages in cyclic arrangement (i.e., without start/end points): Socialization (S), as the process of converting shared experience into new implicit knowledge; Externalization (E), as the process of converting implicit to explicit knowledge; Combination (C), as the process of converting rather simple to more complex explicit knowledge; Internalization (I), as the process of converting explicit into implicit knowledge, by embodying the former into the experts' cognitive background. This illustrative mechanism indicates a movement rather on a spiral than on a cycle circumference, since each recursive procedure in the DPM examined herein changes as a function of time. Therefore, recursiveness is incomplete in both approaches, the top-down by deduction and the bottom-up by induction (see the Introductory Analysis Section). A partial remedy to this incompleteness is to re-establish constancy in product properties and production/storing conditions through quality and process control, respectively.

The quality control of the stored lignocellulosic adsorbent, included in the activities (25,26) and (26,27), may result to the constancy of the adsorptive properties of the product, determining also its partial deterioration or 'ageing' θ, in the

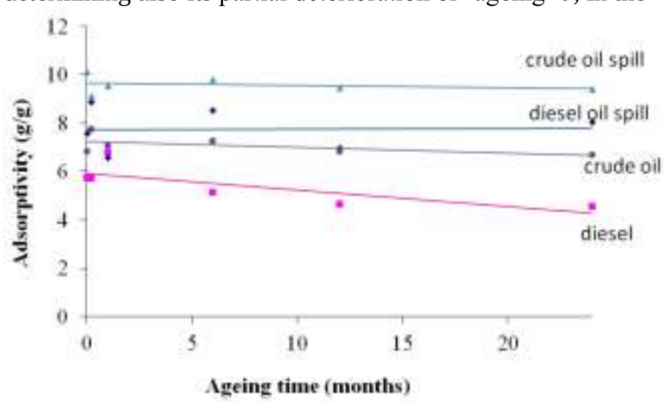

Fig. 7. Ageing within a time period of 24 months; percentage of total ageing in terms of adsorptivity loss: diesel 27.8%, crude oil 7.9%, diesel oil spill not-ageing, crude oil spill 2.5%.

warehouse of either the BPU or the facility, where it is waiting for final usage in water pollution abatement. In the simple case of constant θ, the inventory level I in the warehouse facility at time t is given by the following differential equations, according to [16], [17]:

$$\frac{dI(t)}{dt} = \theta * I(t) = -Z \quad ,0 \leq t \leq t_1 \qquad (1)$$

$$\frac{dI(t)}{dt} = -Z \quad , \ t_1 \leq t \leq T \qquad (2)$$

where Z is the constant demand for the adsorbing material, t_1 is the time at which the inventory level in the 1st (possibly generalized to the jth) replenishment cycle drops to zero (i.e., $I(t_1)=0$), and T is the length of each replenishment cycle.

The constancy of θ has been confirmed by experimental work we have performed within a 24-month period, as shown in Fig. 7. Nevertheless, the value estimated for this parameter is not the same for diesel and crude oil, being higher in the former case; on the other hand, ageing is less under simulated oil spill conditions. These results should be taken into account in the experimental design for accelerated testing.

V CONCLUSIONS

Dynamic Project Management (DPM), based on multistage programming, seems to be suitable for environmental applications, because they are involving decision making (DM) over time. Nevertheless, we have proved that distinct/simple top-down and bottom-up approaches cannot apply, since setting *a priori* conditions/assumptions and making *a posteriori* reformulations usually take place interactively within the same stage, making the design/development of pure recursive functions almost impossible or impractical for common use. The functionality of the methodology we have developed and presented herein, in order to overcome this difficulty, is proved by analyzing the successful procedure followed in the research project ‘Development of New Material from Waste Biomass for Hydrocarbons Adsorption in Aquatic Environments’, carried out in the period 2011-2015.

Moreover, we have proved (i) the feasibility of determining the optimum number of DM nodes at maximum efficiency of the dynamic network, and (ii) that this optimum number increases in case of introducing a computer aided processing of information to reduce the duration of stages already on the critical path. Last, we have indicated a way of entering data/results from laboratory experimental work (on adsorbents ‘ageing’) into an inventory control model in order to optimize the adsorbent quantity in a facility warehouse, waiting for final usage in water pollution abatement.

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Climatic Signal Analysis of Precipitation in the Apulian Peninsula (Italy)

Anastasios Kalimeris and Ezio Ranieri

***Abstract*—**Peninsula of Apulia (in Italy) is a well suited area for the search of climatic variability in the Central Mediterranean. The monthly precipitation height series of six coastal Apulian stations are analyzed by a combination of spectral decomposition techniques such as, the revised Multi-Taper Method, the Singular Spectrum Analysis, and Wavelets; in this way, the statistically significant modes of climatic variability are gradually resolved against a red noise background. Results show a lack of significant regime discontinuities or long time-scale (secular) trends. However, strong oscillations found to be the dominant variability modes of precipitation in the decadal and inter-decadal time scales at the Eastern and Northern part of the peninsula, respectively. In addition, intermittent oscillations found to prevail southwards. The temporal evolution and the spatial distribution of these variability modes are further examined.

***Keywords*—** Precipitation climatic variability, Climatic signal analysis, Spectral decomposition, Central Mediterranean.

I. Introduction

PRECIPITATION is a basic observational parameter in the research of climatic variability. The uncertainty associated with the extreme spatial variability of precipitation, enforces the study of climatic changes in the precipitation regime on a regional and/or sub-regional scale, as it was also suggested by the Intergovernmental Panel on Climate Change [1]. Such a study, aiming to the detection of *statistically significant modes of variability* in the precipitation of the Apulian peninsula (in the southern-eastern Italy) is given here through a combination of spectral decomposition techniques.

The peninsula of Apulia (or Salento) is an elongated nearly flat strip of land (approximately 150 *Km* long and 45 *Km* wide) that invades into the Ionian Sea. It borders the southern limits of the Adriatic Sea at the Strait of Otranto and further shapes the Taranto gulf, on its western side. As a result, it rather forms an islanding –than continental- environment, located just before the strong wind convergence zone of the Western Balkans coastline. From the point of view of the precipitation climate dynamics, Apulia seems to be lying in a locally narrow transition zone, as mild negative trends at its western neighborhood in Calabria [2], [3] progressively neutralize along the central Italy, and finally turn into positive trends at Northern Italy, e.g. [4], [5]; however, strong negative trends and regime discontinuities have been ascertained along Apulia's immediate SE extension, in the Ionian Islands [6]. The aforementioned characteristics make Apulia an interesting area for the detection of climatic signals at the Northern part of Central Mediterranean.

On the synoptic scale, Apulia is freely exposed on the Southern circulation (and the associated Sirocco and Tramontana winds) which is imposed by the frequent passage of Mediterranean cyclones, as well as, on the Northern circulation and the channeled Bora winds, through Adriatic. The prevailing weather conditions, precipitation heights, hydrology, and the climate of the area are strongly determined by the regional cyclonic activity. Classification of cyclone tracks in the Adriatic, [7], show that apart from the in situ developed depressions (i.e. those formed within the Central and Southern Adriatic), the area is lying on the route of Genoan-type, as well as of external-type cyclones (originating from the rest Euro-Mediterranean cyclogenetic areas, such as Alboran Sea, Iberia, Pyrenees, Atlas mountains region, and Atlantic). According to their tracks, these cyclones seem to comprise almost the same frequency of presence in the Adriatic area [7]. However, the cyclogenesis frequency of Mediterranean originating systems seems to decline rapidly, with the exception of the Southern Adriatic region, where cyclogenesis increases in all four seasons, particularly during summer and autumn [8].

On the mesoscale, Apulia is often under the effects of two see-breeze systems originating from the opposite coastal lines (a NW directed wind in the Adriatic coast and a W-SW wind in the Ionian coast) especially under weak synoptic conditions. A convergence zone is then formed along the peninsular axis that triggers local convection and possible precipitation [9].

Apart from the synoptic and mesoscale forcing, significant variability in the inter-annual and decadal precipitation of many Mediterranean areas are induced by anomalies in the North hemisphere pressure distribution patterns, such as the North Atlantic Oscillation (NAO), the Scandinavian (SCAND) and the East Atlantic/ West Russian pattern (EA/WR); they are collectively referred as *climatic teleconnections*, as their effects can be propagated in long-scale distances, e.g. [10]-[13]. The significant decline in the annual precipitation of the West and Central Mediterranean between 1970s and 2000, caused by a persisting positive phase of NAO represents a recent example of their effects; in the same period positive phases of EAWR further enhanced precipitation deficits in the Eastern Mediterranean [14]. Under these stresses, drying

Kalimeris A : Department of Environmental Technologists, Technological Educational Institute of Ionian Islands, Zakynthos Island, 29100, Greece (corresponding author e-mail: taskal@teiion.gr).

Ranieri E : Polytechnic University of Bari, Dicatech, 70125 – Bari, Italy (e-mail: ezio.ranieri@poliba.it).

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became more evident in parts of Central and Eastern Mediterranean, particularly in the Italy–Greece region, e.g. [15]. The climate model simulations in regional [1], [16] and sub-regional scales [6], anticipate mild precipitation deficits until the end of the current century in the Apulian area.

II. DATA AND METHODS

In order to study the precipitation climatic variability in the Apulia peninsula we relied on the monthly precipitation height time series $H_M(t)$, available between 1921 and 2010 from the Italian Hydrographic Office (Ufficio Idrografico) for 6 coastal stations : Bari, Brindisi, Otranto, SM Leuca, Gallipoli and Taranto. The number N_A and N_M of data in the annual and monthly series, respectively, are given in Table I (in the "Initial Data" rows). Data temporal coverage ranges from 94% to 99% with the number of maximum consecutive missing values m_C never exceeding 2.5%, apart from Bari where $m_C \cong 6\%$ (Table I). To proceed with data gap filling, we applied a *multivariate weighted linear least square* procedure, where an estimation of each missing value $\hat{H}_{i,j}$ in the *i*-station at the *j*-month [j=1(1)12] was based on the observed values $H_{k,j}$ in each one of the rest stations [k=1(1)n, n=6, $k \neq i$]. In particular, $\hat{H}_{i,j}$ was computed by the following equation :

$$\hat{H}_i(t_j) \equiv \hat{H}_{i,j} = \sum_{k=1}^{n} r'_{ik,j} \cdot h_{ik,j} \Big/ \sum_{k=1}^{n} r'_{ik,j} \qquad (1)$$

where, $h_{ik,j}$ is the (partial) k^{th}-prediction of the missing value $H_i(t_j)$, which is provided by the linear least square equation $h_{ik,j} = \beta_1 \cdot H_{k,j} + \beta_0$ relating the i^{th} and k^{th} stations precipitation series ($H_{i,j}$ and $H_{k,j}$) at the *j*-month. In addition, $r'_{ik,j} = r_{ik,j}$ whenever the linear correlation coefficient $r_{ik,j}$ between the i^{th} and k^{th} stations is statistically significant at a level α (α=0.05 adopted here), and $r'_{ik,j}$=0 otherwise. In this way, any missing value in the *i*-series is estimated by weighting appropriately the observed values originating only from stations which are significantly correlated to the i^{th} station. The filled monthly precipitation series are depicted in Figs.2, while the numbers n_A and n_M of the total annual and monthly data respectively, are listed in Table I (in the "Final Data" rows). Actually, in order to smooth-out the seasonal precipitation cycle, the *centralized* monthly heights H_{MC} were adopted in the following analysis, and also these values are illustrated in Fig.2. Finally, the *annual* precipitation sums H_A were found, but in reference to the *hydrological year*, whose starting date is considered as the July 1st .

In consequence, *homogeneity* of the annual series was tested through the Pettitt, Buishand, SNHT (Standard Normal Homogeneity Test), and the von Neumann tests [17]-[20]. *All series found to be homogeneous*, as none of the detected possible break points $t_\star$ (listed in Table I) found to be significant even at the 0.1 level. Hence, the mean annual precipitation height $\overline{H}_A$ and the standard deviation σ_A, listed in Table I, are referred to the overall observational period in each station. Interestingly, ranging from 47.9 to 79.2 *cm*, the mean values $\overline{H}_A$ seem to increase towards the SE part of the peninsula (i.e. at the Otranto and Leuca area). These spatial differences found to be highly significant (p-values<0.01) through the Mann-Whitney test, and also time persistent, as H_A heights in Otranto and Leuca predominate over the other stations along the entire observational period. The prevailing SE gradient ∇H of the precipitation height H, might be a result of the local wind convergence induced convective precipitation, that may also account for the observed high variance values in the same area (see the σ_A values in Table I).

The search of possible *long-term (secular) linear trends* in the annual precipitation show only weak, *non-significant*, mixed trends along the peninsula; the strongest one (equal to 1 *mm*/*yr*) is found in Taranto. The detected linear trends along with the corresponding p-values, are also listed in Table I.

Table I : Data time-coverage and descriptive statistics

		Bari	Brindisi	Otranto	Leuca	Gallipoli	Taranto
Observations Period		1938 – 2010	1921 – 2010	1921 – 2010	1921 – 2010	1921 – 2010	1921 – 2010
Initial Data	N_A	67	89	87	85	88	89
	N_M	826	1068	1062	1031	1062	1078
	Coverage	94.3 %	98.9 %	98.3 %	95.5 %	98.3 %	99.8 %
	m_C	5	1	1	2	1	2
Final Data	n_A	73	90	90	90	90	90
	n_M	876	1080	1080	1080	1080	1080
Homog.	$t_\star$	1983	1950	1964	1947~1950	1947	1960~1990
	Sign.	No	No	No	No	No	No
$\overline{H}_A$ [*mm*]		563.8	582.9	791.5	663.1	554.2	478.5
σ_A [*mm*]		128.6	150.6	229.1	194.1	157.6	134.6
Linear Trend	[*mm/yr*]	–0.13	+ 0.86	–0.65	+0.33	+0.32	+1.01
	p-value	0.86	0.17	0.49	0.62	0.70	0.07

The precipitation series spectral decomposition anlayisi in statistically significant *non-linear trends*, *oscillatory components* and *stochastic variations* through the efficient data-adaptive Singular Spectrum Analysis or SSA [21]–[27], and the revised Multi-Taper Method or MTM [28], [29], follows. In order to extend the detectability of long time scale variability components as far as possible, a window width *M* corresponding to 22 *yrs* was adopted in SSA computations and a corresponding eigen-taper number, in MTM. The SSA is particularly successful in analyzing periodicities in the range (*M*/5, *M*) [24], while large values of *M* favor stability (robust-ness) of the emerging spectral features [26]. However, the frequency of oscillatory terms associated with time-scales longer than *M* may be not well specified; such terms are then referred as "slow" components.

Spectral decomposition of the studied monthly precipitation series in oscillatory components and statistical significant trends, enable their reconstruction in the time domain, as described in [27]. The *reconstructed components* (RCs) have the important property of capturing the phase and the temporal variability of the time series. Hence, they actually represent the estimated non-stochastic part of each time series, that is, the estimated *climatic signal*. However, in advance of SSA and MTM analysis, the Blackmann-Tukey (BT) or windowed correlogram [30], and the *Maximum Entropy Method* or MEM [31]–[33], was applied, in order to have a preliminary view of the main spectral features, such as the spectral continuum and

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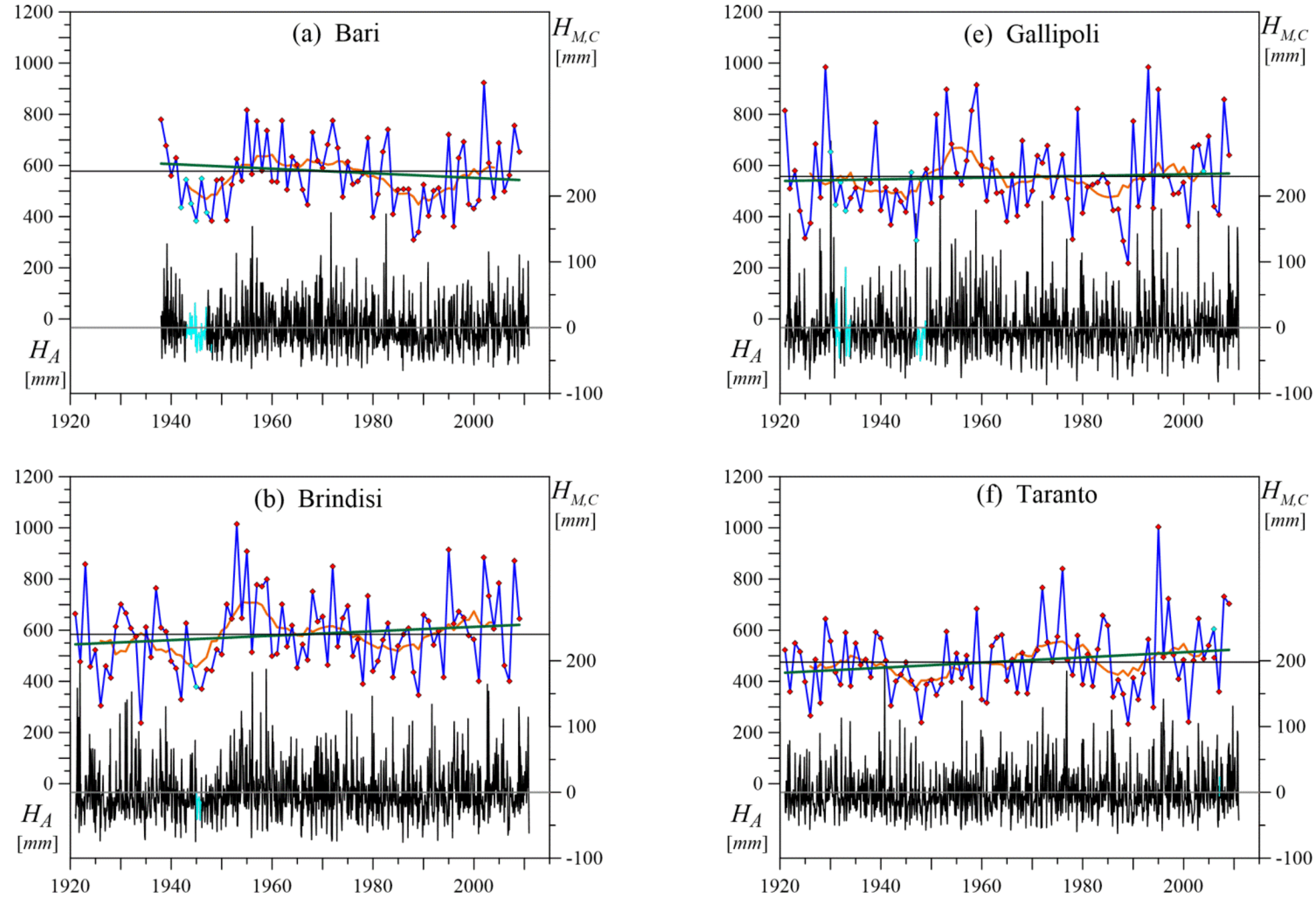


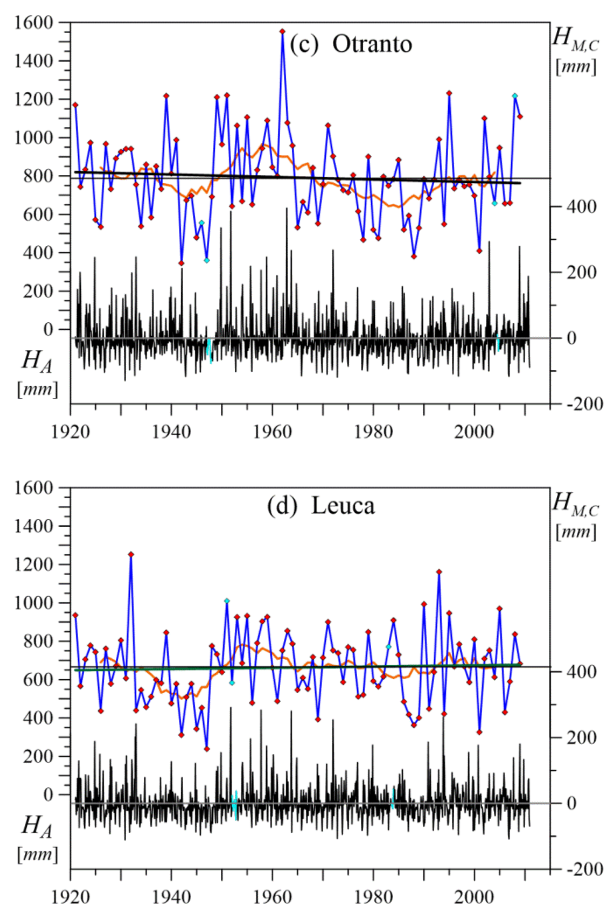


Fig.1 The annual H_A (blue line, scale on the left) and the monthly centralized H_{MC} precipitation heights (black line, scale on the right) for Bari (a), Brindisi (b), Otranto (c), Leuca (d), Gallipoli (e) and Taranto (f). Filled-in data are illustrated by the short cyan lines. The mean *annual* precipitation level is indicated by the horizontal straight lines, while the 11-*yrs* moving average is depicted by the orange line.

the prominent narrowband peaks; it also helps in reducing the by-chance detection of statistically significant components through MTM and SSA. Aftermath, on the basis of the MTM and SSA results, a Wavelets analysis was performed through the Continuous Wavelet Transform [34], [35], in order to examine the temporal evolution of the detected precipitation variability modes in the frequency-time domain. The Morlet function $\psi_0(\eta) = \pi^{-1/4} e^{i \cdot \omega_0 \cdot \eta} e^{-\eta^2/2}$ was adopted as a mother wavelet, with ω_0=6.

Throughout the aforementioned spectral analysis procedure, the *centered* monthly precipitation values H_{MC} used in order to dump the spectral effects of the annual precipitation cycle. Furthermore, all computations repeated for the (12-fold under-sampled) annual series H_A in order to have a rough sense of the effects of aliases.

III. CLIMATIC SIGNAL ANALYSIS

For each station, the computed BT, MEM and MTM spectra of the monthly precipitation time series H_{MC} are compared in the same panel, while the SSA spectra are depicted separately,

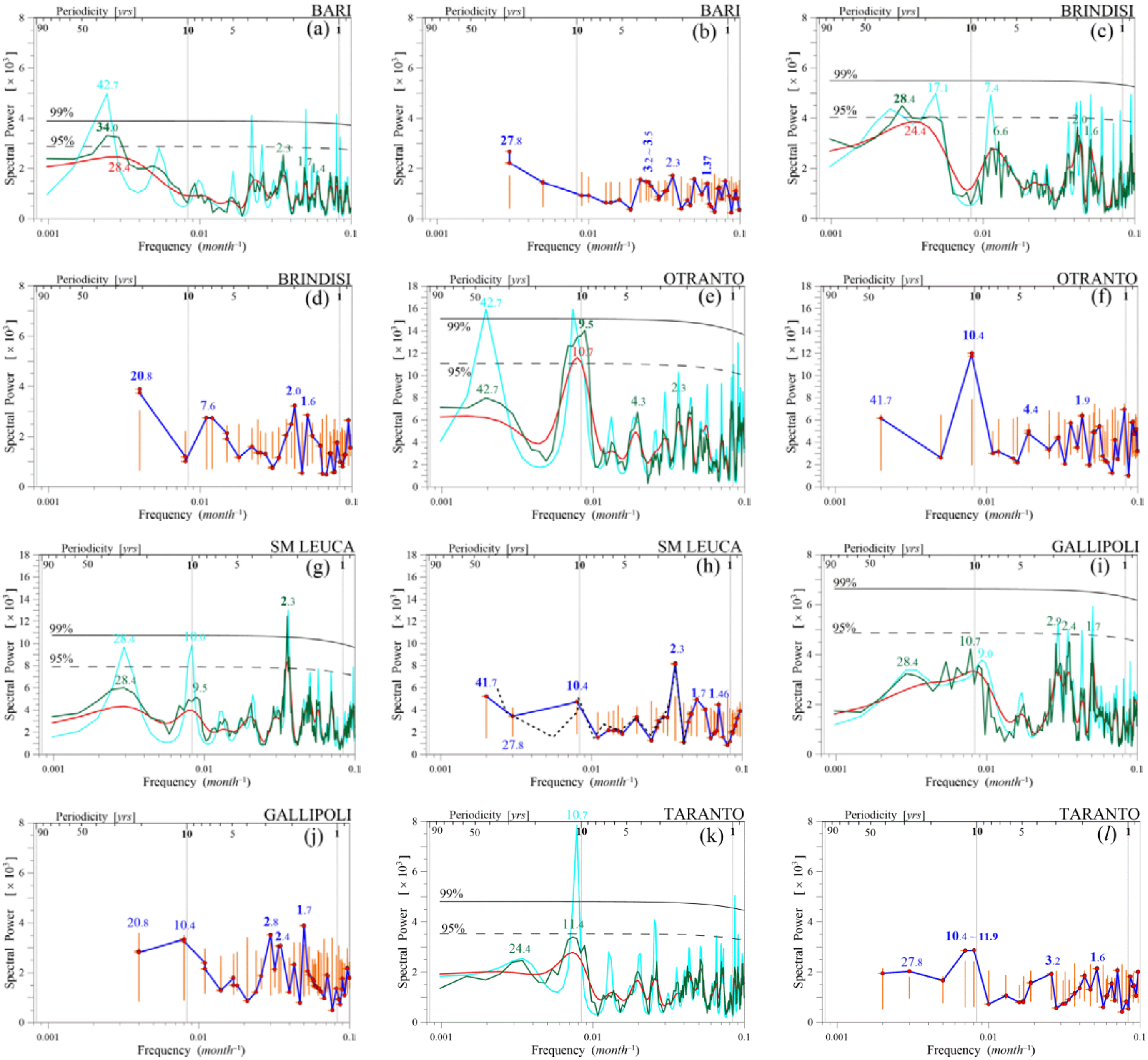


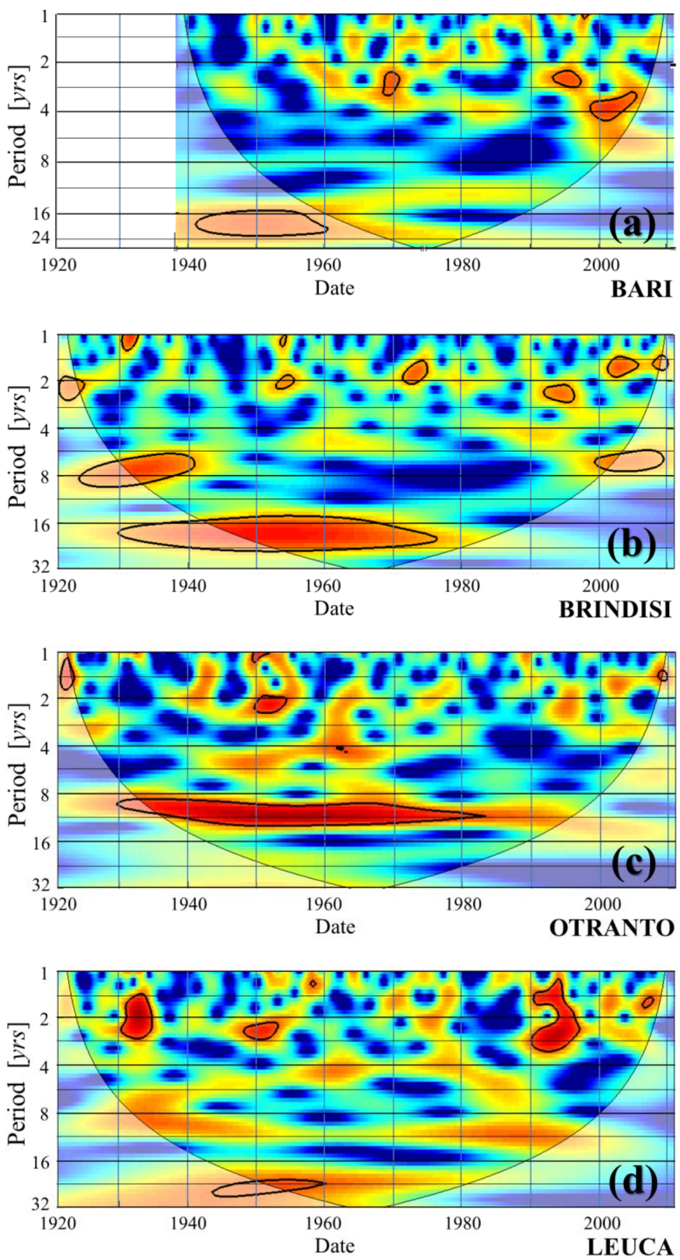
Fig.2 The BT, MEM, and MTM power spectra (with red, cyan, and green lines, respectively) of the centralized monthly precipitation series H_{MC} in Bari (a), Brindisi (c), Otranto (e), Leuca (g), Gallipoli (i) and Taranto (k). The 95% and 99% confidence levels for MTM spectra in respect to a red noise background are indicated by the dashed and continuous black lines, respectively. The corresponding SSA spectra of Bari (b), Brindisi (d), Otranto (f), Leuca (h), Gallipoli (j) and Taranto (*l*) are shown by the blue lines. The 2.5% and 97.5% percentiles of Monte Carlo red-noise simulations are seen by the vertical bars (orange line).

in Fig.2. Wavelet spectra are shown in Fig.3.As we are mainly interested for the precipitation variability at the inter-annual and the decadal time-scales, the high frequency spectral tail has been clipped in Figs.2, at 0.1 *months*$^{-1}$. Statistical significance of each spectral term was tested against the null-hypothesis $\mathcal{H}_0$ that : "*the observed series is nothing more than red noise realizations*", according to the procedure proposed in [29] for the revised MTM, in [21] for SSA, and in [34],[35] for Wavelets. Prominent spectral components are organized in Table II into six discrete time-scales (or periodicity bands). Significant spectral terms (at the 0.05 level) are indicated in Table II by bolded values. These bands are roughly associated with variability time scales of known climatic processes. For example, the quasi-biennial oscillation (QBO) variability (e.g. [36]–[38]) at 27–28 months or 2.3 *yrs*, fall in the [1, 3) *yrs* band. Similarly, ENSO (El Niño-Southern Oscillation) related variability might be met –but not restricted– in the [3, 6) *yrs* band, and NAO related signals in the [6, 9) *yrs* band. Ocean-atmosphere interactions, as well as many other geophysical interacting processes, can induce climatic variability in the decadal and inter-decadal time scales.

Results of the applied combined spectral analysis show that three, distinct, *significant* (at the 0.05 level) variability modes drive the observed precipitation changes in Apulia :

Table I I : Significant and major spectral features, according to the analysis method and the periodicity band.

Periodicity Band [*yrs*]	Method	Bari	Brindisi	Otranto	Leuca	Gallipoli	Taranto
1 – 3	SSA	**1.4** , 2.3	**1.6** , **2.0**	**1.9**	**1.5 , 1.7 , 2.3**	**1.7 , 2.4 , 2.8**	**1.6**
	MTM	1.4 , 1.7 , 2.3	1.6 , 2.0	1.9 , 2.3	1.5 , 1.7 , **2.3**	1.7 , 2.4 , 2.9	1.6
	MEM / BT	1.4 , 1.7 , 2.3	1.6 , 1.9 , 2.0	1.9 , 2.3	1.5 , 1.7 , **2.3**	1.6 , 2.4 , 2.8	1.6
3 – 6	SSA	**3.2** , **3.5**		**4.4**			**3.2**
	MTM	3.2 , 3.9		4.3			3.2
	MEM / BT	3.7		4.5			3.2
6 – 9	SSA		7.6				
	MTM		6.6				
	MEM / BT		7.4 / 7.1				
9 – 12	SSA			**10.4**	**10.4**	10.4	**10.4**
	MTM			**9.5**	9.5	10.7	11.4
	MEM / BT			10.7	10.0	9.0 / 10.0	10.7 / 11.4
12 – 25	SSA		**20.8**			20.8	20.8
	MTM		**19.0**				
	MEM / BT		17.1 / 24.4				
> 25	SSA	**27.8**		41.7	**34.5** , 27.8		**27.8**
	MTM	**34.0**	**28.4**	42.7	28.4	28.4	24.4
	MEM / BT	42.7 / 28.4	34.1	42.7	28.4	28.4	24.4



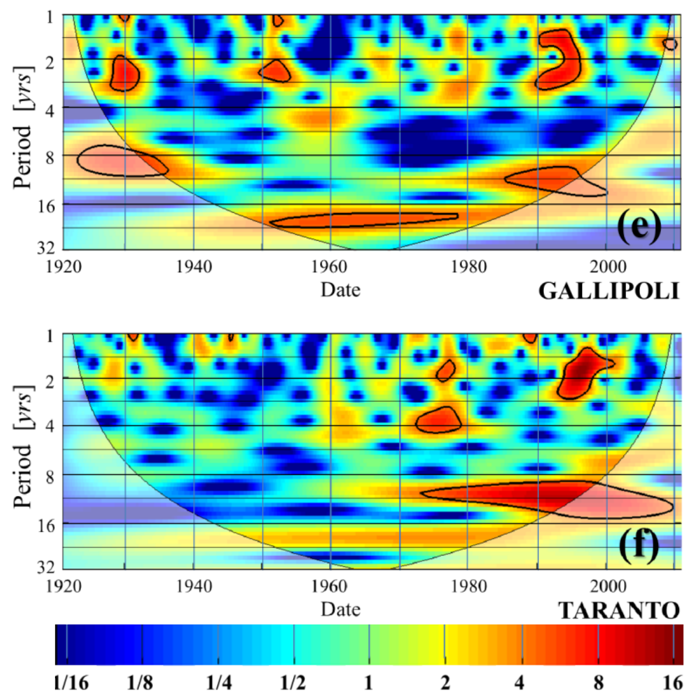


Fig.3 Wavelet spectra for Bari (a), Brindisi (b), Otranto (c), Leuca (d), Gallipoli (e) and Taranto (f). Statistical significant features at the (0.05 level) are marked by heavy lines, while the COI areas are also seen. Color scale units are referred to the local variance σ^2 (Table I).

(i) *Sub-decadal* oscillations, mostly detected in the short time-scale periodicities band of 1.5–3 *yrs*; they found to dominate in the southern part of the peninsula, at *Leuca* and *Gallipoli* area (see Table II, Figs.2g-j and Figs.3d-e).

(ii) Strong oscillations in the *decadal scale*, centered at 10.4 *yrs*, dominating along the SE part; they are maximized in *Otranto* (see Table II, Figs.2e-f, and Fig.3c).

(iii) *Long time-scale* (*inter-decadal*) terms detected at 27–28 *yrs* at the N-NE part (and at about 21 *yrs*, in *Brindisi*); in addition, *slow* oscillations or weak *non-linear trends* at about 34-41 *yrs* prevailing at the Southern part.

The spatial distribution of the aforementioned significant oscillatory modes and/or slow or non-linear trends along the

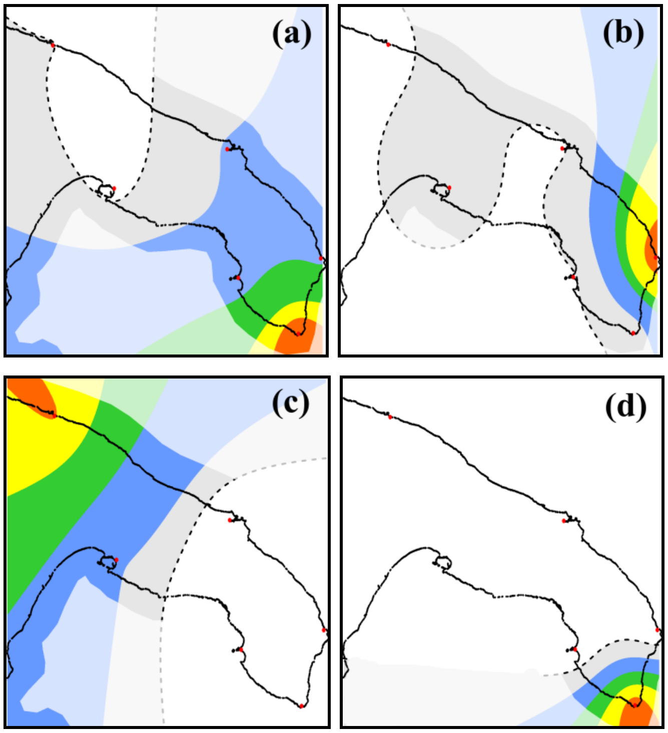


Fig.4. Spatially interpolated distribution of the excessive spectral power of the 2~3 *yrs* term (a), 10.4 *yrs* term (b), 28 *yrs* term (c), and of the long time scale *non-linear trend* at 41.7 *yrs* (d), shown only in the areas where these terms found to be statistically significant (at the 0.05 level) through SSA. Power color scale increases from white (no-significance), to gray, blue, green, yellow and finally, orange.

Apulian peninsula is illustrated according to their *excessive power* (ie. power above the local statistically significance threshold), in Fig.4, while their characteristics are discussed in more details in the next three paragraphs.

A. Sub-decadal variability terms

Short time scale oscillations at 2.3–2.4 *yrs* are detected along the peninsula; however, they become significant only southwards (Fig.4a). As can be seen in the Wavelet spectra (Fig.3), the spectral power of the 2.3–2.4 *yrs* oscillatory mode is actually dispersed in the entire 1.5~3 *yrs* band, that gives rise to a series of neighborhood spectral detections, as listed in Table II. The 2.3–2.4 *yrs* term is rapidly intensifying southwards, and become remarkably strong and significant in *Leuca* area (Fig.4a), accounting there for 20% of the observed annual variability. So far, this is the highest value observed in the Ionian region; a similar 2.3 *yrs* oscillation has been observed along the nearby Ionian Islands, intensifying from Corfu southwards to Zakynthos [6]. The temporal evolution of the short-scale oscillation is illustrated by the corresponding SSA RC in Fig.5; a strong amplitude modulation in the inter-decadal time-scale (40 *yrs* at least) is obvious. This modulation time is more than twofold than that observed in the Ionian Islands [6]. Interestingly, the 2.3–2.4 *yrs* term in Leuca fades-out at about the same period (1955–1985) that NAO was in a persisting negative phase. Since the central frequency of the 2.3–2.4 *yrs* term is remarkably close to the 27–28 months (2.3 *yrs*) periodicity of the Quasi-Biennial Oscillation, it is presumably associated with QBO, although

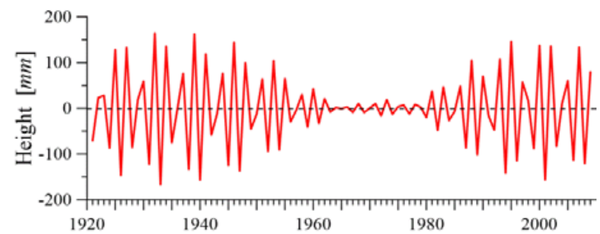


Fig.5 The SSA RC at 2.3~2.4 *yrs*, in Leuca.

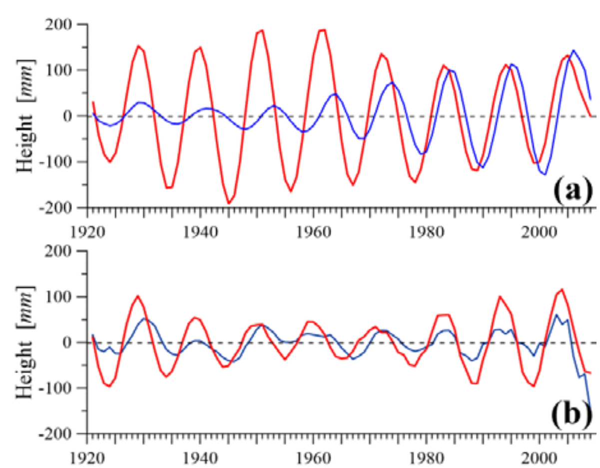
adequate physical evidence is required in order to support this hypothesis.

Apart from the 2.3 *yrs* term, a highly intermittent oscillation at 3 to 4.5 *yrs* band (mainly concentrated at 3.2 *yrs*) is sporadically found along the peninsula, mostly in Bari and Taranto (e.g. see Figs.3a,f).

Another interesting (but significant only in the 0.1 level) sub-decadal variability mode is detected at 6.5–8 *yrs* (actually centered at 7.5 *yrs*) in *Brindisi* area. Such oscillatory terms at 7–8 *yrs* are often observed in many locations of the Euro-Mediterranean area; they are generally associated with the North and Tropical Atlantic variability. However, similar terms have been also detected in a broad variety of different geophysical time series e.g. [39]–[46]. According to Wavelet analysis this term seems to be active in Brindisi before 1945 and after 1995, eliminating between 1950 and 1990 (Fig.3b).

B. Decadal variability terms

At the decadal time-scale, a very strong and significant variability mode is detected at 9.5–10.7 *yrs* (centered at 10.4 *yrs*) particularly in the SE part of the peninsula (Fig.4b). It is worth-noting that so far, along the Apulian – Ionian Islands axis, such an oscillation is only met in SE Apulia. The 10.4 *yrs* oscillation becomes the dominant oscillatory component in *Otranto's* precipitation, where it accounts for the 23.5% of the annual variability. This mode is also detected in *Taranto* (between 10.4 and 11.5 *yrs*) where it accounts for the 17% of the observed variability. The SSA RCs for both locations are shown in Fig.6a; as can be seen, the decadal oscillation in *Otranto* reveals a remarkably stable and time-persistent modulation, while in *Taranto* this term seems to be triggered



Figs.6 The 10.4 *yrs* term in Otranto and Taranto (red and blue line respectively, in panel "a"). also in Gallipoli and Leuca (red and blue line respectively, in panel "b").

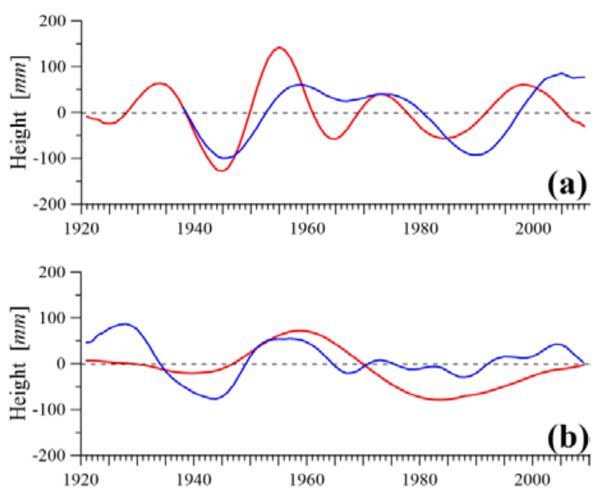
after the 1960s, intensifying since then. Similar decadal terms also prevail in *Gallipoli* and *Leuca* (Figs.2g-j and Figs.3d,e) where they account for 14.5% and 12% of the annual precipitation variability. As can be seen in Figs.6a,b, these terms follow an in-phase synchronization with Otranto's 10.4 *yrs* oscillation; however, synchronization does not seems to extend in their amplitude modulation.

C. Inter-decadal variability terms

Significant inter-decadal variability terms found towards the northern part of the peninsula (Fig.4c), mainly in two distinct scales: First, a slow oscillation at about 28 *yrs*, and second, as non-linear trends associated with a variability scale at about 41-43 *yrs*. One more significant oscillatory term, also detected at 20.8 *yrs* in Brindisi. However, it should be noticed that in these time scales *there is no wide agreement* between the analysis methods (Table II).

The 20.8 *yrs* oscillation is the dominant variability mode in *Brindisi*, where it accounts for 19% of the annual precipitation variability. The periodicity of this term is twofold than that of the powerful 10.4 *yrs* term in Otranto. The corresponding SSA RC (Fig.7a) show that this oscillation was particularly active from 1940s to 1960s. Wavelet analysis confirms and further stress this picture, by showing that this term remained significant until the mid-1970's (Fig.3b). A similar term is also detected in Gallipoli but its statistical significance is downgraded.

The 28 *yrs* oscillatory term, is broadly detected in all Apulian stations except Otranto. However, it is only the northern part of the peninsula where this slow-trend component becomes statistically significant; in *Bari* area it acquires its' maximum power accounting for the 21.5% of the annual variability (the corresponding SSA RC is depicted in Fig.7a). Similar oscillatory terms found by the other methods at neighborhood time-scales (such as the MTM spotted, 34 *yrs* term in Bari and at 28.4 *yrs* in Brindisi) are probably partial detections of the same broadband inter-decadal variability mode, that seems to spread power between 20-30 *yrs* (Fig.3).



Figs.7 The 20.8 *yrs* term in Brindisi and the 27.8 *yrs* term in Bari (red and blue line respectively, in panel "a"), and the non-linear trends in Otranto and Leuca (red and blue line respectively, in panel "b")

Finally, long time-scale non-linear trends are detected only southwards, at Otranto and Leuca (Fig.4d); however, they only account for about 7% of the annual precipitation variability. The corresponding SSA RCs are illustrated in Fig.7b. Both terms have the form of an irregular oscillation, actually associated with variation time-scales in the range of 34 to 42 *yrs*.

III. DISCUSSION

Apulia is a small and nearly flat elongated peninsula that invades in the Ionian Sea by more than 100 *Km*. In the same time it is located just before the strong wind convergence zone of the west Balkans coast (that intensifies local precipitation); still, it supports a remarkable local breeze convergence system along its axis. Significant negative stresses in the precipitation have been detected in Apulia's immediate southern extension, the Ionian Islands, while mild negative trends prevail westwards in Calabria; mixed trends prevail in the central and northern Italy. Thus, Apulia is an interesting area ideally positioned in the Northern Ionian Sea, for search of climatic variability signals in the climatically sensitive area of Central Mediterranean.

A study of the precipitation climatic variability in six coastal Apulian stations is given here by a combination of five well known efficient spectral analysis methods. Among them, we consider SSA as the most reliable spectral decomposition technique, since it is an efficient data-adaptive method equipped with the strict significance tests. In this framework, wavelet analysis is further used in order to accomplish the temporal evolution picture of those variability modes that were detected earlier as significant by SSA and MTM.

Results show a consistent spatial variability pattern of the statistically significant modes of precipitation variation along the Apulian peninsula: *short time-scale* (2-4 *yrs*) *intermittent terms at the southern part, are succeeded by strong decadal oscillatory modes in the* E-SE *part, and finally by inter-decadal oscillations in the* N-NE *part* (Fig.4). The short-scale oscillations (centered at 2.3–2.4 *yrs*) account for a remarkable 20% of the observed annual variability in Leuca. Then, at the E-SE part, a decadal (10.4 *yrs*) oscillation account for 23% of variability in Otranto. Weaker, and out of phase, oscillatory modes in the same time-scale found in Leuca and Gallipoli. Northwards (and mainly along the Adriatic side), significant oscillatory modes make appearance at 21 *yrs* (first in Brindisi area) and at 28 *yrs* towards Bari (where they accounts for the 20% of the annual variability).

Weak non-linear trends (associated with 34 to 42 *yrs* variability time-scales) detected *only in the southern part* of the peninsula. However, no significant long time-scale (secular) trend was found along Apulia.

An additional future spectral cross-correlation and time-coherence analysis, focusing in known patterns of climatic telecon-nections (such as NAO, EAWR, SCAND) could possibly elucidate important aspects of the physical processes that modulate the observed climatic variability modes in this area.

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Thermal power analysis of a single family housing

Stan Ivan Felicia Elena, Dinu Radu Cristian

***Abstract*—**this paper presents a study regarding the determination of the necessary heat for a single family house. In the first part is presented an introduction witch describes the main idea of the paper. The second part includes a mathematical model for the necessary heat equations and presents the main equations that are used. The last part of the paper is a calculation example to determine the thermal power of a single family house. The case study includes the constructive details of the house, determining the necessary heat, sizing boilers for hot water and the calculation of the necessary heat for hot water preparation.

***Keywords*—** thermal power, necessary heat, mathematical model, boilers seizing, hot water.

I. Introduction

THIS material presents the calculation of the heat for single-family house, based on current trends existing in this field worldwide.

The analysis presented is carried out in the international context in which the concepts of energy conservation, reduction of emissions and pollutants, energy independence, environmental impact and others, becomes increasingly important significance.

In Romania, most of the residential buildings were completed without significant concerns for the quality of their energy, but in recent years were introduced precise regulations in this area and there is a growing concern for issues regarding the insulation quality and efficient solutions for thermal energy production. [1], [5]

II. The mathematical model

Heat housing needs can be determined by adding its three major components:[1]

$$\dot{Q} = \dot{Q}_1 + \dot{Q}_2 + \dot{Q}_3 \quad [W] \qquad (1)$$

where: $\dot{Q}_1$ - load or thermal power transmitted through the building envelope, [W]

$\dot{Q}_2$ - Load or thermal power due to the charge of ventilation or airflow, [W]

$\dot{Q}_3$ - Load or thermal power for water heating, [W].

Load or thermal power transmitted through the building envelope presents several components, which can be summarized:

$$\dot{Q}_1 = \dot{Q}_{11} + \dot{Q}_{12} + \dot{Q}_{13} + \dot{Q}_{14} + \dot{Q}_{15} \quad [W] \qquad (2)$$

where: $\dot{Q}_{11}$ - Load or thermal power transmitted through building walls, [W]

$\dot{Q}_{12}$ - Load or thermal power transmitted through ceiling, [W]

$\dot{Q}_{13}$ - Load or thermal power transmitted through the windows, [W]

$\dot{Q}_{14}$ - Load or thermal power transmitted through the floor, [W]

$\dot{Q}_{15}$ - Load or thermal power transmitted through cellar floor, [W]

The thermal loads transmitted through the elements of the building envelope are determined using the calculation relations as:

$$\dot{Q}_{1i} = k_i \cdot S_i \cdot (t_i - t_e) \quad [W] \qquad (3)$$

where: ki -represents the global heat transfer coefficient through the envelope element, [W/m^{2}K];

S_i -is the surface of the envelope element, m^2;

t_i - is the temperature inside the house, °C;

t_e - is outdoor temperature °C.

The overall coefficient of heat transfer is determined using the relationship:[4]

$$k_i = \frac{1}{\frac{1}{\alpha_i} + \sum \frac{\delta}{\lambda} + \frac{1}{\alpha_e}} \quad [W/m^2K] \qquad (4)$$

where: α_i - is the coefficient of overall convection between the building element and the air inside the building, and his

F.E. STAN IVAN is with the Faculty of Electrical Engineering, University of
Craiova, Craiova 200440 Romania (email:ely_felicia@yahoo.com; fivan@elth.ucv.ro;e-mail).
R.C. DINU is with the Faculty of Electrical Engineering, University of Craiova, Craiova 200440 Romania (e-mail: rcdinu@ elth.ucv.ro).

value is considered 8 W/m^2K, which corresponds to the natural convection;

α_e - is the global coefficient of convection between the building element and the air from outside the building, and his value is considered 25 W/m^2K, which corresponds to the most unfavourable conditions

δ - is the thickness of each layer from the building envelope, m

λ - is the conductivity of each component material from the building envelope, W/mK.

In the tables below are presented the thermal conductivity values for a few usual material as well as values of the global coefficient of heat transfer for some types of windows.

Table 1. Values of thermal conductivity for some common building materials

Material	Conductivity [W/mK]
Concrete	1,45
Brick	0,90
Autoclaved concrete cell	0,40
Plated wood	0,10
Hardwood Oak	0,37
Hardwood pine	0,28
Stone	2,90
Polyurethane	0,018
Extruded polystyrene	0,035
Expanded Polystyrene	0,040
Mineral wool	0,041
Coork	0,054

Table 2. Values of the global coefficient of heat transfer for certain types of windows

Window	global coefficient [W/m²K]
Window panes with 3 layers of glass and Kr between starts	0,5
Window panes with 3 layers of glass	0,8
Low E Window panes	1,1
Window panes Float-Float	1,4
Double glazed window	2,0
Window with single glazing	2,5

Because of leaks, for these types of windows in practice global heat transfer coefficient values are higher. Load or thermal power due to ventilation or airflow can be calculated based on heat load transmitted by the tire, with the relationship:

$$\dot{Q}_2 = \varepsilon \cdot \dot{Q}_1 \quad [W] \qquad (5)$$

where ε It is a proportionality coefficient, whose value can be regarded as

0,7	0,8	0,9	1
for buildings without thermal insulation	For building with minimal insulation	For buildings with good insulation	for buildings with high performance insulation (houses with low energy consumption or passive houses)

Thermal power for hot water preparation depends on the number of people using home:

$$\dot{Q}_3 = \frac{n \cdot \rho \cdot V \cdot c_p \cdot (t_{we} - t_{wi})}{\tau} \quad [W] \qquad (6)$$

where: n – the number of persons

ρ - water density, kg/m^3

V –water daily consume, for one person, m^3

c_p - the specific heat of water, kJ/kgK

t_{we} -the temperature for water to be heated, °C

t_{wi} –the temperature of cold water, °C

τ - the period during which the water is heated, s.

III. CASE STUDY

We consider a building with the following constructive details.

Table 3. Construction details for the analyzed building [2]

Element	Material	S[m²]
Exterior wall	Exterior plaster	10,25
	Autoclaved concrete	
	Polystyrene	
	Interior plaster	
Plate over basement	Parquet	67,6
	Cement screed	
	Insulation	
	Concrete	
	Polystyrene	
Roof	Gypsum boards	51,34
	Mineral wool	
	Mineral wool	
	Wood	
Windows	Glass	6
	Frame	

Temperatures of calculation are considered t_i=20°C for indoor temperature and t_e=-15°C outdoor temperature (outdoor temperature average during the heating period for Craiova city).

Further will be determinate the thermal parameters for the 3 components of the building examined.

Table 4 presents the thermal characteristics parameters for the main components of the building and are determined: the temperature difference, heat resistance and the corrected global heat transfer coefficient, and in the final are calculated all the elements of the heat demand of housing.

A. *Determining the heat demand of housing*

According to the relationship (1), it will be determined the thermal power transmitted through the building envelope.

In the table 5 is presented the thermal power transmitted to the building envelope components.

Table 4. The thermal characteristics parameters for the analyzed building components [2]

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Element	Material	S [m²]	$1/\alpha_i$	$1/\alpha_e$	δ[m]	λ[W/mK]	R[m²K/W]	Δt[°C]	R't [m²K/W]	U [W/m²K]
Exterior wall	Exterior plaster	10,25	0,13	0,04	0,02	0,87	0,02	35	9,64	0,10
	Autoclaved concrete				0,18	0,21	0,86			
	Polystyrene				0,3	0,035	8,57			
	Interior plaster				0,02	0,87	0,02			
Plate over basemen	Parquet	67,6	0,13	0,04	0,022	0,13	0,17	35	7,46	0,13
	Cement screed				0,05	1,05	0,05			
	Insulation				0,03	0,04	0,75			
	Concrete				0,16	2,1	0,08			
	Polystyrene				0,25	0,04	6,25			
Roof	Gypsum boards	51,34	0,13	0,04	0,1	0,7	0,14	35	11,08	0,09
	Mineral wool				0,2	0,04	5,00			
	Mineral wool				0,2	0,04	5,00			
	Wood				0,1	0,13	0,77			
Windows	Glass	6	0,13	0,04				35	0,91	1,1
	Frame									

Table 5. Determination of heat transmitted through the building envelope of the analyzed building components

Element	Q_1[W]
Exterior wall	37,20
Plate over basemen	317,03
Roof	162,14
Windows	231

The thermal power transmitted through the building envelope, $\dot{Q}_1$ is:

Q_1=747,37 W ⇒ Q_1 = 0,747371 kW

The thermal power due to ventilation or airflow $\dot{Q}_2$ is:

Q_2=672,63W ⇒ Q_2 = 0,672634 kW

Table 6. Shows the characteristic parameters of the boiler sizing process for water consumption

n	ρ[kg/m3]	V[m3]	c_p[kJ/kgK]	t_{we}[°C]	t_{wi}[°C]	τ[s]
4	1	0,585	4,19	65	5	1200

Load and thermal power for hot water preparation is:

Q_3 =490,23W ⇒ Q_3 =0,49023 kW

Heat housing needs, $\dot{Q}$ it can be determined by adding its three major components:

$$\dot{Q} = \dot{Q}_1 + \dot{Q}_2 + \dot{Q}_3$$

Q=1910234,31W ⇒ Q= 1910,234 kW

B. Sizing boilers for hot water

The calculation for sizing hot water preparation boilers, aims to determine their amount at least equal to the volume of hot water daily needs. In the adjacent tables, according to international standards, it can be observed that for the domestic hot water preparation at 45°C the amount of water should be higher than the DHW to 60°C, to completely cover daily consumption.

Table 7. Consumption of hot water in homes

Temperature	Consume type		
	Low comfort, [l/pers/day]	Normal comfort[l/pers/day]	High comfort [l/pers/day]
60°C	10...20	20...40	40...70
45°C	15...30	30...60	60...100

Table 8. Consumption of hot water in hotel establishments, guesthouses and hostels

Temperature	Room type			
	With bathroom and shower, [l/pers/day]	With bathroom [l/pers/day]	With shower [l/pers/day]	Pensions, hostels
60°C	115...175	90...135	50...90	25...50
45°C	170...260	135...200	75...135	40...75

Indicative sizing, in terms of thermal system for domestic hot water housing, the use of renewable energy sources, it can be considered normal hot water consumption of 50 litters / person/day at 45°C. If the beneficiary is estimated that exceed normal hot water consumption indicated in the table, will take into account this and be sized boiler water consumption indicated by the beneficiary. Minimum volume of the tank V_{bmin} can be calculated with the formula:

$$V_{bmin} = \frac{n \cdot C_{zn} \cdot (t_{acm} - t_{ar})}{t_b - t_{ar}} \text{ [1]} \qquad (7)$$

where: n – the number of persons;
C_{zn} – normal daily consumption per person considered;
t_{acm} - DHW temperature at the point of consumption;
t_{ar} – cold water inlet temperature in the boiler;
t_b – hot water temperature in the boiler.

Taking into account the above, the boiler volume V_b is calculated by the relationship:

$$V_b = f \cdot V_{bmin} = f \cdot \frac{n \cdot C_{zn} \cdot (t_{acm} - t_{ar})}{t_b - t_{ar}} \text{ [1]} \qquad (8)$$

where: f = 1,5…2, for the case of using the solar energy or heat pumps;

f = 1, when using classic fuels, solid biomass, biogas or electricity.

Next will be considered a particular case sizing DHW cylinder, considering a home with four people, a normal consumption of hot water net daily consume(C_{zn}) = 50l/person/day and different energy sources.

Table 9. Determining the minimum amount V_{bmin} and boiler volume V_b

f	n	C_{zn}[l]	t_{acm}[°C]	t_{ar}[°C]	t_b[°C]	V_{bmin}[l]	V_b[l]
1	4	50	45	10	60	140	140

C. Calculation of the necessary heat for hot water preparation

The thermal load required for hot water preparation is determined by the relationship:

$$\dot{Q}_{acm} = \frac{m \cdot c_w \cdot (t_b - t_r)}{\tau \cdot 3600} \ [kW] \qquad (9)$$

where: m is the amount of hot water prepared:

$$m = n \cdot C_{zn} \cdot \rho \ [kg]$$

where: ρ is the density of water, which varies depending on temperature, but for calculation it can be assumed indicative ρ = 1000 kg /m^3;

c_w is the specific heat of water - can be considered, $c_W = 4{,}186$ kJ/kgK

t_b is the cylinder temperature, so the temperature to which the water is heated;

t_r is the temperature of the cold water, with seasonal variation and depending on the geographical position

Generally in summer t_r = 12...17°C, in the winter t_r =5...10°C. For calculations can be considered indicative tr = 10°C;

τ [h] is the time the water is heated.

The thermal load required for hot water preparation:

$$\dot{Q}_{acm} = \frac{n \cdot C_{zn} \cdot \rho \cdot c_w \cdot (t_b - t_r)}{\tau \cdot 3600} \ [kW] \qquad (10)$$

The thermal load required for hot water preparation needed daily for a person can be calculated with the previous relationship, considering n = 1:

$$\dot{Q}_{acmp} = \frac{C_{zn} \cdot \rho \cdot c_w \cdot (t_b - t_r)}{\tau \cdot 3600} \ [kW] \qquad (11)$$

Table 10. Heat determination Q_{acm} required for hot water preparation

m[kg]			c_w[kJ/kg]	t_b[°C]	t_r[°C]	τ[h]	Q_{acm}[KW]	Q_{acm}[W]
n	C_{zn}[l]	ρ[kg/m^3]						
4	50	1	4,186	45	10	8	1,02	1017,431

The thermal load required for hot water preparation needed daily for a person:

Q_{acmp} = 0,25 KW ⇒ Q_{acmp} = 254,3576 W

Heat required Q_{acm} for hot water preparation:

$$Q_{acm} = Q_{acm} \cdot \tau \ [kWh]$$

⇒ Q_{acm} = 8,14 [KWh]

IV. Conclusion

Due to a continuous increase of energy prices, it is necessary the thermal rehabilitation of homes, administrative, commercial and industrial buildings. From the annual energy consumption of homes, 55% is for heating. In a house properly isolated, the heat losses are about 20-25% for the exterior walls, basement and roof by 20-30% and 20-25% level for non-performing windows and doors.

The analyzed building has a good insulation for the exterior walls and the windows are efficient.

From the values of the heat demand of housing results that the power transmitted through the building envelope and the thermal power due to ventilation or airflow are relatively low, Q_1 = 0,747371 kW and Q_2 = 0,672634 kW. Also the heat housing needs has a value that demonstrate the fact the building has an efficient insulation Q = 1910,234 kW.

As a novelty brought by this article is the approach of the heat requirement for a family, starting from the mathematical model. In the paper it is presented a numerical example in order to determine: the heat requirement, the load and the thermal power for hot water, the sizing boilers for hot water and the calculation of heat for domestic hot water.

This approach is quite complex and a great novelty in the field of energy efficiency in buildings.

Future directions of approach are to create a mathematical model and a computer program possibly using common programming languages in order to develop the application, increase computing speed and determination of several parameters in a relatively short time.

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Felicia Elena P. Stan Ivan was born in 1982 in Craiova, Romania. In 2005 she graduated Economic Engineering in power engineering at University of Craiova and in 2009 she received Ph.D. in Energy Engineering from University of Craiova.
At present she is a university assistant at the Faculty of Electrical Engineering, University of Craiova. Her field of interest is energy efficiency of the buildings operation, analysis and value engineering.
Radu Cristian Dinu was born in 1974 in Deva, Romania. In 2000 he graduated Thermoelectric plants at Electrotehnic Faculty University of Craiova. In 2007 he received his Ph.D. in Civil Engineering, Technical University of Civil Engineering Bucharest,
Presently he is a lecturer in Faculty of Electrical Engineering, University of Craiova. His field of interest is Introduction to energy engineering, Thermoenergetics and district heating, industrial energy, modern solutions for energy production.

Temporal distribution of earthquakes on Dasht-e-Bayaz region, eastern Iran by a renewal process

Masoud Salehi, Mehdi Mousavi, Ali Farhadi

Abstract— temporal distribution of earthquakes with magnitude ($M_w \geq 6$) in the Dasht-e-Bayaz region, eastern Iran has been investigated using time-dependent (renewal) model. Time-dependent model can consider time elapsed since last event unlike time-independent (Poisson) model. The time dependent models are mainly based on the assumption that the occurrence of major earthquakes has partially periodicity. Fairly regular events have been occurred in Dasht-e-Bayaz region over the past decades. The main objective of this paper is to explore renewal models for Dasht-e-Bayaz region. For this purpose, three time-dependent interevent distributions including Weibull, Gamma and Lognormal are used. Parameters of models are estimated by using maximum likelihood estimation. Suitable distribution is selected based on logarithm likelihood function. The concept of conditional probability has been applied to forecast the next major ($M_w \geq 6$) earthquake in site of our interest. According to obtained results, the probability of occurrence of an earthquake with $M_w \geq 6$ is significantly high (above 50 percent) based on weibull model as the suitable distribution for Dasht-e-Bayaz region.

Keywords— conditional probability, forecast, temporal distribution, time-dependent model.

I. INTRODUCTION

Iran situated in one of the most seismically active regions in the world namely the Alpine-Himalayan seismic zone. As a reasonable deduction, occurring moderate to major earthquakes in Iranian plateau is inevitable. Dasht-e-Bayaz region, located in Khorasan province, eastern Iran, has experienced major earthquakes that cause high losses of human life and widespread damages. In addition major earthquakes in Dasht-e-Bayaz region occurred with fairly regular intervals. Consequently, by considering the seismic activity and the high level of the seismic vulnerability it is worth to study the seismic hazard in terms of earthquake prediction for this region.

As regards Earthquake prediction still appears infeasible but there are several methods that may makes more development in our capability to predict earthquake, one of them is to use statistics to forecast where next major earthquakes will occur in the near future [1]. Conditional probability as statistical concept has been used to estimate probability of the next earthquake. Several interevent distributions have been used to model temporal distribution of earthquakes. Poisson process is the most conventional temporal distribution model due to its simplicity. Poisson model is based on basic assumption that event occur independently and uniformly in time. In other words, in Poissonian model it is only required to estimate the mean recurrence interval. However in other temporal distribution models known as renewal models (e.g. Weibull, Lognormal, Gamma and etc) time elapsed since last event is considered unlike Poisson model [2]. Parameters of Lognormal, Gamma and Brownian Passage Time for 15 seismotectonic provinces in the Iranian Plateau have been estimated and conditional probability in several time intervals has been calculated [3]. They considered events with magnitude larger than magnitude of completeness to calculate model parameters and conditional probabilities for renewal model. However it is worth to mention that renewal model are proper for regions where major earthquake occur with approximately regular interval [2]. In other words, using non-Poisson models may not be true for all 15 seismotectonic provinces. This is because, in majority of these provinces moderate earthquakes which tend to occur randomly are dominant and Poisson model can describe them more accurately than other recurrence model.

Moreover, non-Poisson models should be considered for regions with some features, include: seismic hazard is dominated by single source, the time since that source's last earthquake is greater than the mean time interval, and the source has strong characteristic time behavior [4].

According to above mentioned statements and initial evaluation of Iranian catalogue, renewal model can be studied for Dasht-e-Bayaz region among all 15 seismotectonic provinces.

The main hypothesis of this study was that the final results when moderate earthquakes are excluded may be changed for Dasht-e-Bayaz region.

For this purpose, in this study, three statistical models, including Lognormal, weibull and Gamma, have been applied to investigate the earthquake recurrence intervals for Dasht-e-Bayaz region, eastern Iran.

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Among these three renewal models, weibull model has not been used for Dasht-e-Bayaz region in previous studies. This model provides the opportunity to overcome the limitation of both exponential and normal distribution in considering time elapsed since last event. Additionally, initial evaluation shows better consistency of weibull distribution compared to other models for Dasht-e-Bayaz region. Moreover, applying this model is not a new procedure, and weibull model has been applied in earthquake inter-event time modeling [5].

Lognormal distribution has been applied for the inter-event time distribution of large earthquakes and proposes a time-dependent model for hazard analysis for the New Madrid seismic zone and Charleston, South Carolina [6].

Gamma distribution is often used as a probability model for waiting times. This feature used in waiting times between earthquakes occurring in California [7].

II. METHODOLOGY

In this study we aim to estimate probability of occurring next major earthquake in Dasht-e-Bayaz region for different time intervals. The conditional probability than next earthquake will occur in next ΔT years given that it is not occurred in the last T years can be obtained from (1):

$$P(T,\Delta T) = \frac{\int_T^{T+\Delta T} f(t)dt}{\int_T^{\infty} f(t)dt} \qquad (1)$$

According to (1), it is required to introduce a probability density function for calculating conditional probability. As a result, three well known distribution namely Gamma, Lognormal, Weibull have been applied in this paper. Probability density functions of above mentioned distribution are presented in Table I.

TABLE I the renewal models used in this study based on the Utsu [1984]

model	Probability density function ,f_t(t)
lognormal	$\frac{1}{\sigma t\sqrt{2\pi}} exp\left\{-\frac{(lnt-m)^2}{2\sigma^2}\right\}$
Gamma	$\frac{c}{\Gamma(r)}(ct)^{r-1}e^{-ct}$
Weibull	$\alpha\beta t^{\beta-1}\exp(-\alpha t^{\beta})$

As can be seen in this table each model has specific parameters that should be estimated. Therefore, in next chapter of this paper the way to calculate these parameters and estimated value are presented.

III. ESTIMATING MODEL PARAMETERS

In order to estimate model parameters, two different approaches can be applied. Firstly, maximum likelihood estimation and secondly, method of moments approach. The detailed procedure to use each method for obtaining model parameters has been described in [2]. Utsu concluded that there is no significant difference among the result of these two methods. As a result, we only used maximum likelihood estimation to estimate model parameters of mentioned distributions. Model parameters for Gamma, Lognormal and weibull distribution include (c, r), (m, σ), (α, β) respectively. Estimated values for model parameters of each distribution are presented in Table II.

TABLE II parameter estimation from the Maximum Likelihood Estimation method

Probability model	Parameter	MLE value
Lognormal model	m	1.75
	σ	1.1
Weibull model	α	0.077
	β	1.12
Gamma model	r	1.17
	c	0.12

For obtaining values illustrated in table II maximum likelihood function has been applied to seismic data of Dasht-e-Bayaz region

IV. SEISMIC DATA

The Dasht-e-Bayaz left-lateral strike-slip fault system in Khorassan province, eastern Iran. Strike-slip faults are capable of producing large earthquakes [8].the Dasht-e-Bayaz region has experienced some great earthquakes in the last century. Two largest instrumentally recorded earthquakes include 1968 August 31 and 1979 November 27 that cause ruptured the entire 120 km length of the Dasht-e-Bayaz fault zone [9] these events caused extensive damage in the region where many village were completely destroyed [10]-[11].Between 7000 and 12000 people were killed and at least 70 000 made homeless [12].fig. 1 shows the seismicity of the Dasht-e-Bayaz region

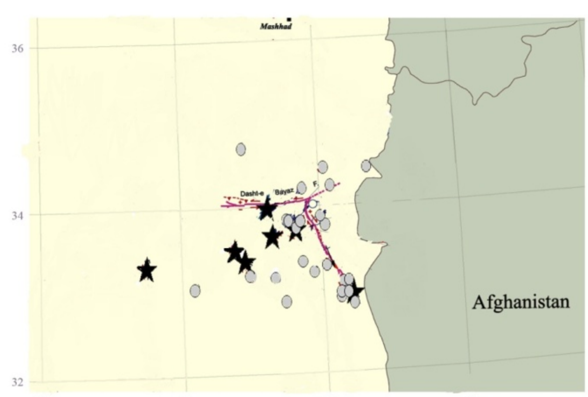

Fig. 1 map of Dasht-e-Bayaz region, eastern Iran showing faults and epicenters of earthquakes between 1941 and 2012 with magnitudes equal or greater than M_w=4.5, the earthquakes with M_w>6, marked with stars.

Major earthquakes in Dasht-e-Bayaz region are shown in table III.

Table III .major earthquakes in the Dasht-e Bayaz fault region

year	month	day	Magnitude(M_W)
1941	2	16	6.3
1947	9	23	6.9
1968	8	31	7.1
1976	11	7	6.2
1978	9	16	7.4
1979	1	16	6.7
1997	5	10	7.3

As can be seen in table III we only consider events with magnitude greater than M_w=6.00.

T_R and S_R are primary parameters required for model calculation.T_R is mean recurrence interval and S_R is standard deviation. Based on major earthquakes occurred in Dasht-e-Bayaz region, these parameters are 9 and 8 respectively.

V. Results

Once model parameters have been determined, we can estimate conditional probability of occurring next major earthquake. However, it is worth to mention that not all distributions are proper for this purpose. In other words, results should be reported for proper models. Among three statistical distribution weibull model is the most proper one. This is because of the greater logarithm likelihood function (Ln L) criteria of this model compared to the other distributions. The value of the logarithm likelihood function (Ln L) is an indication of how well a model fits the data. Ln L for Gamma, Lognormal and weibull distribution represented in table IV.

TABLE IV model comparison using the maximum log-likelihood criterion (Ln L)

model	Criterion(Ln L)
Lognormal	-19.58
Weibull	-19.34
Gamma	-19.36

This means that Weibull distribution gives the largest (best) Ln L for data.

Based on weibull distribution, the conditional probability that an earthquake occurs with $M_w \geq 6$ in Dasht-e-Bayaz region in next 5,10,25,50 and 100 years are calculated. The final results are presented in Table V. In addition to weibull model, Poisson model is also applied to draw a conclusion. Poisson model is the most commonly forecasting method in engineering society.

TABLE V conditional probabilities of an earthquake of magnitude $M \geq 6$ to occur in the next 5,10,25,50 and 100years given that no earthquake has occurred in the last t years since the last occurrence of 1997.

Weibull model					Poisson model				
5yr	10	25	50	100	5yr	10	25	50	100
0.46	0.71	0.96	0.99	1	0.42	0.66	0.93	0.99	1

For Poisson process conditional and unconditional probabilities are identical. The difference between probability calculated by renewal and Poisson is low this is because, time since the last large earthquake in this fault region compared to mean recurrence interval is not so different. However, it should be noted that in the next 5 years, Weibull distribution predict a comparable amount of probability

VI. Summary and Conclusion

This study compared Poissonian model and renewal model in terms of earthquake forecasting for Dasht-e-Bayaz region. In order to estimate conditional probability three renewal models namely, Gamma, Lognormal and Weibull distribution are applied. Model parameters for each recurrence model have been estimated using maximum likelihood estimation and weibull model is selected a most proper distribution. Finally the result of comparison between Weibull and Poisson model shows a little difference. This is because of the time elapse since last major earthquake. However in the near future (let say less than 10 years) the difference might be somewhat considerable. In other words, it is more conservation to consider time-dependent models for Dasht-e-Bayaz region instead of Poissonian model.

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Territorial Capital – An Essential Part of the Entrepreneurial Ecosystem – a Theoretical Approach

Roxana Voicu Dorobanțu, Ph.D.

***Abstract*—**The paper introduces the concept of territorial capital, and in particular the human capital part of it as an essential component of the entrepreneurial ecosystem of a region. This is particularly relevant for the development of targeted regional and national policies built towards developing a sustainable business ecosystem. The paper also presents the situation of Romania, as a case study for the decline of human capital.

***Keywords*—**entrepreneurial ecosystem, territorial capital.

INTRODUCTION

Defined as "collection of agents acting selfish or selfless, bringing added value and synergy learn from others" (Voicu-Dorobantu, 2015), a "logic living system" (Dinga, 2007) becomes known in the current academic research as a business or entrepreneurial ecosystem, difficult to separate conceptually (Anggraeni, Hartigh and Zegveld (2007)), as the literature still struggles with properly decanting the topic.

However, the components of this sort of structure are defined as "actors, flows (such as financial and knowledge flow) and the dynamic of the two" (Iansiti & Levien, Iansiti & Richards, 2002, 2004, 2006) and the function that transforms the inputs in the system in proper outputs is believed to be influenced and supported by the synergic creation of value. This synergy reduces externalities and uses the territorial capital to its best potential (Andriani, 2013; Battistella, Colucci and Nonino, 2012).

TERRITORIAL CAPITAL

Defined by Camagni (2008) based on it components, that is: "Private fixed capital stock; Pecuniary externalities (hard); Toll goods (excludable); Relational private services operating on: external linkages for firms, transfer of R&D results; University spin-offs; Human capital: entrepreneurship, creativity, private know-how; Pecuniary externalities (soft) Proprietary networks; Collective goods: landscape, cultural heritage (private „ensembles"); Cooperation networks: strategic alliances in R&D and knowledge; p/p partnerships in services and schemes; Governance of land and cultural resources; Relational capital: cooperation capability (trust); collective action capability (participation); collective competencies; Resources: natural cultural (punctual); Social overhead capital: infrastructure; Agencies for R&D transfer; Receptivity enhancing tools; Connectivity; Agglomeration and district economies; Collective action: conventions; behavioral codes; representations; values", territorial capital initially defined b OECD in 2001) has not been properly researched (Capello (2011)). The human capital, the structure of a business ecosystem, its actors and its outputs, as well as the ability to adapt and adjust as claimed by the level of education, are relevant indicators of development, although the obvious mismanagement of the knowledge flow may be counterproductive.

Starting from the theories regarding endogenous growth (Lucas 1988, Romer, 1990) and endogenous development, the investment in territorial capital in general and in human capital in particular are closely linked to regional growth and thus to the development of a particular regional business ecosystem (Capello, 2007).

HUMAN CAPITAL AS COMPONENT OF TERRITORIAL CAPITAL

The ingredients of human capital are creativity, entrepreneurship, industrial know-how and situational know-how. A person, a group of people and an organization are endowed to different levels with all of these ingredients. For example, an inventor excels in research and industrial know-how in a specific field, an entrepreneur in entrepreneurship and situational know-how in a market niche, and an intensively knowledge-based service provider on situational know-how in a market niche and of a sectorial industrial one. As in chemistry, these ingredients are associated in different proportions and in different conditions of a valence or of another one in more complex entities, with diverse characteristics and potencies. The territorial proportion and the specialization pattern of each component will reflect its profile and will confer the competitive potential of human capital within that territory.

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Also, each of these ingredients is produced in different measures within the formal, non-formal and informal education systems, through systems of assimilation and accommodation of explicit and tacit knowledge. For example, the technical creativity of an inventor is trained through tacit processes in research environments and in the context of assimilating specialized industrial know-how in formal education. Situational know-how is acquired, however, mainly from experience (informally, as expertise accumulated in the relationship with providers and clients within communities of practice, etc.).

Let us look more closely at the basic ingredients of human capital, as functioning parts of an evolutionary system. In essence, these ingredients are emphasized through cognitive capacities with economic value embodied in territorial residents. Through systemic and systematic association, these capacities with complementary natures generate along the history of that territory entrepreneurial activity – inserting new economic activities and/or impact ones in the existing economic reality/ Of course, the newly inserted activities can be both valid and non-valid, the reality of the economic game is decisive in this regard. The same economic game decided when to close some activities which have lost their validity after a long life span – of sustainable existence. Moreover, any new entry or exit from the game can make the appearance of new activities possible, and can perturb some pre-existing ones and can even eliminate them. Or on the contrary the new entries or exits can enhance sustainability and consolidate these pre-existing activities. Territorial capital must be regarded as a source of the totality of human activities within that territory and also as a source resulting from structural changes and accumulations resulting from those. There is another aspect which must be underlined. Human capital is endowed among other things with a memory. This intrinsically makes the dynamics and evolution of territorial capital should be a hysteresis one - in which the temporary condition essentially depends on the succession of the previous conditions, i.e. of the territorial history. This would be valid however in a territory populated with robots exclusively (robots have a memory). But people additionally have feelings and emotions or infatuations. For example, the mentality of a population living in a region depends both on the living standard as – especially – on whether it was deteriorated lately or on the length of the respective period. In the situation in which previously there was a long period of degradation, any punctual progress will be coloured skeptically. One swallow does not make a summer – will be a reply often heard in that territory. But if the living standard was degraded in a short period of time (an episode perceived as a passing one) a punctual progress will make people rather say The sun is shining above my head!

Complex evolutionary processes which trigger territorial realities have an intentional nature (phenomenological) which cannot be neglected. Treating them in a mechanical manner cannot yield results, except by chance, in some evolutionary calm stages, when the course of events is quasilinear. In transitory stages they become prevalent. In such phases, enthusiasm or on the contrary fury can bring to light completely surprising evolutions. And history fully shows that. In conclusion, when we analyze the situation to change by applying new policies, we must analyze more closely both the momentary state, as well as the history from which it was born. And policy makers should take these into consideration, at least by keeping in mind the following aspect. Successfully applied policies in a region with a macroeconomic state close to the region in which a similar success is followed can have no effect in the region in which the mimetic transfer of these policies is attempted, if the histories of the two regions differ significantly.

A ROMANIAN TRAGEDY – THE DECLINE OF HUMAN CAPITAL

Romania is facing a situation of decline of human capital. In this country the territorial specialization horizon is rapidly narrowing. And this process is practically an emerging uncontrollable one. As it is unique and with a significant impact in the EU, and also being a generator of social issues, this phenomenon must be regarded as a social problem of European, not only Romanian, concern. In our opinion, the growth of the generating capacity of sustainable companies, capable to reduce the income disparity between Romania and the EU should be regarded as a social, temporary objective, assumed both by the Romanian government and the European Commission. Concerning the situation of human capital in Romania, we have to underline the following aspect. Romania is facing a very important emigration within the categories of people who do not belong to highly educated specialists and researchers sub-categories, as well. Nowadays approximately 10% (around 1 million people) of the country's active population works legally in other countries of the European Union. To these we have to add the temporary legal or illegal workers. Estimates concerning them vary between 4% and 10% of the active population. This picture is describing a special social situation, special for both Romania and the EU and shows that entrepreneurship in Romania does not manage to generate sufficient jobs in industries that do not require high qualifications either. The cause can be found in the lack of resources for developing start-ups and in a certain precarity of the Romanian entrepreneurial culture. However, there is initiative – the fact that such a big number of people took the risk of going abroad for a job is an indicator. For example, according to the official data, 4,000 of the 28,000 Romanians who worked in Ireland in 2011 were freelancers. Also in 2009 48,709 Romanian small entrepreneurs who had set up a business or were officially offering their services against pay as freelancers were officially registered in constructions. The proportion of the people with entrepreneurial spirit in Romania is however going down, and this affects even more the entrepreneurial culture. Consequently, Romania is suffering from an important exodus of people with entrepreneurial spirit, along with highly qualified professionals and researchers. In our vision, the cause of this social phenomenon cannot only be a financial one, but also a systemic one, where the financial component is only one aspect.

Historic causes of the decline of Romanian human capital If we read the economic history of Romania in the last half of the century, we will notice a process of forced industrialization, marked by autarchic ambitions, which took place between 1960 and 1989. In this period, Romania created significant activities in the majority of the industrial fields: from the mining industry, siderugical industry, heavy industry to the clothing industry, machinery, precision tools mechanics, electrotechnical industry, electronics, IT, the chemical and pharmaceutical industries and from civil engineering to train engines production, or the aircraft or automotive industries, etc. This attempt of ”multilateral development” could only be put into practice in tight connection with the development of an education system which was efficient enough in technical areas – the evidence is the great number of specialists who were educated at the time who have found and continue to find jobs in developed industrial countries. But the concept of a ”socialist country/society multilaterally developed” – which guided the whole economic development in the period 1970 - 1980 and which marked the education system as well – was at the origin, philosophically speaking, at the root of Romania’s unsustainable development. This was due to several factors, among which three were decisive from our point of view – two of those existing before 1989 and one in the period after 1989.

1. Ignoring the moral ageing and the incapacity to anticipate the effects of disruptive technologies

Firstly, once an economic activity (economic unity) was made, the necessary resources for future modernization, especially those involving imports, were not allocated at a sufficient level to keep pace with international technological evolutions – this factor eroded the productivity of each of the new production units opened from the first years after being launched, especially in the context in which the new technologies (electronics and informatics) were proving to be innovative, due to their high technological spillover potential in the other industries. Thus, at the beginning of the 90’s Romania found itself in the situation of having an extremely diversified industry, but with many morally aged production units. To become competitive or to maintain their competitivity, they needed (simultaneously!) important resource allocations for modernization purposes. This would have meant an extremely important capital infusion. This capital was missing and was difficult to obtain in the context of the turmoil following a bloody revolution which heavily increased the country’s risk perception of international creditors and investors.

2. The machinist illusion

Secondly, while the “multilateral development” continued, the vision behind this was manifested also through the growing centralization of the whole economy. It was decided for this to be managed like a great business group of companies, unstructured in business units, but in industrial specializations. Socialist economic units did not have the structure of a company capable to act autonomously in the market. The marketing, sales and investment functions were practically devoid of substance at the level of these units which were companies only in appearance. These functions were taken over, also from ideological and security control reasons by industry coordinating structures, called ”Centrals” (central management units) and from the State Planning Committee. The industries were going to act and function monolithically, industrial entities were reduced to simple production units which had to respond to orders from the centre – like machines with which one acts and not like actors playing in the economic market. Internal competition was out of the question. External competition was seen only as race for prices. Each economic unit was becoming more and more specialized on a certain category of products or on a certain type of order profile for which it had been created, and transformed itself in some sort of monopoly. Also, profit allocation could not be decided at the level of the management of those organizations. Internal prices were decided in advance, so practically one could not speak of a real profit of a socialist unit. Thus, the units that were going to function after 1989 in market conditions and be privatized were only apparently functioning as real companies; they lacked market experience and necessary relational capital that a real marketing department produces. Also, because of excessive specialization, their capacity to reorient and adapt their production was very limited. Even if one of the first steps in the restructuring was represented by disbanding the central units – also made with the intention of bringing these functions within industrial units – the time necessary to learn (adaptation and accommodation) at organizational level of the new activities exceeded the time allowed by the market and the social environment in transition and in an increasing turmoil. In these conditions, many of the markets especially the ones abroad, were very soon lost. And the effects of each foreign market lost were rapidly spreading, through a domino effect, to the internal markets. Another consequence of the lack of marketing experience in production units was the following one. Any privatization is made as a consequence of due diligence, any due diligence especially emphasizes the team value and the marketing department performances. It is clear that, as these departments were practically improvised, the privatizing value of these socialist units was more often than not appreciated by the investors close to its physical assets (aged). Regarding this factor, we should notice the following fact as well. In the 80’s, the other socialist states, including the ones in the Soviet Union, knew a process of decentralization and of liberalization of the economy. These countries had time for 10 years to assimilate and understand the basics of a market economy both at an individual as well as at an organizational level. In the same period, Romania acted against the flow: it centralized and emphasized the control over the economy to an unprecedented level in the central and East-European space. In this context, once arriving in the situation of acting in a totally new economic environment, the time left for the new companies (new from a juridical point of view!) to learn the basics of

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capitalism and of the market economy was a much shorter one, if we compare it with the companies of the other former communist countries.

3. Excessive offer on the privatization market of the 90's

Finally, the third factor was one of a contextual nature. The sudden apparition of a great number of companies offered for privatization, from central and Eastern Europe and from China constituted in an offer on the equity market which placed investors in an extremely favourable negotiating position. All the former communist countries had this problem to a larger or a smaller extent. But Romanian companies found themselves in a tougher negotiating position, as they confronted in addition with the technological and the managerial deficiencies mentioned earlier. There was an exception. We have to underline the way China acted to prepare its companies in view of privatization. Intuitively or not, China understood better that a free market is characterized firstly by the existence of a free competition and only then by the public, mainly public, mainly private or private nature of property. Consequently, the Chinese government created first a competitive environment for its companies by attracting greenfield investment made by Western companies, and only then it proceeded to the privatization. In this way, on the one hand, companies and staff were given time to learn organizationally in the new free market conditions, and on the other hand it made possible a fairer evaluation of the companies to be privatized.
"

CONCLUSION

Research in territorial capital in general and in human capital in particular is far from being comprehensive, one aspect being the link between the generation of knowledge through research and development and its valuation via the entrepreneurial endeavors. Whether the decline of the human capital in an area (an ecosystem) is reversible or not is not the purpose of this paper, but may definitely constitute further research starting from the systems theory on whether a system with deteriorating components may yield the same outputs. Whether Romania is able to reverse the decline of its human capital is an important question for entrepreneurs, policy makers, as well as citizens alike.

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Modeling Zero Energy Building with a Three-Level Fuzzy Cognitive Map

Eleni S. Vergini[1], Theodora-Eleni Ch. Kostoula[2], P. P. Groumpos[3]

***Abstract*—** The concept of Zero Energy Buildings (ZEB) is briefly reviewed and its characteristics are presented. A number of categories of ZEBs are defined and briefly are discussed. An attempt is made to model Zero Energy Buildings (ZEBs) using theories and algorithms of Fuzzy Cognitive Maps (FCMs). The basics of FCMs and the Hebbian learning algorithm are briefly reviewed and outlined. A new three level model for ZEBs using FCMs is developed. The new model is used to conduct simulation studies for summer and winter cases. Interesting results are obtained and briefly discussed.

***Keywords*—** Zero Energy Buildings, Fuzzy Cognitive Maps, Non-linear Hebbian Learning Algorithm.

I. INTRODUCTION

IN recent years there has been a worldwide effort in environmental protection and energy saving in any human activity possible. Buildings, consuming about 30-40% of all primary energy produced worldwide and being responsible for 36% of CO_2 emissions, could not be missing from that effort. Scientists and engineers, using active and passive techniques, started to improve buildings' energy performance, always taking into consideration the human need to ensure comfortable living conditions while saving energy and reducing environmental pollution.

In addition the EU "Energy Performance of Buildings" Directive (EPBD), released in 2010, and the "Energy Efficiency Directive", released in 2012, lead member nations towards Zero Energy Buildings (ZEBs), with the obligation that by the end of 2020 all new buildings will have to be nearly Zero Energy Buildings (nZEBs). The same direction is given in USA member nations, where the US Department of Energy (DOE) has set a similar goal.

In the second section there is a brief reference to the characteristics of a ZEB and its parameters. In the third part of the paper there is a synoptic presentation of the method of FCMs and the algorithm of Non Linear Hebbian Learning. In the fourth section there is a description of the FCM which is used in this paper to model the operation of a ZEB, and in the fifth part the simulation results are discussed. Last but not least, in the sixth section there are the conclusions along with thoughts on further research.

E.S Vergini, Laboratory of Automation and Robotics, Electrical and Computer Engineering Department, University of Patras.

Th.E. Kostoula, Laboratory of Automation and Robotics, Electrical and Computer Engineering Department, University of Patras.

P.P. Groumpos, Laboratory of Automation and Robotics, Electrical and Computer Engineering Department, University of Patras.

II. ZERO ENERGY BUILDING DEFINITION

Zero Energy Building (ZEB) is based on the concept of a building which, within its boundaries, produces as much energy as it consumes, usually on an annual basis. The produced energy mainly comes from renewable energy sources which are located near the building, do not pollute the environment and their cost is reasonable. Since a specific way to achieve the desirable energy balance has not yet been defined and established, the aspect of ZEBs is rather challenging. The absence of specific characteristics and equipment requirements is the reason why an accurate definition has not yet been expressed [1]-[5].

In order to be appropriate for use, buildings should provide specific comfort conditions for people who are inside. Those conditions are achieved by consuming energy for heating, cooling, lighting and other services. Buildings mainly consume electrical energy, other types of energy which are consumed, such as thermal, are usually produced either by converting electrical energy or by passive techniques, such as solar heating or geothermal energy.

The energy requirements of each building depend on its utility. There are three categories of buildings according to their use. These are 1) commercial, 2) public and 3) residential buildings. Another important factor related to the required energy is the geographical position of each building. Usually in regions with lower temperature a larger amount of energy is consumed in space heating whereas in warmer regions more energy is consumed in air-conditioning and cooling.

A ZEB is characterized by its connection to the grid according to the following reasoning. Usually in regions where a connection to the grid is not accessible buildings are not connected to the grid. Those ZEBs are characterized as autonomous or stand-alone ZEBs.

On the other hand ZEBs which are connected to the grid are separated in three categories [6]:

- **Nearly Zero Energy Building (nZEB)** is a ZEB connected to the grid which has nearly zero energy balance. This means that the consumed energy is slightly higher than the produced energy.
- **Net Zero Energy Building (NZEB)** is a ZEB connected to the grid which has zero energy balance. In that occasion the consumed energy is equal to the produced energy.
- **Net plus or Positive Energy Building** is a building with positive energy balance. The positive energy building consumes less energy than it produces and the excess energy is supplied to the grid.

In all the above cases the energy balance is calculated on annual basis.

The design of each building is made taking into consideration the energy requirements and the applications which are used to satisfy those requirements. The required energy is mainly produced by renewable energy sources, but when those sources are not enough to satisfy the load, conventional energy sources might be used as well. The energy sources may be on the building, on its site or at a distance.

It was mentioned above that in cases of positive energy buildings excess energy is usually provided to the grid. Alternatively, that energy might be saved for later use in energy storage devices. Those devices can also be used in autonomous buildings in order to save energy for later use. However those devices have the disadvantages of 1) limited technology and 2) the need of regular maintenance and replacement, [7]-[8].

III. Fuzzy Cognitive Maps

A. FCM Structure

Fuzzy Cognitive Maps (FCMs) are a combination of fuzzy logic and neural networks. They are a method of modeling complex problems, based on human reasoning. A human can make a decision even if a problem is uncertain or ambiguous, using his experience and assessment ability. FCMs are based on that reasoning. They are a graphical presentation of the problem. Each parameter (variable) is presented with a node and it is called “concept”. The interaction between concepts and the way they affect each other are presented with “weights”. The number of concepts, the kind of interaction between them and the values of the weights are determined by experts, who know the dynamics of the system and the way it reacts to various changes [12]-[13].

Concepts take values in the interval [0, 1] and weights belong in the interval [-1, 1]. The sign of each weight represents the type of influence between concepts. Between two concepts C_i and C_j there could be three cases:

- $w_{ij}>0$, an increase in C_i causes an increase in concept C_j, and a decrease in C_i causes a decrease in concept C_j.
- $w_{ij}<0$, an increase in C_i causes a decrease in C_j, and a decrease in C_i causes an increase in C_j.
- $w_{ij}=0$, there is no interaction between concepts C_i and C_j.

The amount of influence between the two concepts is indicated by the absolute value of w_{ij}.

During simulation, the value of each concept is calculated using the following rule:

$$A_i(t) = f\left(A_i(t-1) + \sum_{\substack{j=1 \\ j\neq 1}}^{n} A_j(t-1)\cdot w_{ji}\right) \qquad (1)$$

Where t represents time, n is the number of concepts and f is the sigmoid function given by the following equation:

$$f = \frac{1}{1+e^{-\lambda x}} \qquad (2)$$

In which $\lambda>0$ determines the steepness of function f.

Usually in problems there is a number of concepts and **A** and **w** are matrices.

The FCM concepts take initial values and then they are changed depending on the weights and the way the concepts affect each other. The calculations stop when a stable state is achieved and the values of concepts do not change furthermore.

In some cases, there are systems which can be presented by a FCM organized in levels. In the lower level there are concepts which affect only other concepts in the same on in the above level and not the output, those concepts are **Factor**-concepts. The concepts which are affected by Factor-concepts and then they determine the output are called **Selector**-concepts and finally, in the higher level, there are the **Output**-concepts. [9]

B. Non Linear Hebbian Learning

Based on neural networks, FCMs have a non-linear structure. The algorithm of non-linear Hebbian learning is used in this paper to train ZEB FCM to predict the energy balance. The algorithm uses a learning rate parameter η_κ and a weight decay parameter γ, in order to calculate updated weight values, changing only non-zero weights that the expert gave, and then update the concept values. The non-linear Hebbian learning algorithm is based on the equation:

$$w_{ji}^{(k)} = \gamma \cdot w_{ji}^{(k-1)} + \eta_k A_i^{(k-1)}(A_j^{(k-1)} - (w_{ji}^{(k-1)})w_{ji}^{(k-1)}A_i^{(k-1)}) \qquad (3)$$

There are two different termination criteria which determine when the algorithm stops. In [10] there is a detailed description of the algorithm and its parameters.

IV. Modeling a ZEB with a Three Level FCM

In this paper a three level FCM (Fig.1) will be used to model the operation of a ZEB. In order to make a FCM to represent the interconnection of the components of ZEB architecture during real-time operation, an expert should consider each component as a concept and determine the weights between them.

In this paper a house was considered to be the ZEB and the parameters that each concept represents are the following:

- C1 : Photovoltaic System
- C2 : Wind Turbine
- C3 : Lighting
- C4 : Electrical/Electronic Devices
- C5 : Heating
- C6 : Cooling
- C7 : Solar Radiation
- C8 : Wind Velocity
- C9 : Windows
- C10 : Natural Light
- C11 : Shading
- C12 : Internal Temperature
- C13 : External Temperature
- C14 : Geothermal Energy
- C15 : Total Production
- C16 : Total Consumption

In the first level there are concepts C7-C14, which represent the weather conditions and the parameters which

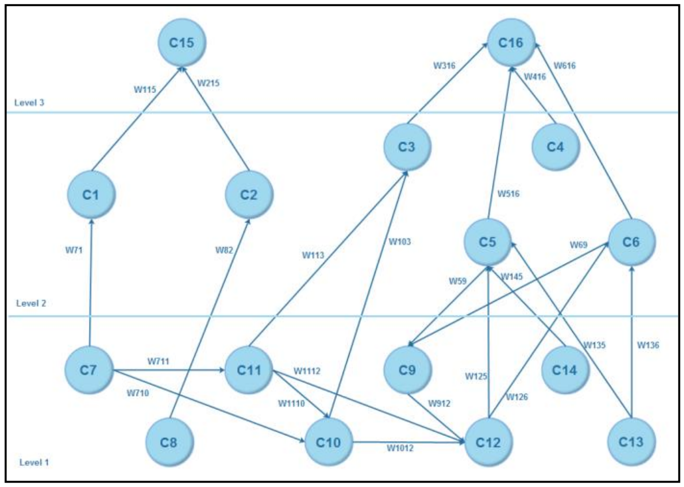

Fig.1 Three Level FCM modeling ZEB.

affect the values of the higher level concepts. Those are the Factor-concepts. In the second level there are concepts C1-C6, those are the Selector-concepts. C1 and C2 are the energy production units, and C3-C6 are the energy consumption parameters. In the third level C15 and C16 are the output values, total production and total consumption, since the most important consideration of a ZEB is the Energy Balance, which is given by the equation:

Energy Balance=Total Production–Total Consumption

The amount of energy that each concept produces or consumes was considered based in [11], in order to determine the linguistic values of the concepts and to specify the weights. More specifically:

- C1 (***PV***): Output Power 0-10KW→Concept value **0–1**.
- C2 (***Wind Turbine***): Output power 1KW→Concept value **0-0.1**.
- C3 (***Lighting***): It is estimated that the house has 15 light bulbs, and each bulb has power consumption

TABLE 1																
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	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,8	0
C2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,2	0
C3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,1
C4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,3
C5	0	0	0	0	0	0	0	0	-0,5	0	0	0	0	0	0	0,15
C6	0	0	0	0	0	0	0	0	-0,5	0	0	0	0	0	0	0,15
C7	0,95	0	0	0	0	0	0	0	0	0,6	**0,1**	0	0	0	0	0
C8	0	0,85	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C9	0	0	0	0	0	0	0	0	0	0	0	**0,1**	0	0	0	0
C10	0	0	-0,3	0	0	0	0	0	0	0	0	0,01	0	0	0	0
C11	0	0	0,3	0	0	0	0	0	0	-0,2	0	-0,01	0	0	0	0
C12	0	0	0	0	0	0,2	0	0	0	0	0	0	0	0	0	0
C13	0	0	0	0	0	0,2	0	0	0	0	0	0	0	0	0	0
C14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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20W. An average use of the lighting is estimated, using 4bulbs × 3h/day, giving a total consumption in lighting equal to 240W/day→Concept value **0-0.024**.

- C4 (***Electrical/Electronic Devices***): The devices that a typical house has are:
  - ✓ *Fridge*: 90W/h→2160W/day
  - ✓ *Electric Oven*: 2000W/h
  - ✓ *PC*: 300W/h, average use 3 hours per day
  - ✓ *Electric Iron*: 1000W/h
  - ✓ *Vacuum Cleaner*: 1000W/h
  - ✓ *TV*: 41W/h
  - ✓ *Washing Machine*: 2800W/h
  - ✓ *Electric Water Heater 80lt*: 4000W/h

  Considering an average day, using the fridge 24h, the electric oven 1h, the PC 3h, the vacuum cleaner 1/2h and the electric iron 1h, the average consumption for the devices is equal to 6560W/day→Concept value **0-0.656**.
- C5 (***Heating***): 2 Air Condition 1000W/h, average use 2h, average consumption 4000W/day→Concept value **0-0.4**.
- C6 (***Cooling***): 2 Air Condition 1000W/h, average use 2h, average consumption 4000W/day→Concept value **0-0.4**.

Concepts C7-C14 vary between **0** and **1**, since their contribution is considered only linguistically.

V. Simulation Results and Discussion

The simulation procedure was designed for two cases. The first case is a typical summer day and the second is a typical winter day. The weight matrix for each case is shown in Table 1 and Table 2 respectively. Except for the weights W7-11, W9-12, and W14-16, all the other weights are common in both cases, which is reasonable since they refer to the same system. W7-11 expresses the interaction between solar radiation and shading. In summer it is positive, since a thicker shadow is necessary as the solar radiation increases. On the other hand, in winter it is negative because less shadow is desired as the radiation increases, in order to take advantage of it to heat the rooms and have more natural light. In addition W9-12 expresses the interaction between windows and inside temperature. During summer, when the outside temperature is higher than the inside, an open window causes an increase in the inside temperature. Whereas, in the winter, when the outside temperature is lower than the inside, an open window causes a decrease in the inside, that is why W9-12 is negative in winter and positive in summer. W14-16 expresses the contribution of geothermal energy in the total consumption, since in order to take advantage of geothermal energy a heating pump should consume a small amount of energy.

A. *Summer*

In order to have a good approach of the buildings' operation during summer, the appropriate weather conditions are set to the initial input values, approaching the Greek climate.

Solar radiation (C7) has been set high and wind velocity (C8) has been set low, those concepts define the energy production setting the PV energy production (C1) to high and wind turbine energy production (C2) to low. Apart from the production, the weather concepts define the initial values of natural light (C10), which initially has medium high value and shading (C11), which has a medium initial value.

In addition, the concepts which determine the energy

TABLE 2

WINTER

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**
C1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,8	0
C2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,2	0
C3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,1
C4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,3
C5	0	0	0	0	0	0	0	0	-0,5	0	0	0	0	0	0	0,15
C6	0	0	0	0	0	0	0	0	-0,5	0	0	0	0	0	0	0,15
C7	0,95	0	0	0	0	0	0	0	0	0,6	**-0,2**	0	0	0	0	0
C8	0	0,85	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C9	0	0	0	0	0	0	0	0	0	0	0	**-0,3**	0	0	0	0
C10	0	0	-0,3	0	0	0	0	0	0	0	0	0,01	0	0	0	0
C11	0	0	0,3	0	0	0	0	0	0	-0,2	0	-0,01	0	0	0	0
C12	0	0	0	0	-0,2	0	0	0	0	0	0	0	0	0	0	0
C13	0	0	0	0	-0,05	0	0	0	0	0	0	0	0	0	0	0
C14	0	0	0	0	-0,2	0	0	0	0	0	0	0	0	0	0	0,05
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

consumption have been set to the appropriate values. Lights energy consumption (C3) is low since the natural light is high. Devices (C4) are set to low, heating (C5) is zero and cooling (C6) is medium.

All the above initial values, considering the weight matrix for summer building operation and the non-linear Hebbian learning algorithm, lead to the diagram in Fig.2.

In that diagram the above line represents the total production and the bottom line is the total consumption. It is assumed from the diagram that **during summer the Energy Balance is positive**. The fact that the balance is positive is reasonable and expected, since in Greece during summer the solar energy is intense and some months, such as August, the wind may be quite strong as well. Those conditions offer more than the necessary amount of energy, giving the opportunity not only for a zero energy balance but for a positive one.

B. Winter

Following the same thoughts as during the summer, the winter conditions were formed as following. Solar radiation (C7) has been set low and wind velocity (C8) has been set high, those concepts lead the PV energy production (C1) to low and wind turbine energy production (C2) to high. The weather concepts define the initial values of natural light (C10), which initially has a low value and shading (C11), which has zero initial value.

In addition, lights energy consumption (C3) is high since the natural light is low. Devices (C4) are set to low, it was assumed that the human activity does not change but it is the same as in summer, heating (C5) is medium and cooling (C6) is zero.

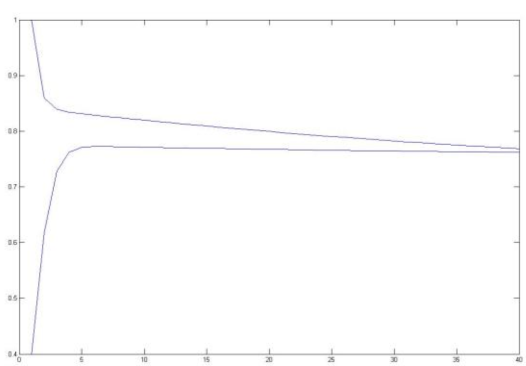

Fig.2 Total Production and Total consumption of a ZEB during summer.

All the above initial values, considering the weight matrix for winter building operation and the non-linear Hebbian learning algorithm, lead to the diagram in Fig.3.

In that diagram the total production starts with a higher value of the total consumption, but in the end it is obvious that the total consumption exceeds the production. This means that **the Energy Balance is negative during an average winter day**. This result was expected since, most of winter days the produced energy are not enough to cover the needs and the energy balance is considered to be negative.

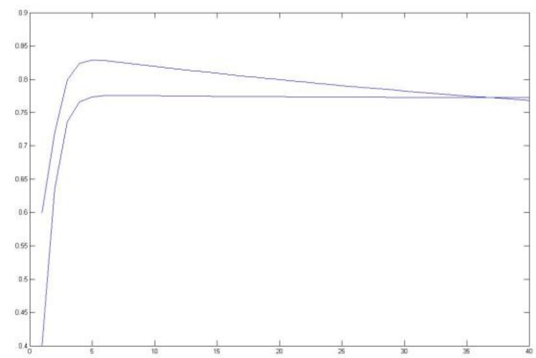

Fig.3 Total Production and Total consumption of a ZEB during winter.

The above results cover two typical days, with average weather conditions and average energy consumption, one in summer and one in winter. It is a fact that not every day will be like those, but the goal of a Zero Energy building is not the achievement of balance in only one day, it is within one year. In summer, when most days have a positive balance, the extra produced energy will be provided to the grid and in winter, when the energy balance most of the days is negative, the grid will provide the necessary energy to the building, balancing the interchange of energy.

Another important factor is that buildings, apart from production and consumption variables, also have parameters, such as materials and utility, etc. Those parameters define the behavior of each building, and play a rather important role in the energy balance. Buildings with the same size and same energy production equipment may not cover their needs in the same way and this is a challenging problem.

VI. Conclusions and Future Research

ZEBs attract the attention of scientists and engineers in recent years. However, their modeling has many difficulties, due to the large number of parameters, the different possible

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ways of approach and the fact that an accurate definition has not yet been defined.

This paper is a modeling approach of a ZEB. The simulation results are promising, since the FCM model outputs are the same with those which were expected from the real system. Therefore, FCM could be characterized as a useful tool and one could assume that a first step towards the simulation and modeling of a ZEB has been done.

However, there are many unanswered questions on the aspect of ZEB. The next research steps could be the application of control methods, in order to make the building "intelligent". The implementation of load management and energy efficiency control systems is necessary for the achievement of Energy Balance, mainly when the weather conditions are not cooperative. Definitely, the aspect of ZEB has still many unlighted sides and scientists should give their lights towards that direction.

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Innovative tool for vertical wind speed profiling by combining remote investigation method based on Lidar measurements and sky photometry

I. Vetres, A. Cioabla, I. Moisescu

Abstract**—**The main goal is to create a method for determining vertical wind profile by combining data from an elastic lidar system (simple construction on a single wavelength – 532 nm) and video tracking of clouds movement obtained from a webcam. The complementary techniques can be achieved easily because it is accessible and efficient method for determining wind speed and vertical profiling. This will solve and try to avoid the risks of a potential reduction in energy efficiency recovery from wind energy installations.

Keywords**—**Lidar, OpenCv, vertical profiling, wind speed.

I. Introduction

Wind speed profile has major importance for wind farm project implementation, and also to validate forecast and dispersion models. Currently to determine wind speed and direction we are using meteorological towers, Doppler Lidar systems or windcube systems and sodar, the disadvantage of these methods is that they are very expensive. The method for determining wind profile by combining elastic Lidar system (simple construction on a single wavelength – 532 nm) and a web camera (CCD) is a cheap way in construction. Lidar system provide vertical dynamics of air masses containing aerosols and CCD camera provides the information of "picture frames" that can be analyzed to determine the direction and velocity of air masses through pixel analysis.

Using Lidar system [1], [2] are retrieved information about the temporal and vertical structure of aerosol mass in motion [1], the height of the layers that can be used for further analysis. A web camera with CCD (charge coupled device sensor, charged coupled device), working with the same temporal resolution as Lidar system, will take images of the sky of the investigated area. The images obtained then go through a preprocessing stage, it consists of the removal of noise (noise) by using a Gaussian filter [3], [4]. In the processing phase will use Canny edge detection algorithm [5], [8] so the regions of interest are highlighted (ROI) [5], [6]. To improve detection result can use the previous method and filtering Canny Sobel [7], [8], which emphasizes high contrast areas on adjacent pixels, thus easing the clouds detecting process [9], [10] [12], [13]. By contours detected position, picture by picture, we can build motion vectors. These motion vectors are then transposed and corroborated by height data from the Lidar system, thus obtaining the final vertical profiling. OpenCv framework is used for the image analysis and obtaining speed vector from clouds dynamics in front of camera lens.

II. Experimental Data and Processing Model

Two day's data will be presented in the paper, Lidar measurements for at least two hour of continuum measurement.

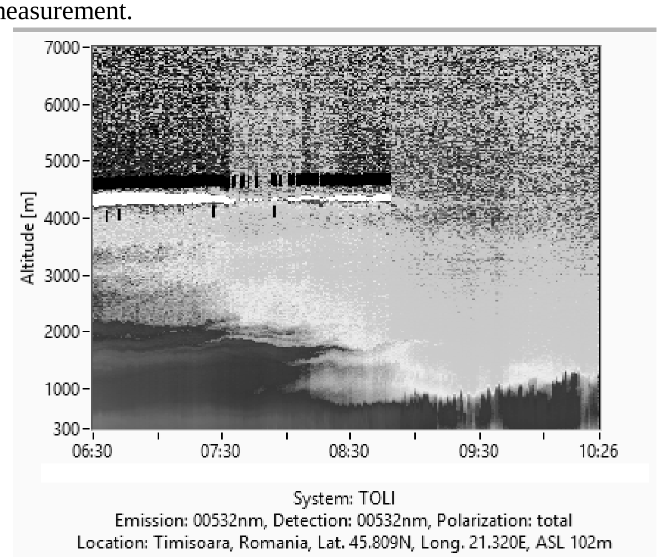

Fig. 1 RCS Lidar signal for 18.06.2014 in Timisoara laboratory, measurement from 06:30 UTC – 10:30 UTC

Fig. 1 shows turbulent activity in the lower atmosphere (300 m – 2200 m), and a well defined aerosol layer at 4500 m. In 22.06.2014 the layer is at 2500 m with a slight descent evolution.

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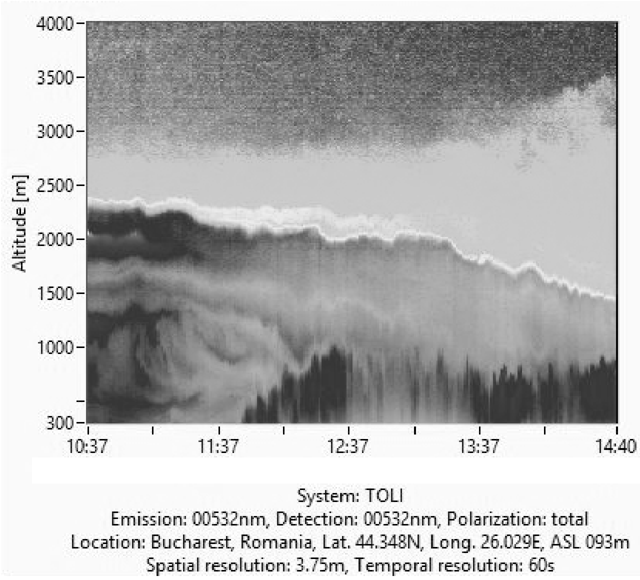

Fig. 2 RCS Lidar signal for 22.06.2014 in Timisoara laboratory, measurement from 10:30 UTC – 14:30 UTC

For further analysis of aerosols and clouds height we have implemented Haar function, the wavelet analysis based on a time-series decomposition in frequency space - time.

The function has the form:

$$W(a,b)=\int_{Z0}^{Z} f(t)\frac{1}{\sqrt{|a|}}\psi^{*}\left(\frac{t-b}{a}\right)dt \qquad (1)$$

Where a and b are real constants and the symbol * designates complex conjugation operation.

It is noted that wavelet signals $\psi_{a,b}(t)$ are translated and scaled versions (dilated or compressed along the time axis) of the basic wavelet signal $\psi(t)$. Scaling can be done by expansion (when a>1) or compression (for a<1). Wavelet transform involves convolution calculation of the analyzed signal and a set of signals that form a particular base in the vector space of finite energy signals.

The results of Haar function application are presented in the following figures.

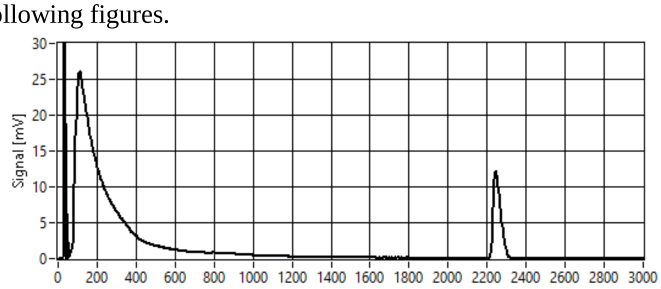

Fig. 3 Lidar signal for 18.06.2014 in Timisoara laboratory, layer height at approximately 2300 m

The results for Haar function that was applied on 18.06.2014 data has depicted two height layers, one at 2265 m and one at 4780 m. We have to take in account that the function is giving us the top of the layers and is the height where the derivative of the function is equal to 0.

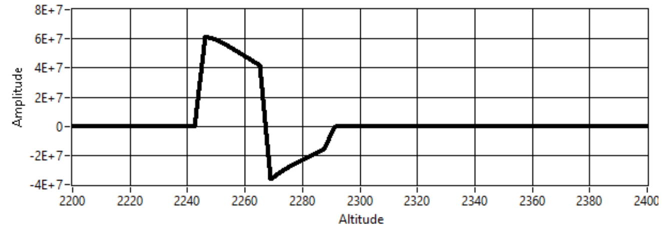

Fig. 4 Haar function result for 18.06.2014 data – 2265 m the layer height

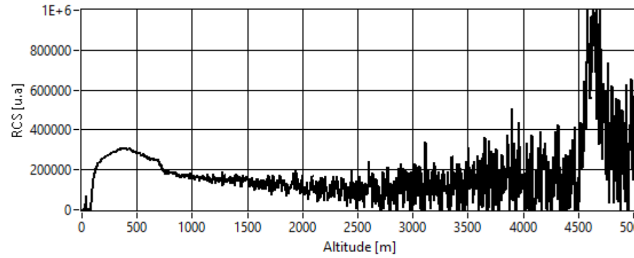

Fig. 5 Lidar signal for 18.06.2014 in Timisoara laboratory, layer height at approximately 4500 m

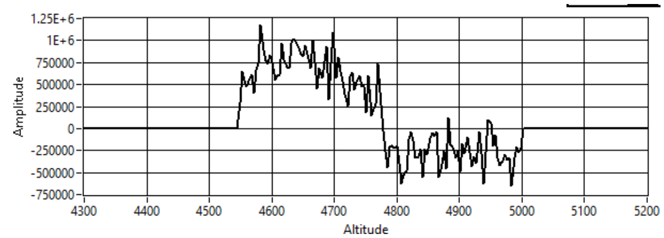

Fig. 6 Haar function result for 18.06.2014 data – 4780 m the layer height

A more complicated RCS image is for the data from 22.06.2014, the eye can not predict where the top of layers are, because of the mixing layers. Instead Haar function give us the height of 1298 m for the data analyzed, as seen in Fig. 8

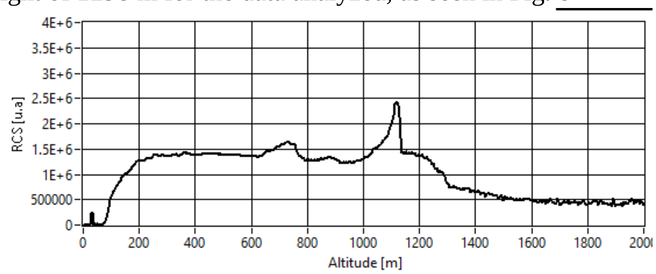

Fig. 7 Lidar signal for 22.06.2014 in Timisoara laboratory, layer height at approximately 1300 m

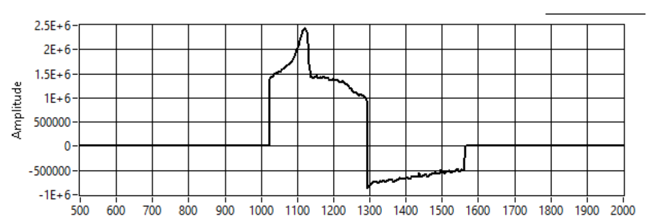

Fig. 8 Haar function result for 22.06.2014 data – 1298 m the layer height

Nr. crt	Time of measurement	Haar function result Layer height [m]	
1	18.06.2014 - Timisoara	2265	4780
2	22.06.2014 - Timisoara	1298	
3	23.06.2014 - Timisoara	2650	
4	26.06.2014 - Timisoara	3250	
5	27.06.2014 - Timisoara	1460	
6	30.06.2014 - Timisoara	1750	3780
7	02.07.2014 - Timisoara	1780	

Table I – Haar function result for layer height for seven episodes of measurements

Next step in data analyzing is to extract with the help of OpenCv framework the speed and direction vector for the air masses depicted by the Lidar.

The framework has module for object detection and image noise removal. By detecting the position and direction of the clouds moving we can calculate the speed vector of the air masses.

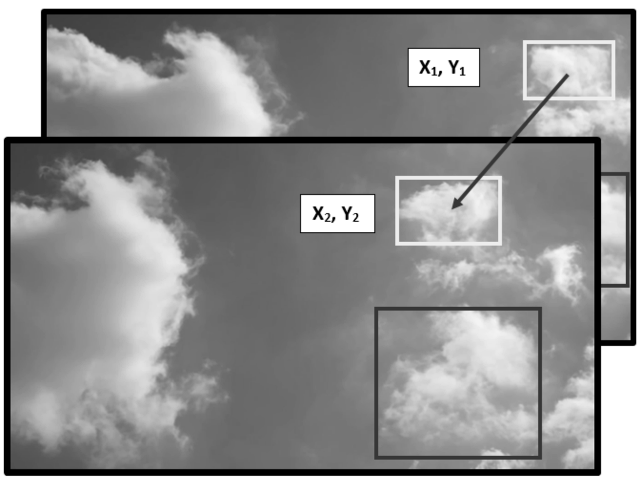

Fig. 8 OpenCv cloud detection – feature detection method - Canny edge combined with moments module

By combining different modules from OpenCv [9], [10] , feature detection and Canny edge modules [11], we can obtain the centroid coordinate of clouds, characterized by the position X and Y, and by corroborate the coordinates from different frames we can obtain the distance traveled by the detected object and also the direction.

$$d = \sqrt{(x_2 - x_1) + (y_2 - y_1)} \qquad (2)$$

d is the traveled distance between the two points in the camera field of view. And thus can easily determine speed of the air masses to be:

$$u = \frac{d}{t} \qquad (3)$$

where t is the time passed between the movements of the detected cloud from X_1Y_1 to X_2Y_2.

For the vector direction angle we have to use simple mathematical calculation for the two point's extracted coordinates:

$$angle = a\tan\left(\frac{y_1 - y_2}{x_2 - x_1}\right) \qquad (4)$$

where x dirrection is North oriented, and has possitive values from right to left of the screen.

Nr. crt	Date	Wind speed measured at ground level, at 5 m [ms^{-1}]	Wind speed measured at layer height [ms^{-1}]	
1	18.06.2014	2.1	7.85	8.35
2	22.06.2014	2.1	7.23	
3	23.06.2014	2.6	8.56	
4	26.06.2014	5.1	20.67	
5	27.06.2014	1	4.7	
6	30.06.2014	6.7	22.77	22.95
7	02.07.2014	3.6	13.26	

Table II – Wind speed at ground level and at layer height (determined by use of OpenCv [9], [10] framework on images captured)

The simplest form of calculating wind speed at ground level in this case is to utilize logarithmic form of the vertical wind profile, equation (5).

$$v_1 = v_2 \frac{\left(\frac{h_1}{z_0}\right)}{\left(\frac{h_2}{z_0}\right)} \qquad (5)$$

Where v_2 is the wind speed detected at layer height (h_2), v_1 is the wind speed at ground level (h_1) and z_0 is the groung roughness.

Ground roughness classification	
0.0002	Water surfaces: seas and Lakes
0.0024	Open terrain with smooth surface, e.g. concrete, airport runways, mown grass
0.03	Open agricultural land without fences and hedges; maybe some far apart buildings and very gentle hills
0.055	Agricultural land with a few buildings and 8 m high hedges seperated by more than 1 km
0.1	Agricultural land with a few buildings and 8 m high hedges seperated by approx. 500 m
0.2	Agricultural land with many trees, bushes and plants, or 8 m high hedges seperated by approx. 250 m
0.4	Towns, villages, agricultural land with many or high hedges, forests and very rough and uneven terrain
0.6	Large towns with high buildings
1.6	Large cities with high buildings and skyscrapers

Table III – Ground roughness – European Wind Atlas classification

Nr.	Wind speed	Wind speed	Deviation

crt	measured at ground level, at 5 m (measured) [ms^{-1}]	measured at ground level, at 5 m (calculated) [ms-1]		[%]	
1	2.1	2.30	2.24	9.62	6.96
2	2.1	2.25		7.55	
3	2.6	2.74		5.54	
4	5.1	5.79		13.70	
5	1	1.44		38.56	
6	6.7	6.85	6.60	2.38	1.36
7	3.6	3.98		10.74	

Table IV – Wind speed at ground level – measured and calculated

As we can observe from Table IV if the wind speed is low at ground level the error in calculation is significant, but also is dependent of the ground roughness.

III. Conclusion

For a wind farm to be productive speed exceeding 6 ms^{-1} it is a must. As we can see also the proposed model has significant low error in calculation for speed upper than 6 ms^{-1}. For low speed and height it is better to use sodar or radiosounding. Simple and compact instruments with a single wavelength Lidar and a CCD camera can successfully replace more expensive and heavier equipment's.

Acknowledgment

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Some consideration about the superheaters modelling of steam generators

A. M. Duinea, D. Ruşinaru

Abstract — The paper presents, in the first part, the importance of the steam generator in the operation of power plants, especially, the importance of the superheaters, the heat exchange surface on the route of the combustion gases, with all physical phenomena produced, which lead to the shaping of the physical model. The paper proposes the development of a mathematical model in absolute units and the simulation the operation of the steam superheater of the steam generator. The theoretical model proposed is implemented in Matlab-Simulink for simulations in dynamic regime.

***Keywords* —** mathematical model, simulation, superheater

I. INTRODUCTION

Among the priority issues that the modern society has to be solved, include also the energy and environmental issues. The notion of control, process control, has expanded in recent years, encompassing new areas such as automatic control of quality, the data processing with decisional purpose for one strategic leadership, ensuring uninterrupted of the system maintainability and thus, security and viability of the entire ensemble. In this context are part and the simplified simulation methods of the energetic installations from the power plants. Simulation can be defined as a method used for studying the behavior of a real system or phenomenon. Thermal power plant simulations can be for operator training, operator guide or as a design aid. A training simulator need to be able to simulate very wide phenomena, all in real time, where as for design aid simulation range is much smaller and real time capability is not needed, in the case of operator guide real time and on-line capabilities is required.

The most important component of the conventional power generation plant for fuel optimization studies is the steam generator. The control of the steam generator to archive optimum performance is a difficult problem that has been studied during the last years. The steam generator is a heat exchanger that converts water into steam pressure and temperature required, by the heat produced by the combustion of fossil fuels. The production of steam or hot water in the boiler is achieved by two successive energy conversion or chemical burn and transfer of heat. Chemical energy of the fuel is converted into heat in the combustion process, resulting combustion gas with high temperature that transfers heat water or steam through pipes generator metal surfaces. The steam generator is continuously fed with water and debit continuous hot water or steam. The heating and water vapours takes place practically at constant pressure, neglecting frictional losses inside. The evolving gases from the steam boiler are steam boiler combustion air and gases resulting from combustion, their rates are directly proportional to the amount of fuel burned, [2].

It is well known that in the steam generator, the supplied suffers a succession of phases in various, and with diverse design heat exchangers with an adequate diameter in order to obtain an acceptable heat transfer coefficient and low pressure losses with restrictions regarding the metal temperature. The transformations are: liquid heating in economizer, vaporization in the evaporator under superheating in the superheater, and reheat in the intermediary superheater. It’s worth mentioning that this delimitation it’s not always that obvious, especially between the economizer and evaporator, or the evaporator and the superheater. Between these heat exchange surfaces there are input-output collectors.

In order to outline the analyzed physical processes Fig.1 presents the configuration of the superheater system of a high power steam generator.

As it is shown in Fig. 1, the superheater I is situated between the two flue gasses passes. From the collector 6, behind the II gasses pass, the steam flows through the pipes of the first, I, pass and reaches the output collector.

From the collector’s extremities the steam climbs through two ϕ324 x 25 pipes, that intersect each other and enters the collector 7 at the input of the superheater II as in Fig. 1. The II superheater is upper part of the furnace in the first gasses road. From the input colector, 7, the sustaining pipes are descending of the first gasses road where the pipes of the II superheater start. After these pipes the steam reach the output colector 8. By the intricate latera connection pipes, the steam reaches the input colector of the superheater III, 9. In the superheater III the steam travells against the flue gasses, over the convection superheater I and over the superheater IV, [7].

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A.M. Duinea is with the Faculty of Electrical Engineering, University of Craiova, Craiova 200440 Romania (phone: 0040771617793; fax: 0040251436447; e-mail: aduinea@ elth.ucv.ro).

D. Rusinaru is with the Faculty of Electrical Engineering, University of Craiova, Craiova 200440 Romania (e-mail: drusinaru@ elth.ucv.ro).

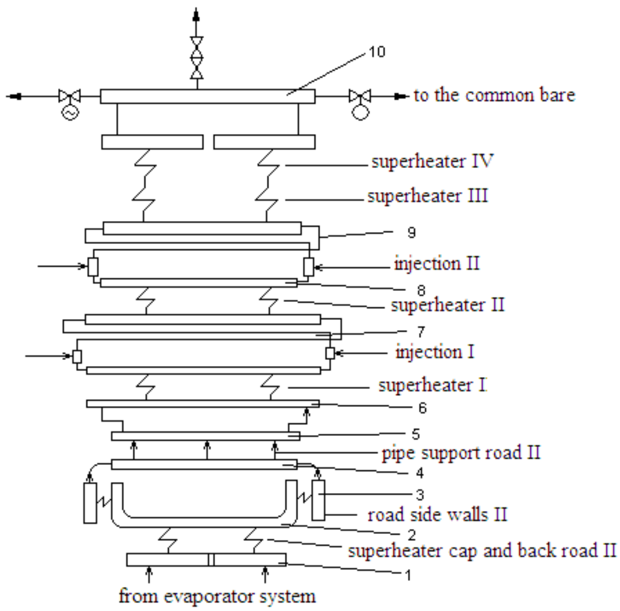


Fig. 1. Scheme of the steam superheater system

The superheater IV continues directly after the superheater III pipes without an intermediary colector.

The steam passes through the pipes of the superheater IV against the flue gasses and reaches the output colector, 10.

All these informations create the basis of the heat exchange surface mathematical model for our mathematical modeling.

II. THE PHYSICAL AND MATHEMATICAL MODEL OF THE SUPERHEATER

The paper proposes the development of a mathematical model in absolute units and the simulation of a convective heat exchange surface operation for the steam generator in steady and dynamic regime. The theoretical model proposed is implemented in Matlab-Simulink obtained simulations in dynamic regime.

In the dynamical modeling and the steam generator control there are three one-dimensional categories of models for:

- the analysis of the fuel burning stability at partial loads - for the exact calculation of the combustion process; it necessitates an exact calculation of the combustion dynamic considering also the kinetic reactions;
- the dynamical analysis of the fuel - gasses pass - to design pressure control systems;
- forecasting the spatial distribution of the water-steam properties - models for pressure, temperature, level, and dynamical load variation control.

The modeling and simulation of heat exchangers it's a difficult task for any simulation software and especially for the ones dedicated to steam generators mainly for the following general concepts, [6]:

- segmentation - dividing the heat exchangers in more sections based on the complexity of the physical reality.
- decoupling - separate equations solvers for fluids, gasses, steam-water considering the heat accumulation in the metallic wall.
- biphasic mixture - important for the generator's dynamics because the boilers surface constitutes an important part of this one, a major issue for the interaction of the two phases.
- thermal transfer - influences the predominant metallic wall temperature profile - a main difficulty for the simulation process.

Based on the block scheme and tacking into account the energy mass conservation we have tried to obtain a simplified model of the boiler that simulates its behaviour in dynamic regime.

For the elaboration of the model we have considered the following hypothesis: the pressure influence over the water supply enthalpy is negligible; equivalent the distributed furnace burners with one concentrated burner; calculating the exit gasses temperature leaving the furnace with the usual methods based on their enthalpy of the air and of the feed water; the determination of the experimental coefficients for pressure loss calculation for the analyzed unit; estimating the enthalpy from the steam water tables based on the measured parameters.

As it was presented, the superheater constitutes a heat surface where the steam is superheated until the nominal temperature. It is a step processes due to the modification in large limits of the specific volume.

The physical model for the superheater is presented in Fig.2.

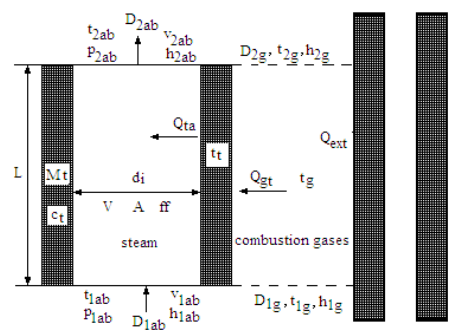


Fig.2. Physical model of the steam superheater

In Fig. 2 the D_{1ab}, D_{2ab} are the mass flows of the steam input-output, kg/s; D_{1g}, D_{2g} are the mass flows of the combustion gases input-output, kg/s; Q_{gt} is the heat transmitted from the combustion gases to the pipe, kW; Q_{ta} is the heat transmitted from the pipe to the steam, kW; Q_{ext} is the heat transmitted to other outdoor surfaces, kW; t_{1ab}, t_{2ab} are the temperatures of the steam input-output, ^{o}C; t_{1g}, t_{2g} are the temperatures of the combustion gases input-output, ^{o}C; p_{1ab}, p_{2ab} are the pressures of the steam input-output, ^{o}C; p_{1g}, p_{2g} are the pressures of the combustion gases input-output, ^{o}C; h_{1ab}, h_{2ab} are the enthalpies of the steam input-output, ^{o}C; h_{1g}, h_{2g} are the enthalpies of the combustion gases input-output, ^{o}C; v_{1ab}, v_{2ab} are the specific volumes of the steam input-output, ^{o}C; v_{1g}, v_{2g} are the specific volumes of the combustion gases input-output, ^{o}C; M_t is the mass of the metal pipes, kg; c_t is the specific heat for the metal kJ/kg°C; f_f is the friction coefficient, L, d_i, A and V are the geometrical dimensions, m, m^2, m^3.

The physical processes that describe the superheater operation are the heat transfer by convection and radiation from the gasses to the pipes and the monophase convection from pipes to the steam; the heat accumulation in pipes and monophase flow through the pipes.

In the development of the mathematical model a series of hypothesis were adopted such as:

- only steam enters the superheater, the variables of the model are in respect the physical principles,
- the model with concentrated parameters has only time derivatives;
- gravitational and acceleration losses are irrelevant.

The mathematical model proposed in absolute units, is based on mathematical equations specific to heat exchange area and some existing models that were suitable - the equations of mass and energy conservation, heat transfer and heat accumulation - applied to the two fluids - combustion gases and steam, [3].

The simulation was developed in Matlab-Simulink with a 1 % error of the calculated values by comparison with tables data obtained for a time smaller than the rated time (0.2...0.5 s), of the system in real time.

The conservation equation for the primary superheater is reduced to:

$$p_{2ab} = p_{1ab} - \beta D_{1ab}^2 \quad (1)$$

Convection heat transfer equation from the flue gasses to the superheater pipes is:

$$Q_{gt} = \alpha_{gt} S \left(T_g - T_t \right) \quad (2)$$

with α_{gt} the convective heat transfer coefficient from the flue gasses to the superheater pipes, W/mK; T_g, T_t are the average flue gases temperature and of the pipes respectively, K.

Predominantly radiant heat transfer equation from the flue gasses to the superheater pipes is:

$$Q_{gt} = \alpha_{rgt} S \left(T_g - T_t \right) \quad (3)$$

where α_{rgt} is the global radiation heat exchange coefficient from the flue gasses to the superheater pipes, kW/K^4.

Predominantly convection heat transfer equation from the superheater pipes to the steam:

$$Q_{ta} = \alpha_{ta} S \left(T_t - T_a \right) \quad (4)$$

where α_{ta} the heat transfer coefficient from the superheater pipes to the steam, W/mK.

Heat transfer equation, mainly by radiation, from the superheater to the steam is:

$$Q_{ta} = \alpha_{rta} \left(T_t - T_a \right)^3 \quad (5)$$

where α_{rta} is the global heat transfer coefficient by radiation from the superheater to the steam, kW/K^4.

Mass conservation equation for the steam is:

$$\frac{d}{d\tau} \left(V_{ab} \rho_{ab} \right) = D_{1ab} - D_{2ab} \quad (6)$$

with V_{ab} the steam volume, m^3 and ρ_{ab} the average steam density, kg/m^3.

Conservation equation for the flue gasses is:

$$\frac{d}{d\tau} \left(V_g \rho_g \right) = D_{1g} - D_{2g} \quad (7)$$

where V_g is the gasses volume, m^3; ρ_g flue gasses average density, kg/m^3.

Superheater heat accumulation equation:

$$M_{tSI} c_t \frac{d}{d\tau} \left(t_t \right) = Q_{gt} - Q_{ta} \quad (8)$$

Energy conservation equation tacking also into consideration the mass conservation for the steam:

$$V_{ab} \rho_{ab} \frac{d}{d\tau} \left(h_{ab} \right) = Q_{ta} + D_{1ab} h_{1ab} - D_{2ab} h_{2ab} \quad (9)$$

Energy conservation equation tacking also into consideration the mass conservation for the flue gasses:

$$V_g \rho_g \frac{d}{d\tau} \left(h_g \right) = D_{1g} h_{1g} - D_{2g} h_{2g} - Q_{gt} \quad (10)$$

For the main superheater we have considered the outside variables such as: D_{2ab}, t_{1ab}, t_{1g} and D_{mc}.

The unknown variables specific to the main superheater are D_{1ab}, p_{2ab}, t_{2ab}, t_{2g}, Q_{gt}, Q_{ta}, t_t and t_g.

III. THE SIMULATION OF THE SUPERHEATER

The mathematical model of the steam superheater is part of the steam generator model. So, beside the unknown heat surface variables in the scheme also appear input variables from the previous simulation blocks and from the furnace simulation block.

The proposed analytical methodology covers the following general requirements:

- modeling technology specific to the heat exchange surface of the steam generator – in this case the superheater; simulation schemes operating between 50 and 100%;
- the entry data for each model are considered known, while the related data are calculated by the model (flow, pressure, temperature);
- the outputs for each model are: flow rate, pressure, temperature, and enthalpy.

As stated in the presentation of the mathematical model equations, of heat transfer models, used in relative units, the data from the literature were replaced by equations of the convection heat transfer. Both convective heat transfer coefficients, of combustion gases to the metal and the metal to the steam, are determined using the criteria equations given in the literature, depending of the thermophysical properties of the fluid and the and the flow characteristics:

$$\alpha_{gt} = 0{,}2 \cdot \frac{\lambda}{d_e} \left(\frac{w \cdot d_e}{\nu} \right)^{0{,}65} \cdot \Pr^{0{,}33} \cdot C_z \cdot C_s \quad (11)$$

The simulation scheme for the steam superheater integrates the calculation subsystems, including MATLAB functions, for cinematic viscosity, thermal conductivity and specific heat for the steam and the flue gasses, all this being determined by the pressure and temperature of the fluid attained.

A part of these variables are determined based on the output variables for the furnace block scheme, and respectively the fuels composition, its humidity and of the burning products SO_2 , CO_2 volumes and water vapours, [5].

For example, the flue gasses specific heat is determined as a function of the components specific heats determined by the implementation of the MATLAB functions as in Fig. 3, respectively Fig. 4, [3].

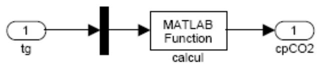


Fig. 3. MATLAB function for the calculation of the specific heat

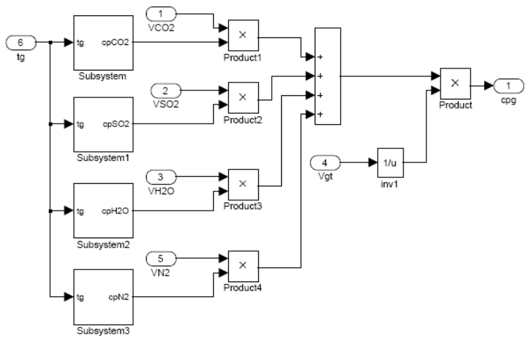


Fig. 4. Specific heat calculation diagram

Also, Fig. 5 and Fig. 6 presents the MATLAB functions that were created for Prandtl number and friction coefficient.

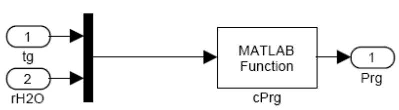


Fig. 5. Specific heat calculation diagram

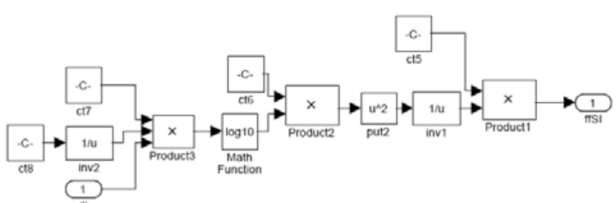


Fig. 6. Specific heat calculation diagram

For both the convective heat transfer coefficients were created the calculation block diagrams. Fig. 7. presents the diagram of calculation for the convective heat exchange coefficient from de combustion gases to the metal of the pipes.

In Fig. 8 is presented the steam superheater calculation diagram and the calculation block scheme in Fig. 9

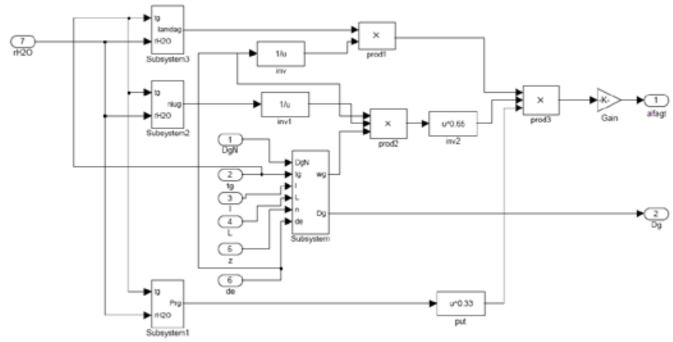


Fig. 7. Diagram calculation of the convective heat exchange coefficient

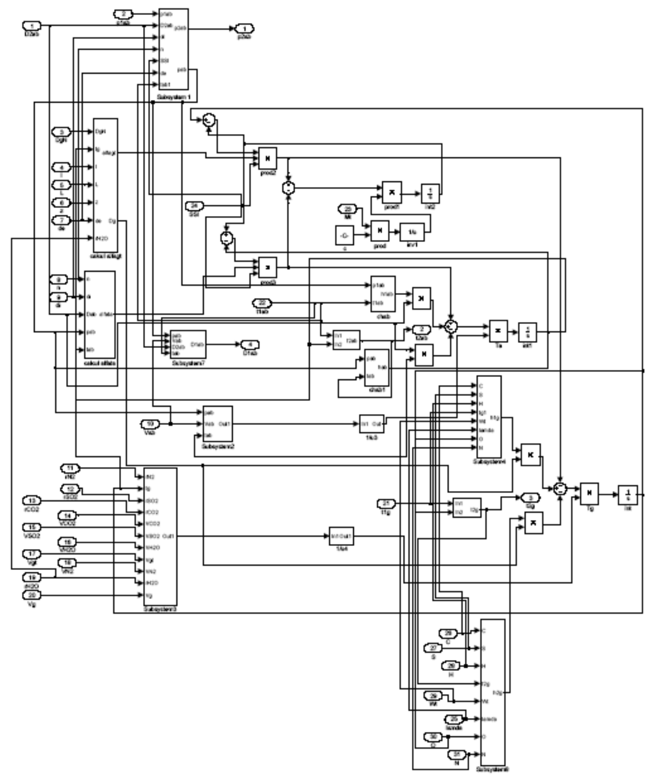


Fig. 8. Steam superheater calculation diagram

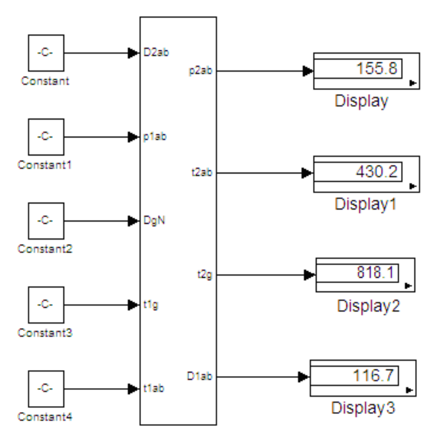


Fig. 9. Block diagram with external variable

On the superheater block scheme we have analyzed the influence of the dynamic regimes over the input steam flow, the pressure of the input flow, p_0, and its temperature, t_0, considering 10% step variations. In the Fig. 10 - 12 we have presented the dynamic behavior of the superheater for the step variation of these parameters.

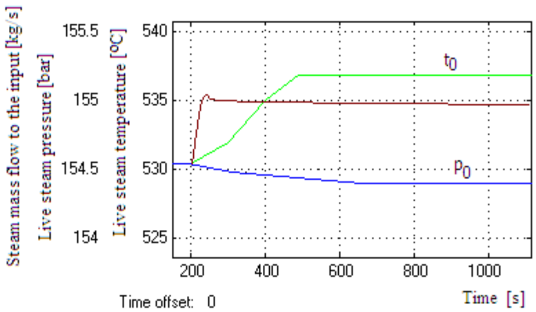
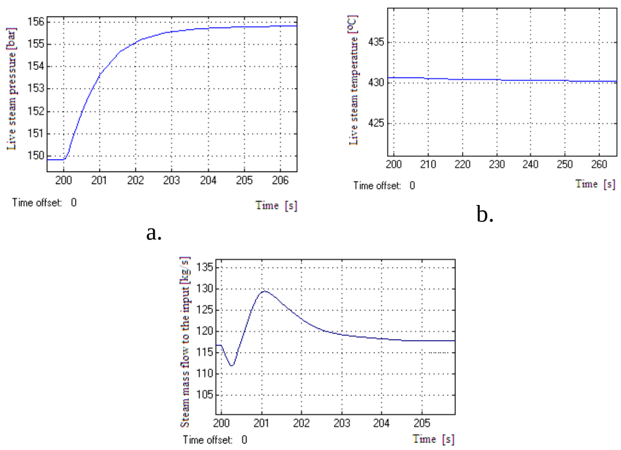
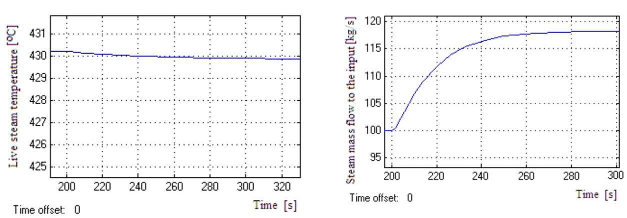


Fig. 10. Vaporization temperature influence



a. b. c.

Fig. 11. Input superheater steam pressure influence
a. over the steam pressure; b. Over the steam temperature; c. over the input steam flow



a. b.

Fig. 12. The demanded steam influence over
a. the live steam temperature
b. the steam flow at the input

The live steam temperature has the slowest variation. The calculated values of the parameters are close to the reference values (used for calculations) and the values from the boiler's observation sheets with an average error of 1.2%.

IV. Conclusion

The mathematical model it's part of the larger generator model, being the basis for its operation simulation. It has the major advantage of eliminating the recalculation of the parameters for each step of the algorithm – in relative units model, as in previous works – the entire coefficients set being determined and included in the model as a function of the parameters from the previous operation regimes.

The linear tendencies around the stabilized operation point are removed. The nonlinear characteristics are included in the model. It manages to find the operation points on the nonlinear characteristics and refreshes the parameters' values.

The model allows the determination of the heat exchange coefficients and of the heat exchange surfaces in real time, the results of the calculations respecting the recommended limits from previous works.

Acknowledgment

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Adelaida Mihaela D. Duinea was born in 1971 in Craiova, Romania. In 1995 she graduated Thermoenergy Engineering at University of Craiova and in 2009 she received Ph.D. in Energy Engineering from University of Craiova. At present she is a lecturer in Faculty of Electrical Engineering, University of Craiova. Her field of interest is power plants' operation, energy efficiency, computer based design of energy equipments.

Denisa G. Rusinaru was born in 1968 in Craiova, Romania. In 1993 she graduated Electromechanical Engineering at University of Craiova. In 2002 she received her Ph.D. in Power Engineering from University Politehnica of Bucharest. Presently she is a senior lecturer in Faculty of Electrical Engineering, University of Craiova. Her field of interest is power quality, energy management, power grids.

The Characteristics of Effective Performance Measurement System: Case Study Analysis

First A. Michaela Striteska, Second B. Lucie Jelinkova

Abstract — Gaining a competitive advantage by achieving a certain level of business performance is the primary prerequisite for the successful operation of a company in the long term in today's highly competitive environment. For this reason, the performance measurement and management system becomes more and more important tool for evaluating of company performance. This paper deals with performance measurement systems of selected Czech companies. The main aim of the paper is to investigate the characteristics of effectively created performance measurement and management systems of monitored companies through interviews with managers and analysis of internal materials of these companies. The performance measurement systems are examined at two different levels. First the analysis of performance measurement system as an entity is carried out by exploring issues such as: multi-dimensionality of performance measures, interconnection with corporate strategy and defining performance measures at the operational level. Second the analysis of relationship between performance measurement system and environment in which it operates is performed. There is investigated whether the strategy is reformulated on the basis of performance measures evaluation and weather exist the relationship between performance measurement and reward system. The research findings are evaluated within the context of the theoretical background and the conclusions of similar studies. Based on these findings, a research field is defined and significant gaps in performance management process are formulated. The paper is elaborated on the basis of literature review and case studies analysis of selected companies.

Keywords—Characteristics, management control, measurement, performance, system.

I. Introduction

Increasing demands on human resource management and organizational changes, new assumptions of strategic importance, the information revolution, knowledge management and productivity of "knowledge" employee can be considered as the challenges of the 21st century [1]. Companies have to learn not only to respond to these challenges, but also be able to recognize them and be ready for them. Therefore, it is essential to accurately mapping the environment, the trends in industry and sector in which they operate and the needs of the customers. It is also necessary to constantly monitor the progress of science and technology and be able to use findings learned for innovation not only of the products, but also of the processes within the company.

Recognition and innovation of all processes that take place in the company, setting their targets, their measurement, monitoring and comparing the specified values is essential for performance management. Businesses develop and implement performance measurement and management systems to ensure all these activities. The comprehensive provision of all these activities is its greatest benefit [2].

Although it has long been recognised that performance measurement plays a crucial role in the efficient and effective management of companies, it remains a critical and much debated issue [3]. The reason is that in the field of performance measurement, a diverse and multi-disciplinary research is appearing. This brings different attitudes towards performance measurement and causes complications. Marr and Schiuma [4] state that there is a lack of a cohesive body of knowledge in the field of business performance measurement. The reason is that researchers contributing to performance measurement come from different disciplines mainly strategic and general management, operations management, marketing, and finance and accounting. This multi-disciplinary of research is appealing carries the danger of hindering developments in the field of business performance measurement [3]. This fact has also led to a large number of performance measurement system (hereinafter PMS) definitions and very little consensus on key components and features [5].

We can find a large number of research studies that propose how to develop and implement PMS, but it is still not clear when PMS can be called “effective”. Since a dominant theory has not been developed, vast majority of managers simply continue with what they’ve used in the past. In the last two decades many companies invested considerable effort to implement performance measures that reflect all dimension of their business activities and are clearly linked to the strategy, but with different results. The words of Eccles [6] in his article “Performance measurement manifesto” became a true: “Within the next five years, every company will have to redesign how it measures its business performance”.

Therefore the main purpose of this paper is enhance the body of knowledge in the field of performance management by pointing the characteristics of effective PMS, which can helps

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F. A. Author is with the University of Pardubice, Faculty of economics and administration, Institute of Business Economics and Management, Pardubice 532 10, Czech Republic, (e-mail: michaela.striteska@upce.cz, phone: +420 466 036179).

S. B. Author is with the University of Pardubice, Faculty of economics and administration, Institute of Business Economics and Management, Pardubice 532 10, Czech Republic, (e-mail: lucie.jelinkova@student.upce.cz).

managers identify whether and how they should improve their performance management system. Finally the research field is defined for clearer understanding of components and their relationships in effective performance management process (hereinafter PMP).

II. Literature review

Performance measurement system is an integral part of a company's management control system [7]. It is an information system that is at the heart of the performance management process [8], [9]. If PMS is understood as an information system supporting managers in the performance management process, then fulfills two fundamental functions [10]:

- enabling and structuring communication between all business units (individuals, teams, processes, functions, etc.) involved in the process of target setting,
- collecting, processing and delivering information regarding the performance of people, processes, products, services, operations, business units, etc.

According to [8] we can add that also gives feedback to employees about the results of their actions.

From the strategic point of view a crucial role of PMS is to help managers successfully implement strategies within the company. A Simons [11] outlines four key levels of control systems that facilitate strategy implementation: belief systems, boundary systems, diagnostic control systems, and interactive control systems. Among these control mechanisms, managers usually rely on critical performance measures to monitor the strategy implementation and to diagnose deviations from their preset standards of performance [11]. Moreover, performance measures align employees' incentives and motivate them to enhance performance and achieve the strategic goals [12], [13], [14], [15]. Marr and Schiuma [4] present three basic reasons for measuring a company's performance: verifying the company's strategy, influencing the behavior of employees and external communications and company performance management.

From the definition of [16] that consider PMS as balanced and dynamic systems, resulting other basic characteristics. The notion of balance refers to the need to use different measures and perspectives that together provide comprehensive information on the company performance [14]. The concept of dynamism highlights the need to create a system that continuously monitors the internal and external context and evaluate the objectives and priorities [17]. [18] in this respect highlights the changing nature in measurement initiatives; measures should be conceived as part of the fast feedback management systems; and measures should be designed for stimulating continuous improvement capability rather than simply monitor operations strategy. Although a strategic management function is identified in the implementation of performance measurements, a specific role could be related to continuous improvement capability development.

Gimbert et al. [19] see the role of strategic PMS in the strategy reformulation. They argue that they influence strategy reformulation by stimulating the development within the organization of a more comprehensive strategic agenda. On the basis of this argument, the authors distinguish between performance measurement framework and strategic performance measurement framework (SPM framework). The latter being a subset of the former and could be characterised by four key attributes: integration of long-term strategy and operational goals, presence of multi-perspective indicators, inclusion of cause-effect linkages, and presence of a sequence of goals-targets-action plans [20]. A strategic performance measurement system is then a set of nonfinancial and financial objectives and performance measures representing a causal chain of activities that articulates management's hypothesis of strategy [21].

Within this context effectively created PMS can be characterized according to [22]:

- The measures used by an organization have to provide a 'balanced' picture of the business.
- The framework of measures should provide a succinct overview of an organization's performance.
- The performance measures should be multi-dimensional.
- The performance measurement matrix (PMM) provides comprehensive mapping.
- The performance measures should be integrated across the organization's functions and through its hierarchy.
- The performance measurement system can provide data for monitoring past performance and planning future performance. It implies the measures should measure both results and the drivers of them.

Gomes et al. [23] state why to date, researchers have not adopted a universally accepted best-practice. It is due to the following requirements on PMS:

- Must reflect relevant non-financial information based on key success factors of each business.
- Should be implemented as a means of translating strategy and monitoring business results.
- Must be aligned and fit within a strategic framework.
- Should be based on organizational objectives, critical success factors, and customer needs and should monitor financial and non- financial aspects.
- Must accordingly change dynamically with the strategy.
- Must make a link to reward systems.

III. Methodology

Neely at al. [16] state that PMS can be examined at three different levels: at the level of individual performance measures, at the next higher level as an entity and at the level of relationship between the PMS and the environment within which it operates. Within this paper PMSs are analysed as an entity and in the context of environment.

The case study was chose as the research method, because can bring an understanding of a complex issue. The case studies were conducted in selected companies at the beginning of the year 2014 in the form of semi-structured interviews and analysis of internal company materials relating to the areas surveyed. The data collection phase of the study began with a general examination of relevant literature and research studies, to provide researchers with a sufficient theoretical background. The interview structure was designed to investigate the key themes identified form the literature reviewed. The case studies try to find answers for the following research questions:

Research questions related to the analysis of PMS as an entity:

- Do you have any strategic performance measures which would ensure strategy implementation?
- Does your performance measurement system provide balanced view on the business? In what particular areas do you measure the performance of your company?
- Have all the appropriate elements - internal, external, financial, non-financial been covered?
- Does your performance measurement system contain the causal links – thus meaning the cause-effect links between the particular areas of performance measurement (strategic objectives)? Do you create a strategic map?
- Do you have any performance measures on the operational level (for the short-term goals)?

Research questions related to the relationship between the PMS and the environment:

- Is your performance measurement system linked with the reward system and motivation of the employees? Are the results obtained in the performance measurement reflected in the reward system?
- Do you re-formulate you strategy according to the performance measurement system?

The semi-structured interview was based on the methodology and rules presented by [24], [25]. The interviews were conducted with 10 managers of selected large and middle sized companies. The structure of the sample consists of companies which are expected relationship to the topic survey (e.g. the assumption that the companies have an established system of performance management).The relationship of the selected companies to the topic of the survey was detected by earlier conducted secondary analysis. A content analysis technique is used.

The final sample for interviewing included a total of 10 managers, 4 of which were at the highest management level and 6 were at mid-level management of the companies. Selected companies are from different sectors (1 food processing, 1 plastics production and processing, 1 opencast mining processing, 2 metal-working processing, 1 service in heating plant and energy area, 1 service for automotive, 1 information technology, 1 banking, 1 insurance) and were chosen to introduce diversity into the sample. According to Commission Regulation (EC) No. 800/2008 [26], the selected companies can be divided into 3 large companies (over 250 employees, over 50 million Euro), 7 medium companies (51 - 250 employees, over 10 to 50 million Euro). Small companies are not represented. In terms of the forms of ownership, the sample contains 6 domestic companies with their headquarters in the Czech Republic and 4 foreign companies with headquarters in Italy, Austria, Scotland and USA.

The results and partial results are compared with a theoretical construct, which is based on results of foreign studies.

IV. Findings and discussion

Analysis of PMS as an entity

In the last two decades more and more attention has been paid to the issue of performance measurement as a tool for the strategy implementation and revision. Most surveys have focused on the area of transforming strategy into action, thus confirming that the PMS is an effective tool in this regard [14], [27], [15], [28]. Therefore we focused first on the relation between performance measurement and corporate strategy. The research of Knapkova [29] conducted in Czech companies found that, on average, 73% of companies in the Czech Republic base their performance measurements on their company strategies and objectives. Within our survey almost all companies, except one, confirmed that their performance measurement is based on the vision and strategic goals. At first glance it might seem that there is constantly growing trend and that meeting with medium or large company in the practice who’s PMS is not connected with strategy is a rarity. Unfortunately subsequent deeper analysis of PMSs shows that this is only partially true, because not all strategic objectives are really measured. Summarizing, we can say that current PMSs are based on corporate strategy, but not for all strategic objectives are defined performance measures.

This statement confirms the analysis of specific performance measurement areas, which should show how “balanced” view of corporate performance current PMSs provide. The previous research studies [30], [31], [32] revealed that the vast majority of companies measure performance particularly in the financial area. Chow and Van der Stede [33] stated that in a study carried by Wm. Schiemann &Associates, the executives widely acknowledged the limitation of traditional financial measures. Nevertheless, they still favored them over nonfinancial measures because they saw them as being generally less ambiguous. Despite the results of newer studies point to the fact that companies are increasingly beginning to realise how important it is to also monitor the process and customer areas [34]. Yadav et al. [35] also stated that in the era post 2000 can be seen some new performance measures, such as leadership, training, education, innovation, capabilities, knowledge, personal improvement, etc.

The analysis conducted in the surveyed companies shows that monitoring performance in various fields is slowly becoming more balanced. 6 companies from 10 have already created PMS with strategic performance measures in financial, customer, and processes as well as employees area. All companies monitor performance in the area of finance and customer, 7 in the area of processes and 6 in the area of employee. These results show that the companies surveyed no longer primarily monitor the financial sector. However remains, the problematic question of defining performance measures in the area of employee and innovation processes. Although many research studies have confirmed the strong relationship between human resources management and the attitude of the employees on the one hand and the performance of the organisation on the other hand [36] provides a number of relevant research surveys), HRM indicators are not yet the norm in examining the effectiveness of human resources management and its impact on company results [37]. This is closely related to the issue of multi-dimensionality of performance measures.

The effective PMS should be created by all appropriate performance measures – financial, non-financial, internal, external, lag and lead. 8 of 10 surveyed companies use both financial and non-financial measures as well as internal and external. The other two companies mainly rely on financial indicators. Unfortunately more detailed analysis revealed that performance measures aimed at improvement are still rarely seen in the PMSs of monitored companies. Measures related to knowledge, employee improvement and innovation were found only in PMSs of 2 companies. The survey of Stivers et al. [38] conducted in U.S. Fortune 500 and Canadian Post 300 companies revealed that customer service factors are perceived to be the most important measures by executives and factors in the innovation and employee involvement categories were perceived to be less important in goal setting. More than fifteen years later, the results of our study are similar. The question is, why this is so?

As one of the causes we can consider that managers don't identify the logical relationships among key performance indicators used. Only 1 of surveyed companies creates strategic map and 1 determines partly causal links in the description of each performance measures. In other surveyed companies these relationships are not examined or their examining remains at the level of apparent hypothesis. According to numerous authors [39], [40], [41], [42] the BSC framework's inherent complexity creates difficulties in communication and comprehension of its underlying logic which hinder implementation. This statement applies to all performance management frameworks. Research on causal modelling suggests that strategy maps can simplify and facilitate the transmission of complex systems, and thus implies that strategy maps have the potential to help managers overcome the cognitive challenges posed by the BSC [43], [44].

Communication and comprehension of strategy is closely linked to the cascading of strategic measures to the lower hierarchical levels. For example, [13], [14] argue that only when lower-level employees and managers understand and agree with the organization's strategies and methods of implementing them can they bring this focus to their daily tasks. Consensus on strategy implementation is critical to achieving the benefits of PMS. It improves the coordination and cooperation within a company, which, in turn, creates synergy from employees' coherent behaviors [45]. Therefore it is crucial to set goals and measures on operational level. The analysis of internal materials confirmed that only 4 of surveyed companies cascaded strategic performance measures to the operational level. The rest of surveyed companies' measure operational measures related to financial indicators, production and productivity of employee. But we can't speak about real cascading of strategic measures through the company.

Analysis of PMS in the context of environment

In addition, when operational performance measures are used in reward systems, they can help even better communicate the organization's goals and plans, so that lower-level managers and employees know their specific roles in the implementation of strategies [14], [39], [46]. Furthermore, performance goals in incentive plans can motivate employees to exert effort toward implementing the organizational strategies, which ultimately enhances organizational performance [15]. Only in 2 of surveyed companies are performance measures fully integrated into remuneration policy. In other companies only in certain departments is remuneration system based on individual goals and performance measures.

An emerging stream of research studies points out that PMS may effectively be used not only for the strategy implementation but also for shaping the processes of their formulation [19], [27]. Unfortunately the use of performance measures for strategy re-formulation in practices is limited. Despite the fact that 8 of 10 companies stated that they reformulated the strategy on the basis of performance measures, the subsequent analysis revealed great rift between the answers and reality. Only in 5 of surveyed companies we were able to map the entire process of key performance measures evaluation, strategy review and reformulation.

V. Conclusion

According to Gomes et al. [23] the recent dramatic environmental and market changes have fundamental influence to the literature relate to performance measurement. The most recent literature highlights that is necessary approach to performance measurement from a more open systems perspective. The business focus should be redirected from performance measurement to performance management, should capture the dynamic nature of the market and environment and include it in the PMS.

Through the research field can we identify individual components and their relationships within the PMP. Decomposition of relationship among individual variables that influence or are influenced by the PMS or PMP can provide a simple overview on some important processes and their context.

Created research field (Fig.1) confirms the fact that PMS is at the heart of PMP. PMP is based on information obtained from PMS.

The PMP is determined by the definition, implementation and review of strategy on the basis of information obtained from PMS. The basic components in the PMS are:

- Balanced (Multi-dimensional) strategic performance measures - a stakeholder oriented approach should be created that lead to balanced view in its perspective.
- Causal maps and system dynamics - by using causal map can be determined the missing measures in PMS and so can be provided a balanced view to the company; through a system dynamics then can be understood the functioning of the whole system, all variables of PMS and relationships between them; after that, is possible to change these variables, to influence their behavior and manage them.
- Engagement of all hierarchical levels - according to Kennerley and Neely [22] the performance measures should be integrated across the organization's functions and through its hierarchy.
- Remuneration policy and motivation – PMS must be interconnect with the remuneration policy as an instrument for employee motivation; problematic remains the question of defining performance measures in the area of employees, despite, that one of the most common reasons for performance management is influencing the behavior of employees, their motivation and their remuneration.
- Continuous improvement - Maskell [18] defines that measures should be conceived as part of a fast feedback management systems; and measures should be designed for stimulating continuous improvement capability rather than simply monitor operations strategy; although a strategic management function is identified in the implementation of performance measurements, a specific role could be related to continuous improvement capability development.

The quality of PMP is subsequently influenced by four key factors:

- Quality of processes - comprehensive approach to developing, clearly defining and setting processes.
- Corporate culture - through corporate culture the top management declare visible commitment and support to performance measurement, make sure consistent communication and transfer knowledge of learn from a mistakes and adaptation to changing environment.
- Trained people - PMS should take in consideration the human factor, including new and innovative incentive/reward systems, and their links to performance measurement in order to involved employees in the performance measurement process and motivate them.
- Systems - Information systems and technology are the facilitators of the performance measurement and management process.

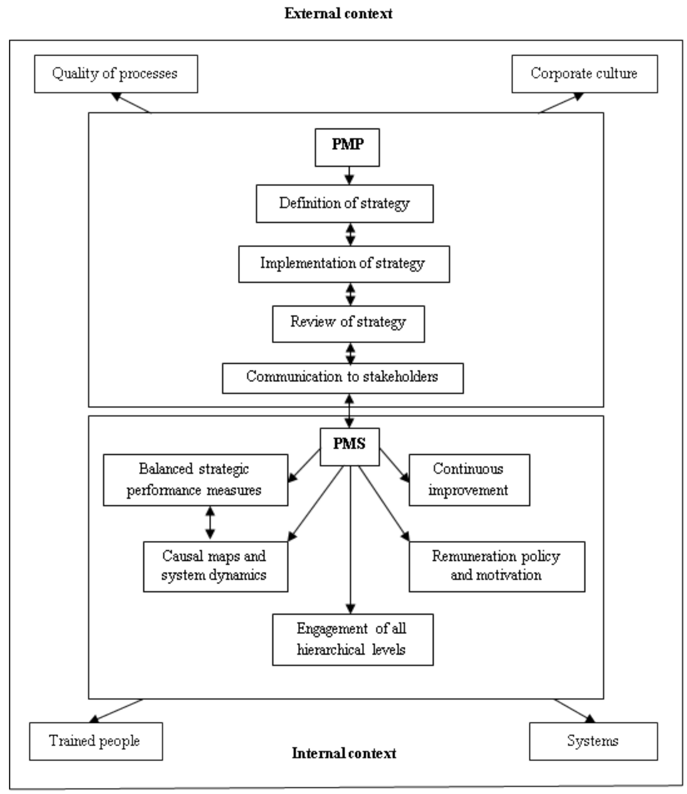

Fig. 1 research field

Based on the research field and case studies analysis we identified two significant gaps. First gap lies in the development of PMS, as companies are still not paying sufficient attention to the potentials - measures focus on improvement, people, culture, environment, processes, etc. still missing. The reason may be lack of knowledge and inability to use causal models and detecting causal relationships.

Second gap is in implementation of PMS, because companies are not able to secure dynamics of PMS. Attention is paid to what should be measured today, but little attention is paid to the question what should be measured tomorrow. Measurement systems should be dynamic.

In summary, we can conclude that only 1 of the surveyed companies has developed, implemented and managed PMS according to "effective" characteristics resulting from literature review.

Based on the gaps identified through research field further research will be conducted. The main aim of future investigation will be find answers to two key questions:

1) How to secure, that measures concerning employees and improvement will be put into PMS?
2) How to secure that PMS and after that also PMP will be dynamic?

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Macroeconomic determinants of competitiveness in the countries of Visegrad Group plus

I. Majerová, J. Nevima

***Abstract*—** The competitiveness is the cornerstone of the development of countries, regions and companies. Competitiveness can be so understood at different levels: micro-level, regional level and macro-economic level. The high competitiveness is the objective of the European Union and its member states. This article discusses the macroeconomic competitiveness of the selected EU countries that form the Visegrad Group plus - Czech Republic, Slovakia, Hungary, Poland, Austria and Slovenia. Namely, relation between measurable output indicators is analyzed, among them the degree of openness, export performance, transformational performance and relative power of specialization are ranked. These relationships have been tested through a panel regression in the years 1995-2013, when we assumed significant correlation between export performance and other variables and the degree of openness and the others variables. However, this assumption was confirmed only in the case of export and transformational performance.

***Keywords*—**Competitiveness, macroeconomic determinants of competitiveness, panel regression, Visegrad Group plus.

I. Introduction

THE competitiveness is the ability of a country to facilitate an environment in which enterprises can generate sustainable value [1]. Because of its relative value, the competitiveness must be constantly compared with other economies and regions [2]. Competitiveness is divided into microeconomic, sectoral (regional) and macroeconomic competitiveness.

The last one will be discussed, which is measured by two kinds of indicators, both those measurable, quantitative, to which we rank the indicators of inputs (costs) and outputs (measure and quantitative) as well as non-measurable, in other words, qualitative. To the input (measurable) indicators we rank the analysis of unit labour costs, labour productivity, relative prices and the real effective exchange rate. Output (measurable) indicators are degree of openness of economy and the export performance of economy, intensity and structure of specialization through relative specialization indicators and adding value of exports through the transition effect/performance. Non-measurable indicators include comprehensive competitiveness of the economy and are determined by two ways: trough the World Competitiveness Scoreboard of the Institute for Management Development (IMD) and though the Global Competitiveness Index of the World Economic Forum (WEF). Measurable data include only part of competitiveness and are calculated on the basis of hard data. Non-measurable indicators use both hard data and soft data because the questionnaire surveys capture indicators that can not be measured with hard data.

In our previous studies, we have dealt with the analysis of both quantifiable and measurable indicators of macroeconomic performance in various economies, like other authors, see Part II. Very popular is the comparison of the competitiveness of the European Union and the countries of the Visegrad Group (hereafter V4). We decided, as part of a research project to analyze this problem on an extended group of countries namely selected countries of the Visegrad Group plus (hereafter V4+), which include the V4 countries and Slovenia and Austria on the ground of Regional Partnership Agreement from 2001. There are two reasons: first - these countries are economically and politically part of the Central European region, which plays an important role in the development of Europe and its competitiveness. The second reason is that the enlargement of the V4 was relevant in the past and the most suitable candidates were Austria and Slovenia. Nevertheless, consensus on this problem has been never achieved and nowadays the open V4+ format is to be used for cooperation with other countries or regional groups such as Ukraine, Slovenia and Austria.

This article aims to analyze various macroeconomic measurable indicators and their mutual relations in the V4+ from 1995 to 2013. Longer time series could not be used with respect to availability of certain data. For this analysis all measurable output indicators were selected, for which is assumed, according to the general usage, that interact each other. It was also our hypothesis. Annual data were collected

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I. Majerová is with the Department of Economics and Public Administration, Silesian University in Opava, School of Business Administration in Karviná, Univerzitní náměstí 1934, 73401 Karviná, Czech Republic (corresponding author to provide phone: 00420-603574796; e-mail: majerova@opf.slu.cz).

J. Nevima, is with the Department of Economics and Public Administration, Silesian University in Opava, School of Business Administration in Karviná, Univerzitní náměstí 1934, 73401 Karviná, Czech Republic (e-mail: nevima@opf.slu.cz).

from the database of Eurostat and converted into indexes. Given the length of the time series the verification of the mutual relations made through panel regression, and tested for statistical significance, implemented t-test, autocorrelation and heteroskedasticity.

It was found that only model with verified relation between export performance and transformational performance was statistically significant without autocorrelation and heteroskcedasticity.

II. Theoretical Approach to the Problem of Competitiveness

According [3], the competitiveness as one of the most monitored characteristics of national economies is becoming part of evaluation of their prosperity, welfare and living standards. According [4] is just competitiveness often associated with the question of how to increase economic welfare, prosperity, living standards and wealth distribution. [5] claim that competitiveness remains a concept that is not well understood and that can be understood in different ways and levels despite widespread acceptance of its importance.

[6] approaches to competitiveness as to the reflection of the important features of the world economy, while refusing the neoclassical theory of equilibrium prices of production factors. In his concept, competitiveness is obvious only in such economies where the benefit of increased productivity in the form of rents remains in the country of its origin. According [7] the competitiveness is a function of dynamic progress, innovation and ability to change and improve. [8] defines competitiveness as the ability to provide an ever-increasing standard of living in the decreasing involuntary unemployment. The source of national (macro) competitiveness is regional competitiveness [9].

A. Macroeconomic Competitiveness

Competitiveness can be related to the economy, respectively to the country as a whole, but also to the company, to the product, or to the sectors and otherwise defined group of manufacturers. We could argue that the basis for the competitiveness of the economy is the competitiveness in foreign trade, therefore the exported goods and that it holds the sequence: the product - the company - the economy. But in economics, there is a certain business environment of the government's economic policy and the effective operation of the state. The state thus by setting the economic environment retrospectively affects companies and their activities, either stimulates or inhibits on the contrary, and thus feedback between the economy and the company exists.

So that the economy could be competitive, as a whole and in the functioning of its various entities, it must operate with certain conditions. These conditions - the golden rules of competitiveness - provided [10] ("update" version in 2014) and are listed in Table I.

Table I. The Golden Rules of Competitiveness

No.	Rule
1.	Create a stable and predictable legislative and administrative environment
2.	Ensure speed, transparency and accountability in the administration
3.	Pledge to maintain budget, fiscal and debt discipline
4.	Diversify the economy, from a sectorial and geographical point of view
5.	Invest in traditional and advanced infrastructure, logistics and the linkage of activities
6.	Support medium sized enterprises, with home grown technology and export orientation
7.	Balance aggressiveness on international markets with attractiveness for added value activities in order to sustain a current account surplus
8.	Preserve the industrial base of the nation, and the “made in...”
9.	Focus on a dual track education system (apprenticeship and higher education) to foster the employability of the younger generation and reduce youth unemployment
10.	Promote a science and entrepreneurial culture
11.	Maintain social consensus on policies and social mobility upward
12.	Return the tangible signs of competitiveness success to the people (better roads, hospitals, schools, housing, etc.) as a symbol of achieved prosperity

Macroeconomic competitiveness is young term it was mentioned in the literature in the beginning of 80es of the last century [11]. The [12] defined competitiveness as the degree of production that passed the test of international competition, but in the same time to maintain and develop its incomes at national level. This narrower concept and initially synonymous of export performance has been replaced by a broader concept [13]. This concept considered the competitiveness as the ability not only to produce goods and services that will succeed in the international market, but also the ability to maintain and enhance a high and sustainable level of economies. According to [14] as aggregate competitiveness, which is based on the growth of productivity through the growth of macroeconomic indicators, living standards and employment, but where all of these variables must have a sustainable basis. According to [15], if the economy is able to penetrate foreign markets and international trade to gain comparative advantages, it is competitive. [16] claim that the idea of national competitiveness shows the ability of a country to sustain a high level of national income and a favourable position in the world economy and the ability of a country to create a business environment in which the local firms are able to compete internationally.

III. Macroeconomics Determinants of the Competitiveness

Macroeconomic competitiveness was initially the synonym for export performance, on the basis of which the evaluation and testing was practiced [17]. Over time, this narrower conception has been replaced by a broader concept, which includes the concept of competitiveness explained as the ability not only to produce goods and services that will succeed in the international market, but also the ability to maintain and enhance high and sustainable level of economies. [18]

International competitiveness is measured by two kinds of indicators: measurable, to which we rank indicators of inputs (costs) and outputs (measured results) as well as non-measurable, qualitative. Measurable data include only a part of competitiveness and are calculated on the basis of hard data. Non-measurable indicators use both hard and soft data (interview surveys for recording indicators that cannot be measured with hard data. These measurements are made by international organizations such International Institute for Managerial Development in Lausanne (IMD) or World Economic Forum in Geneva (WEF).

We will deal with the first type of indicators, specifically measurable "output" indicators, among which the degree of openness of the economy, the export performance of the economy, intensity and structure of specialization through indicator of the relative strength of specialization and value-added exports through

A. *Degree of openness*

As mentioned, macroeconomic competitiveness was initially the synonym for export performance, on the basis of which the evaluation and testing was practiced. Over time, this narrower conception has been replaced by a broader concept, which includes the concept of competitiveness explained as the ability not only to produce goods and services that will succeed in the international market, but also the ability to maintain and enhance high and sustainable level of economies.

The degree of openness of economy is the basic indicator that characterizes the intensity of foreign trade. It shows the degree of connection to national economy with the world economy. It is measured by the share of exports (turnover) of the country's GDP in the year, as shown in (1).

$$DOE = \frac{VX}{GDP} \quad (1)$$

where DOE is degree of openness, VX is value of exports of goods and services and GDP represents gross domestic product.

There is a relationship between the size of economy and its maturity on one hand, and its openness on the other hand. From the empirical analyses of foreign trade in the world economy, the following relations were made out: The greater the economy, the less is the average relative involvement into international division of labour, for small economies it is vice versa and the more advanced the economy is – regarding comparable economic size, the more intensive is its involvement in the international division of labour, compared to the economy with a lower level of economic development.

The above problem can be seen from our point of view in two ways. When we analyze the individual economies in particular, we can conclude that the above rule does not apply, since Slovakia and Hungary would be the most open economy, followed by the Czech Republic, Slovenia (the smallest one), Austria and Poland. But if we take into account the division by country´s size, ie Austria, Slovakia, Hungary, Slovenia and the Czech Republic as small economies and Poland such as the economy of medium size (ie larger), the rule is confirmed (see Figure 1).

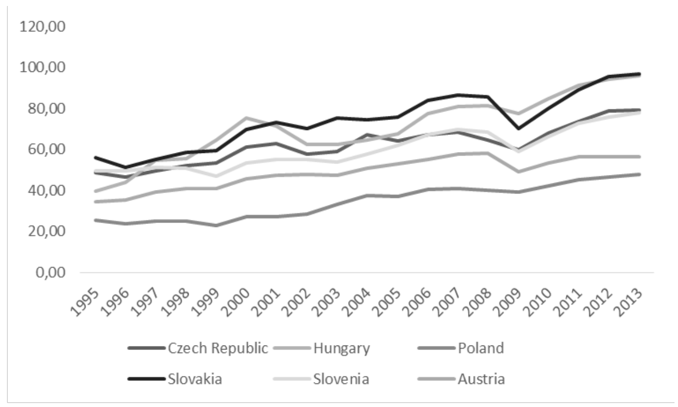

Fig. 1 Development of degree of openness in the V4+ in the 1995-2013

B. *Export performance*

The export performance reflects the productivity of economy in foreign trade. We measure it by the volume of exports per capita, see (2). In all countries, this indicator should grow and the differences in this indicator suggest the ability of the country to participate in international division of labour and have benefits from it.

$$EP = \frac{VX}{NC} \quad (2)$$

where EP represents export performance, VX is value of exports of goods and services and NC is number of citizens.

Fig. 2 shows the evolution of export performance of economies in time and here it is observed that although Slovakia and Hungary are the most open economy of the six compared, the productivity of foreign trade is up for Austria. Poland has the worst value of EP in the comparison with Austria and less than half that of the Czech Republic. On the other hand, we can say that the consequences of the economic crisis (in the form of a drop EP) are the mildest in Poland, while Austria has seen a significant drop.

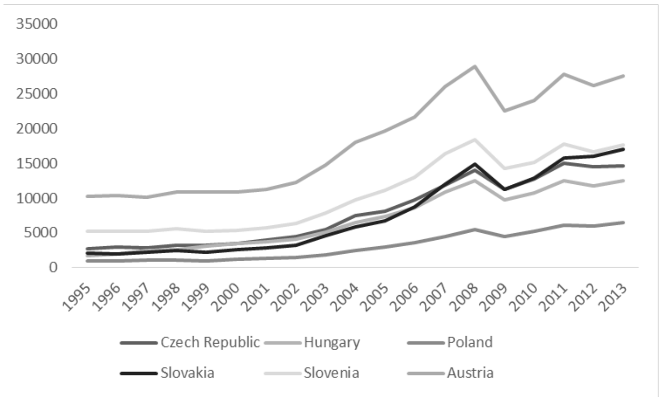

Fig. 2 Development of export performance in the V4+ in the 1995-2013

Export performance of economies, which is a more conclusive indicator of competitiveness measuring, is no longer valid in distinction between small and large economies, since the smallest performances are reached by the largest monitored economy (Poland) and the highest performance is reached by the third smallest economy (Austria). In this statement of competitiveness, we see an opposite effect than in the previous indicator - while in DOE the economies mutually converged, in the EP the divergence appears.

C. Intensity and structure of specialization

In the measurement of international competitiveness is important not only quantitative measure of exports, but also its structure. For a more competitive economy it is vital that mainly technologically intensive commodities were represented in the exports. We are for the purposes of our analysis, selected one indicator that reflects the structure of specialization in international trade, and that is an indicator of the relative strength of specialization.

This indicator characterizes a relative advantage or disadvantage in the trade for a specific product or group of products of selected economies in the group of countries. This indicator can be expressed by the following equation (3).

$$RSS_k = \frac{\frac{X_{ij}}{\sum_i Xij}}{\frac{Xi}{\sum_i \sum_j Xij}} \qquad (3)$$

where RSSk is the coefficient of relative strength of specialization, Xij is the export of j-commodity or group of commodities from i-economy, ΣiXij represents the sum of world export of j-commodity or commodity group from i-economy, Xi is export of commodity of manufacturing industry and ΣiΣjXij represents the whole world export of manufacturing industry.

In our analysis, we have selected for X the technologically demanding products (high-tech, such as medicine, communications equipment, computer equipment, medical equipment, aircraft, etc.). Based on the above formula, we have compiled a ranking of economies according to their relative strengths of specialization in the period 1995-2013. Those economies that show a high rate of specialization, should achieve greater competitiveness than others and vice versa.

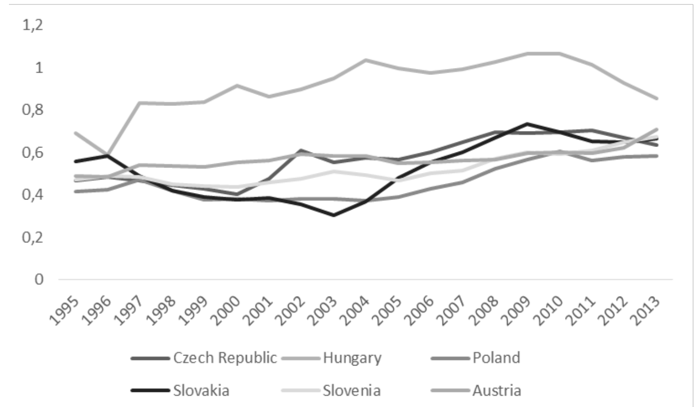

Fig. 3 Development of structure of specialization in the V4+ in the 1995-2013

Fig. 3 shows that the most competitive is surprisingly Hungary, although with a declining trend, which approximates to other compared economies. Other results are also remarkable - in the last five years, the level of specialization in all the remaining economies consolidates and approaches the same level. It seems that efforts of economies to maximize export of high-tech products are successful (with the exception of Hungary, which gets the same level than in 1995).

D. Transformational Performance

In previous output intensity, productivity and structure of export was examined, now its effectiveness is also subjected to a brief analysis. This efficiency is expressed by transformational performance indicator that represents added value by processing of imports and reflects the ability and the degree of their appreciation. The same rule is applicable as in the previous indicator - the higher the value of the indicator, the higher value of added exports per capita, the higher the efficiency and competitiveness. Like an indicator of the relative strength of specialization, this indicator reflects the relationship, and so difference between export manufacturing industries and import of primary production per capita, see (4).

$$TI_i = \frac{X_m - I_p}{NC} \qquad (4)$$

where TI_i is the indicator of transformational performance of i-economy, Xm represents the export of the manufactured commodities (SITC 5-8), Ip is the import of the primary production (SITC 2 a 3) and NC is the number of citizens.

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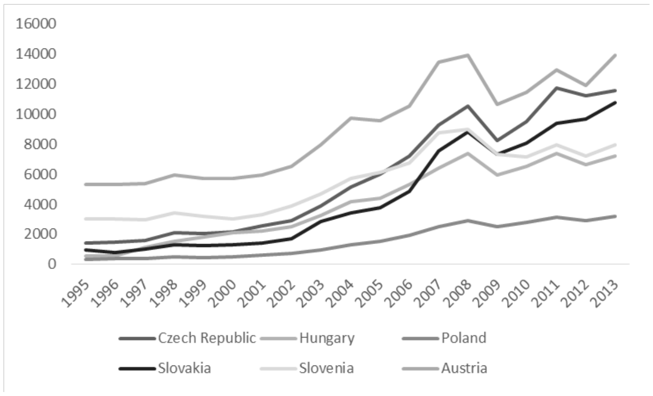

Fig. 4 Development of added value of export in the V4+ in the 1995-2013

According to Fig. 4, the added value of exports per capita is highest in Austria, constitutes almost ten times of value added of Poland. The second economy in order is the Czech Republic, further Slovakia, than Slovenia, Hungary and Poland the last. Highest improvement achieved the Czech Republic which added value more than doubled in the period, a similar improvement reached other former centrally planned economy - Slovakia. Poland has the smallest progression which value added remained in the period almost unchanged.

IV. Methodology and Empirical Approach

As noted above the comparison of the competitiveness is very popular in the case of the countries of the V4. The authors used and use various method to obtain the required results.

[19] used two selected methodological approaches to evaluating competitiveness: macro econometric modelling and Data Envelopment Analysis (DEA). Econometric panel data regression model determine the order of impact of each V4 NUTS 2 region on overall competitiveness of the European Union. DEA method provides a different view of regional competitiveness assuming that efficiency mirrors competitiveness

[20] investigates the competitiveness of V4 economies from a new angle, related to fragmentation of global value chains (GVC). In the paper, a new methodology of analyzing competitiveness of economies, developed by [21], was employed, making use of World Input-Output Database. [22] used for ranking the V4 countries in the field of macroeconomic competitiveness the polardiagram and dendogram. Bartha and Gubik used the FOI model that offers a new typology of development factors, but it is also capable of structuring these factors along three clear development directions.

According to Ramík and Hančlová the technology for the evaluation of regional competitiveness is based on the application of two methods of multi-criteria decision making. The first one is the method of Ivanovic deviation, the second one is the known DEA.

[23] focus on the evaluation of the competitiveness of countries based on the country's involvement in international trade by individual commodity areas and highlight the comparative advantages of the countries surveyed. For this purpose she use the RCA index and Michaely index.

We decided to analyze the problem of competitiveness on an extended group of countries namely selected countries of the V4+, which include the V4 countries, plus Slovenia and Austria. The aim of this paper is determine the dependence of measurable determinants of macroeconomics competitiveness of analyzed economies, by using the correlation and panel regression analysis with the period of the years 1995-2013. Values of determinants were calculated from the data in Eurostat database [24].

For evaluating the competitiveness we used the method of panel regression analysis. This method is carried out using least squares method, using 114 observation, included 6 cross sectional units and time series length of 19. Firstly, spatial correlation was determined by using the Pearson correlation coefficient, further constancy variance was tested using graphical methods. Secondly the test of significance and T-test were used. These assumptions were tested in program Gretl. A correlation has been made of mutual linkages of measurable aggregates of macroeconomic competitiveness in individual economies for the period 1995-2013. The analyzed indicators are correlated, and the information is supposed to show the relationship among them.

By using the Pearson correlation coefficient r, see (5) the assumption should be fulfilled that both variables are random variables and have a common two-dimensional normal distribution - then a correlation coefficient of zero means that the variables are independent, with a value of one factor shows the absolute dependence of the monitored variables.

$$r_{xy} = \frac{\sum_i \left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right)}{(n-1)s_x s_y} \tag{5}$$

where n is the number of measurement, i is 1, ..., n, xi, yi are normally distributed random variables X and Y, are average values and sx, sy are standard deviations.

The basic equation for expressing panel regression is the following (6).

$$y = \beta_0 + \beta_1 x + \varepsilon \tag{6}$$

where β_0 and β_1 are the values of the parameters of the regression, ε is a random component.

Regarding the statistical significance of the model as a whole, it is first necessary to establish a zero (H_0) and alternative (H_1) hypothesis and then test these hypotheses at the significance level α = 0.05.

H_0: The linear regression model is statistically insignificant.

H_1: The linear regression model is statistically significant.

Another important requirement is to perform T-test, which examines each parameter β_0 and β_1 separately, if they are not equal to zero. Even in this case null and alternative hypotheses are determined and tested at a significance level $\alpha = 0.05$.

H_0: Parameters $\beta0$ a $\beta1$ are equal to zero.
H_1: Parameters $\beta0$ a $\beta1$ are not equal to zero.

To perform regression analysis, one independent variable was selected, that explain one dependent variable in individual economies for the period 1995-2013. The dependent variable in the model 1 to 3 is export performance, in the model 4 and 5 it is the degree of openness and in the model 6 the relative strength of specialization.

The autocorrelation was tested mathematically by Durbin – Watson (D–W) test. The value at D–W test at estimated model is below 1. The value acts for evaluation of autocorrelation presence (serial dependency of residual components connected with sectional and time influences of panel model). According to critical values of D-W test, the presence of autocorrelation was proved. The test of heteroskedasticity was made by using the White test.

The results of our tests are shown in the Table II.

Table II. The Results of Panel Regression

Model 1 EP

	Coefficient	Std. Error	t-ratio	p-value
const	350.055	2079.07	0.1684	0.8666
DOE	149.181	34.12	4.3722	<0.0001

R-squared	0.1458
adjusted R-squared	0.1382
p-value(F)	0.0002

Model 2 EP

	Coefficient	Std. Error	t-ratio	p-value
const	3168.56	2148.41	1.4748	0.11431
RSS	9905.64	3472.38	2.8657	<0.0001

R-squared	0.0683
Adjusted R-squared	0.0599
P-value(F)	0.0049

Model 3 EP

	Coefficient	Std. Error	t-ratio	p-value
const	-61.4674	304.962	-0.2016	0.8406
TI	1.79364	0.04883	36.7308	<0.0001

R-squared	0.9233
Adjusted R-squared	0.9227
P-value(F)	2.67e-64

Model 4 DOE

	Coefficient	Std. Error	t-ratio	p-value
const	26.8307	4.7688	5.6263	<0.0001
RSS	53.3102	7.7076	6.9165	<0.0001

R-squared	0.2992
Adjusted R-squared	0.2930
P-value(F)	3.02e-10

Model 5 DOE

	Coefficient	Std. Error	t-ratio	p-value
const	46.7143	2.47055	18.9085	<0.0001
TI	0.00230	0.00039	5.8186	<0.0001

R-squared	0.2321
Adjusted R-squared	0.2253
P-value(F)	5.73e-08

Model 6 RSS

	Coefficient	Std. Error	t-ratio	p-value
const	0.511824	0.02737	18.7003	<0.0001
TI	1.5895e-05	4.3825e-09	3.6268	0.0004

R-squared	0.1051
Adjusted R-squared	0.0971
P-value(F)	0.0004

The level of significance is compared with the p-values (F) in the table above. Thus, if these values are lower than the level of significance (they are in all cases), the null hypothesis can be rejected and so the alternative hypothesis is valid, therefore, variables are statistically significant. In all models, the probability value (significance F) is less than tested significance level of 0.05, which means that the null hypothesis is rejected, and regression model is statistically significant.

The level of significance is compared with the value P in the table above. Thus, if P value is lower than the level of significance, as in all of cases, we reject null hypothesis and so alternative hypothesis is valid, therefore, that both parameters are not equal to zero.

The values of correlation coefficient, which are shown as R-squared indicates the strength of dependence of selected variables only in model 3. Specifically, it means that the values set by export performance are approximately 92% dependent on changing of the transformational performance. In other models the indicators are independent of each other.

Other values shown in the Table II are the values of adjusted R-squared – it indicates how much of the total variance of the dependent variable is explained by this model. With exception of export performance variable with 92%, it is less than 30% in other cases.

The tests of autocorrelation and heteroskedasticity showed that our models have the high value of the first mentioned one (exept model 3) and no heteroscedasticity.

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V. Conclusion

Competitiveness is a frequent subject for discussions and vocational articles. It is very important part of economic issue from the national, regional and firm point of view.

The measurement of macroeconomic competitiveness can be approached from the perspective of input indicators and output indicators. The output indicators of were chosen. They were based on these mathematical results the comparison of the economies of Visegrad Group plus - the Czech Republic, Hungary, Slovakia, Poland, Slovenia and Austria were carried out.

The aim of this paper was determine the dependence of measurable determinants of macroeconomics competitiveness of analyzed economies, by using the correlation and panel regression analysis with the period of the years 1995-2013. The autocorrelation and heteroskedasticity was tested as well.

According the model of panel regression we found, that all models are statistically significant, but only model with export performance and transformational performance showed the strong dependence without autocorrelation and heteroskedastiticy.

In our future research we try to make the test with the method GMM (Generalized Method of Moments) to compare our past results with the results of it.

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Contribution of PV Power Plants to Flicker Severity in Power Distribution Grids

Denisa G. Rusinaru, Leonardo G. Manescu, Adelaida, M. Duinea and Cristian C. Bratu

Abstract— This paper presents some results of an extended power quality investigation based on complex measurements in the substations of the local distribution grids having a photovoltaic system interconnected to. To track practical considerations about the propagation of the electromagnetic disturbances in the studied grid, all information on PV units operation were collected and analyzed, for different operation grid's configurations. The results of the experimental investigation proved that the presence of the grid-connected PV system cause power quality problems, but its responsibility could be split with other former connected consumers depending on the network topology.

Keywords— Distribution grids, power quality, monitoring, grid-connected PV power plant, power quality, flicker.

I. Introduction

THE actual impact of the power quality (named here PQ) on the power systems' operation covers issues as lost production, equipments' failures or additional costs of operation and investment.

Since more utilities are aware that a proper evaluation of PQ level is necessary for their service, they agree with their users under contracts to provide a specified PQ level, especially in the presence of the grid-connected renewable energy sources. On the other hand, the increasingly number of sensitive customer loads alongside the renewable generation ask nowadays for a more proper, unitary and honest manner to define and evaluate PQ by the power companies and their customers, too.

Therefore a set of right parameters, limits and procedures should be defined for evaluating the PQ product and service, as well as for establishing right responsibilities for the grid's users that mainly help the power grid users in keeping the compatibility between their loads and the quality of grids' electricity [1, 2].

The PQ level in the transmission and distribution grids must be verified periodically at the strategic or suspicious buses: e.g. boundaries between grids, area with numerous customer complaints regarding the quality of the supplied power or renewable energy grid-connected sources [1, 2]. For this purpose, some PQ performance targets should be selected so that the contractual agreements between grid's operators and their users to be concluded.

In these circumstances, the renewable energy sources, especially PV systems, have become more significant sources of energy in the national power system. Nonetheless, the connection of large PV systems to utility grids may cause several operational problems for distribution networks, as well as for the quality of the power delivered by these ones. The severity of these problems directly depends on the percentage of PV penetration, the geographical location of the installation, as well as the network topology [3, 4, 5]. Hence, knowing the possible impact of grid-connected PV systems on distribution networks can provide in advance feasible solutions for operation improving.

The over-voltages, harmonics, frequency fluctuations or rapid voltage variations (flicker) can be outlined as possible effects that PV systems may impose on PQ in distribution systems due to the fluctuation in solar radiation. The factors influencing the PQ are generally varied and the interactions between these factors are complex. The more the number of the disturbing loads in interaction with PV-grid connected systems, the more the complexity.

The present paper points out the impact of a 5 MW PV system on the PQ level in the MV distribution network in which this one is connected. A particular attention is paid to the flicker propagation in the network and its sources' location. The experimental analysis is based on field measurements for different operation configurations of the interconnecting distribution grid.

II. Test Conditions for PQ Analysis in Distribution Network with grid-connected PV systems

The capability of the power system to absorb the PQ disturbances is depending on the fault level at the point of common coupling. In weak networks or in power systems with a high PV generation penetration, the integration of these sources can be limited i.e by the flicker level that must not exceed the standardized limits. The PV systems interconnected to the main grid with the help of power electronics converters can also cause important current harmonics.

The MV grid-connected PV power plants (PVPP) should

D. Rusinaru is with the Faculty of Electrical Egineriing, University of Craiova, 200440-Craiova, Romania (phone: 0040754077373; fax: 0040251436447; e-mail: drusinaru@elth.ucv.ro).

L.Manescu is with the Faculty of Electrical Egineriing, University of Craiova, 200440-Craiova, Romania (e-mail: amanescu@elth.ucv.ro).

A. Duinea is with is with the Faculty of Electrical Egineriing, University of Craiova, 200440-Craiova, Romania (e-mail: aduinea@ elth.ucv.ro).

C. Bratu is with the Faculty of Electrical Egineriing, University of Craiova, 200440-Craiova, Romania (e-mail: cbratu@elth.ucv.ro).

fully respect the requirements of Electricity Distribution Grid Code, as well as Romanian Norm *Technical requirements for photovoltaic power plants connected to the Romanian National Electric Grid* [6, 7, 8, 9, 10]. Accordingly, the compatibility levels of flicker severity Plt is 1 p.u. in conformity with the EN 50160 specification at MV. The practical assessment of flicker and corresponding indices is an important area of further research, as the implications of meeting the Plt requirements of one unit is significant for utilities and their customers.

Particularly the present study was performed as an initiative of a local grid operator to solve the numerous recent complains of its grid user after connection of a PV system regarding especially the voltage fluctuations over-exceeding the unity.

The studied PV system is a 5 MW one and is a direct-coupled one, without electrical energy storage, connected to the 20 kV utility grid. It injects in the power system a power that follows the intermittency of the primary energy source and important voltage variations occurred at the PCC. Determination of voltage fluctuations (flicker effect) due to output power variations of PV systems is difficult, because depend of the weather conditions, generator's characteristics and network impedance.

A measurement campaign could be a more efficient way to assess flicker levels produced by this type of generation than the use of flicker prediction algorithms. Taking into account that the solving of grid customers complains asked for a rapid resolution, the grid operator used the practical measurement results to evaluate the flicker propagation through its network, its severity and consequent measures.

Based on operator's experience and requirements, two base configurations were chosen for the connection network in order to investigate the impact of the PV system on the flicker severity without power plant's service interruption. The PV power plant impact on flicker severity in a normal operation grid topology, named as Config1 and given in Fig.1 is compared with the case of a temporary network configuration, named as Config2 and given in Fig.2.

Under normal operation the power is injected by PVPP upstream of the distribution grid, toward substation SS1. SS1 is a 110/20 kV distribution substation, equipped with two 10 MVA power transformers, one of them being in continuous operation and the other serving as permanent reserve.

During temporary operation the power is injected by PVPP downstream of the distribution grid, toward substation SS2. Both of the SS1's transformers are in operation this time. The consumers supplied through SS1 are split between the two busbars' sections as following: the consumers supplied from OVHL 1-2 are connected to section BbI, while the other group of consumers (mainly petroleum installations) are connected to section Bb II.

By performing test measurements in both grid configurations the flicker severity contribution of each group of the network could be estimated and the impact of the PV system could be properly evaluated without plant's interruption.

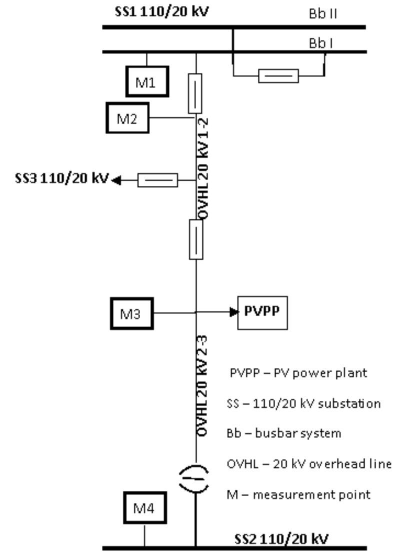

Fig. 1 PVPP connection into normal operation configured distribution grid – Config1

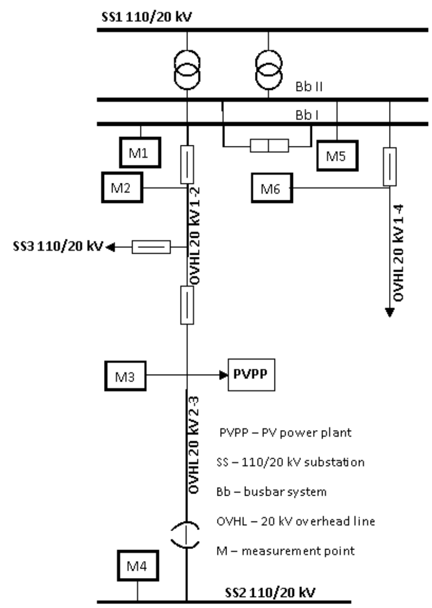

Fig. 2 PVPP connection into temporary operation configured distribution grid – Config.2

III. Experimental Results

A. Purpose of experimental analysis

This experimental analysis aims to support the distribution network operator to evaluate the correct contribution of PVPP at the flicker severity in the MV grid at which it is connected. This network area is feeding different types of loads (almost 4.5 MVA average load), and particularly the petroleum installations (almost 1.5 MVA average load) containing variable speed drives and supplied connected mainly to the feeder OVHL 1-3. The voltage flicker at the MV network is the combined result of emissions from loads connected at this voltage level and flicker transferred from the HV grid. Therefore, the flicker emissions from individual installations are superimposed and determine the overall voltage flicker level in the network. By using different network topology the potential flicker sources could be isolated, without supplying interruption and the contribution of the PVPP with a stochastic generation to flicker can be more accurately determined.

B. Measurement conditions and tools

A set of synchronized measurements have been performed in the 20 kV radial distribution network area boarded by the two 110/20 kV distribution substations, named SS1 and SS2. PQ meters have been installed in six strategic measurement points:

- M1 (available in both configurations): 20 kV BbI of SS1
- M2 (available in both configurations): 20 kV cell of OVHL 1-2
- M3 (available in both configurations): 20 kV PCC of PVPP
- M4 (available in both configurations): 20 kV busbar SS2
- M5 (available in Config2): 20 kV BbII of SS1
- M6 (available in Config2): 20 kV OHVL 1-4 with petroleum installations' loads

Power analyzers of Fluke 434/435 type are placed in M2, M3 and M5. Chauvin Arnoux CA8335 equipments are located in M1, M4 and M6.

The meters having error pursuant to Class A fulfill specifications required by distribution operator according to IEC 61000-4-30:2008 Std. "Testing and measuring techniques – Power quality measurement methods" [11].

The measurement data were collected over one-week period in each network configuration for solar irradiance under similar weather conditions. Sets of 7x24x6=1008 ten-minutes average-values have been supplied at each measurement site. By sorting the measured data, the weekly 95th percentile values of the Plt values are statistically determined and compared to the unitary compatibility value.

C. Measurement results

The following PQ aspects were monitored and reported: frequency, supply voltage variations, harmonic distortion, supply voltage unbalance, flicker. In this work a special attention is granted only to the rapid voltage fluctuations - flicker. So that, a snapshot view on the flicker severity for the two network configurations are reported in as in Fig. 1-4.

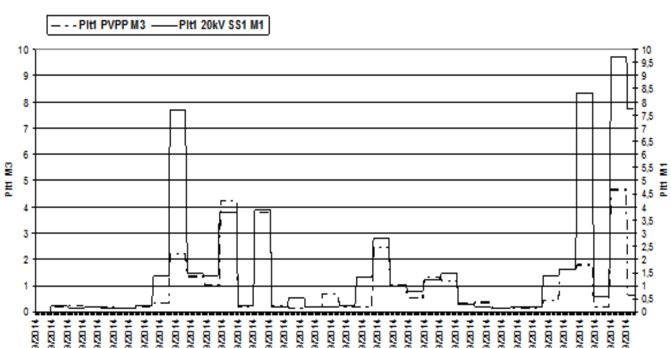

Fig.1 Time evolution Plt1 at 20 kV PCC of PVPP (M3) vs. Plt1 at 20kV busbar of SS1 (M1) in Config1

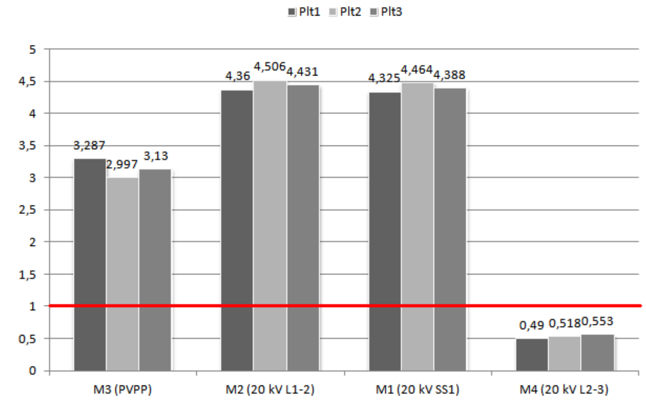

Fig. 2 Plt distribution in PVPP's distribution network for Config1

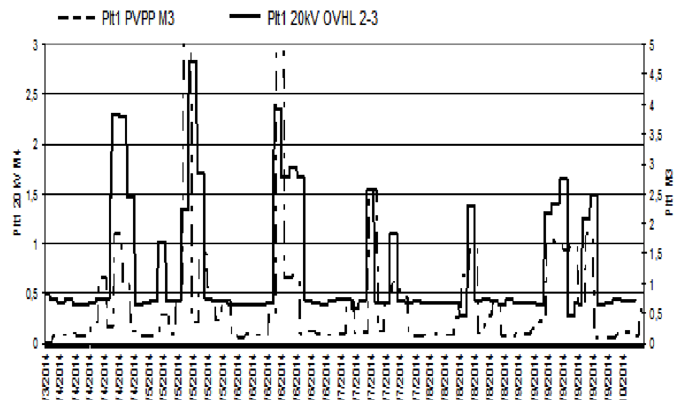

Fig.3 Time evolution Plt1 at 20 kV PCC of PVPP (M3) vs. Plt1 at 20kV busbar of SS2 (M4) in Config2

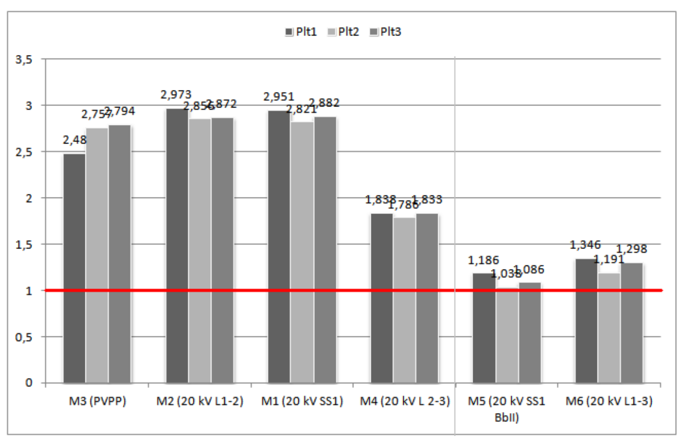

Fig. 4 Plt distribution in PVPP's distribution network for Config2

Table I shows the main statistics of the 95% Plt weekly values measured at three phases in the distribution network to which the PVPP is connected.

a) Practical considerations regarding Config1 – Fig. 1, 2

• In this configuration the PVPP has fully operated with a maximum output power of 4.4 MW. The flicker 95% Plt factor in 20 kV PCC of the PV system (M3) has exceeded the limit on all 3 phases.

Table I The 95th percentile Plt values over one-week measurements

Measurement point	Plt 95% in Config1			Plt 95% in Config2		
	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
M1	4.325	4.464	4.388	2.951	2.821	2.882
M2	4.360	4.506	4.431	2.973	2.856	2.872
M3	3.287	2.997	3.130	2.480	2.757	2.794
M4	0.490	0.518	0.553	1.838	1.786	1.833
M5	-	-	-	1.186	1.038	1.086
M6	-	-	-	1.346	1.191	1.289

• The flicker Plt factor exceeded also the unit limit on all phases on 20 kV secondary busbars of substation SS1 (M1).

• The time variation of Plt recorded in 20 kV SS1 is similar to that one recorded in the PCC of PVPP - see Fig,1.

• For 4th measurement location, the 20 kV busbars of substation SS2 (M4), no limit exceeding was registered for flicker Plt factor.

• Nevertheless, the higher values of the Plt in 20 kV SS1 compared to the flicker severity in PCC of PVPP has suggested an additional contribution from the loads connected to 20 kV of the SS1 substation busbars or from upstream of this substations. Further investigations have been requested.

b) Practical considerations regarding Config2 – Fig. 3, 4

• In this configuration the PVPP has fully operated with a maximum output power of 4.3 MW. The flicker 95% Plt factor in 20 kV PCC of the PV system (M3) has also exceeded the limit on all 3 phases.

• This time the PV flicker behavior's influence is detected in the time evolution of the flicker Plt measured on 20 kV busbar of SS2 (M4) – see Fig. 3. Here the 95% Plt exceeded the unitary value, too.

• The flicker Plt factor exceeded also the unit limit on all phases on 20 kV secondary busbars section BbI of substation SS1 (M1), but it is lower than the values registered in the previous configuration. The influence of the loads connected to its busbars is considered this time.

• The flicker Plt factor on the other busbar section BbII of substation SS1 (M5) exceeded also the unit limit on all phases on 20 kV. Due to the actual network configuration, this fact is determined solely by the flicker contribution of the petroleum installation loads connected supplied form this substations (M6).

The propagation of flicker Plt factor through the distribution network buses leads to the conclusion that responsibility not clearly belongs to a single source (in this case CFV), but rather it is an effect of interaction between different flicker sources to which contribute more factors: e.g. network configuration, operation mode of PVPP, atmospheric conditions. The increased value of the Plt factor at 20 kV SS1 without PV system feeding this network area suggests that in certain operating conditions the PVPP may have even a slight beneficial effect. On the other hand, its connection to the network section including substation SS2 has relatively little influence on the overall level of disturbance.

Phenomenological explanation is the fact that voltage changes are directly related to reactive power flow that occurs among distributed reactive components, depending on the operating conditions of the network, its composition and topology, and being strongly favored by power electronics applications (inverters).

By considering the PV having a singular culpability for flicker severity source of disturbance CFV is risky. There is rather about the effect of interaction with consumers in the area, closely related to network configuration.

In these circumstances the recommended measures should target not eliminate the cause, but the consequences by ensuring an efficient control of reactive power in the buses with disturbance sources.

IV. Conclusions

The renewable sources interconnected with the main supply can influence the PQ at the point of common coupling and generate electromagnetic disturbances that must not exceed the stipulated limits. The existing trend of installing more renewable sources implies the establishment as accurate as possible of their impact on power system operation.

In this paper the voltage fluctuations determined by a 5 MW PV power plant's power variations are analyzed, for two network configurations, in order to properly establish the plant contribution to the flicker severity. The photovoltaic plant, connected to the power system through power electronic converters determines flicker fluctuations that should respect the regulations recommendations. A better characterization, from the practical point of view, of the flicker severity determined by PV power plants interconnected to the mains supply through power electronic converters is necessary, based on experimental analysis.

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Denisa G. Rusinaru was born in Craiova (Romania) on September 25th, 1968. She has graduated Electrical Engineering in 1993 at University of Craiova, Romania. She received her Ph.D. in power engineering in 2002 from University Politehnica of Bucharest. Today she is a senior lecturer with the Faculty of Electrical Engineering, University of Craiova. Her fields of interests are power quality analysis, power distribution, energy efficiency.

Leonardo G. Manescu was born on September 30th, 1964. He received the M.Sc. degree in 1989 and the Ph.D. degree in Electrical Engineering in 1998 from the University of Craiova, Romania. Currently, he is a Full Professor with the Faculty of Electrical Engineering at the University of Craiova. His main research interests include power systems analysis, power distribution and transmission, smart grids, and power quality. He is a Member of IEEE.

Adelaida M. Duinea was born on June 19th, 1971. She received her M.Sc. in 1995 and Ph.D. degree in 2009 both in Energy Engineering at University of Craiova. Presently she is a lecturer with Faculty of Electrical Engineering, University of Craiova. Her research interests are power plants analysis and design, energy efficiency, computer-based design of energy installations.

Cristian C. Bratu was born on September 15th, 1978. He received the M.Sc. degree in Electrical Engineering in 2002 and the Ph.D. degree in 2010 from the University of Craiova, Romania. Currently, he is a lecturer with the Faculty of Electrical Engineering at the University of Craiova. His main research interests include renewable energy sources, electrical energy efficiency, power distribution.

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A Systems Approach to Measuring and Managing Company Performance

First A. Lucie Jelinkova, Second B. Renata Myskova

***Abstract* —**The key condition in today's tough competitive struggle is the ability to distinguish oneself from the competition. Naturally, an insufficient level of knowledge of modern management theory and deficiencies in systems thinking prevent managers from being able to set a company apart from its competitors. Nevertheless, it is possible to see competitiveness and competitive advantage as one of the decisive factors for a company's performance. A comprehensive information system is decisive for company management and other concerned parties in order to monitor company performance, evaluate and understand it and to reveal all factors affecting its development. Therefore, a systems approach for measuring and managing performance becomes an important condition for successful company management. This report deals with the problematic of the systems approach to measuring and managing performance at a specific manufacturing company. Findings acquired on the basis of an analysis conducted using internal company materials and a managed partially-structured interview are evaluated in the context of theoretical framework to apply the systems approach in the given area. Subsequently, this company's system is described and graphically depicted, and a recommendation is presented for potentially increasing the system's effectiveness.

***Keywords*—**approach, management, performance, system.

I. Introduction

In today's tough competitive struggle, a competitive company must have potential that can be seen by the competition; otherwise, it is impossible to speak of competitiveness [1]. The decisive majority of company managers know quite well how, specifically, their company should be better in order to attain greater competitiveness for their products, company, or the field in which they are active. An insufficient level of knowledge of modern management theories and deficiencies in systems thinking prevent them from being able to set their company apart from the competition [2]. Another problematic area for companies is applying a systems approach in the field of measuring and managing performance. The requirements for a performance management system – not only in conception and methods of management but also in securing information and professional qualification for managers – are influenced by constant changes in business conditions, i. e., changes in the competitive situation or in technical and technological development; changes in values in the world of work or in the company; and, not least, change in attitude towards the environment, which is characterized by pressure to lower demands on resources. "The common denominator for the current fluctuating conditions of business processes is the decisive role of the customer, the dynamic of the innovation of processes and products and the growing measure of uncertainty for attaining success in the future." For this reason, measuring and managing performance should be a company priority. [3]

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F. A. Author is with the University of Pardubice, Faculty of economics and administration, Institute of Business Economics and Management, Pardubice 532 10, Czech Republic, (e-mail: lucie.jelinkova@student.upce.cz, phone: +420 466 036 664).

S. B. Author is with the University of Pardubice, Faculty of economics and administration, Institute of Business Economics and Management, Pardubice 532 10, Czech Republic, (e-mail: renata.myskova@upce.cz).

II. The Specifics of the Systems Approach to Measuring and Managing Performance

According to [4] it is possible to consider the systems approach as a way of thinking, a way of resolving problems or a way of behaving where features are perceived comprehensively according to their internal and external relationships. [5] regard the systems approach to be a process of gradually exploring reality with its fundamental traits being:

- the purposeful simplification of the characteristics and relationships of the investigated features,
- their depiction in a newly created abstract object – system,
- preserving the comprehensiveness of the depiction of the processes and the characteristics and relationships of the observed features,
- functional relationships corresponding to the goals of observation are the only subject of the concern being researched,
- the rigorous application of the principle of causality in recognizing relationships between the analyzed abstract objects and their parts.

Bures [6] defines the systems approach similarly – as being founded on the concept that the phenomena we commonly encounter are part of a whole created from individual parts, which are mutually connected in various ways. He states that the given parts have their own place in the system determined by their relationships to other parts and have their own role and significance in the system as a whole. The system functions as a whole, i. e., if there is a change in one of its parts, this results in a change in other parts of the system.

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Strizova [7] believes that the systems approach encompasses ways of heading towards fulfilling goals, is dependent on the organization's development within its surroundings and explores the effects of interactions. Additionally, she believes that primary attention is given to the harmony of its functions with the purpose of the whole and to the organization of the whole with its surroundings and that it integrates its structure with its function.

We can then see the application of the systems approach to performance in the definition of performance itself; for example, Pitra [8] defines business performance as "the result of the organized activities of specific people who have joined their strengths and resources to attain clearly defined goals." He believes that business performance is not only an economic requirement but also a society-wide requirement and that employees, managers and owners who make decisions concerning its quality bear personal responsibility for its fulfillment. "Performance embraces all types of business activities that it is necessary to combine in order for the result to be a functional and prosperous company with a long-term prospect for existence." [9]

Performance management then represents a methodical attempt by a company to improve its performance by means of its individual parts. It is possible to conceive of these parts as including the company's parts, people, processes, etc. [10] and [11] state that it is necessary to perceive performance management not only as a process but also as a system that is involved in an entire range of key areas within a company that are simultaneously critical factors for the success of the company overall (see Fig. 1).

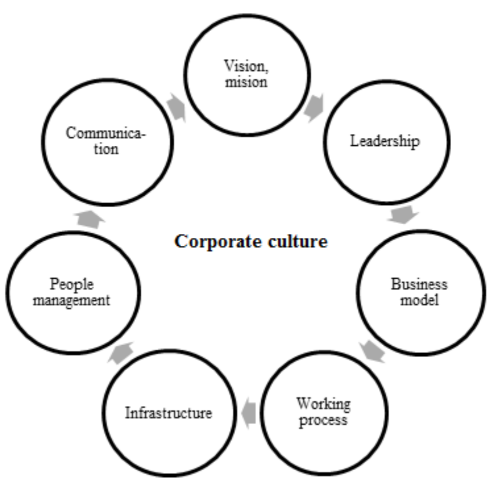


Fig. 1 key Factors for a Company's Success

Business performance is provided primarily by the individual performance of its employees.

The fundamental condition for performance management is its measurement. It is possible to define measuring business performance as an approach to evaluating performance in relationship to its goals, inclusive methodologies, scope and specific indicators that help businesses formulate and evaluate strategies, motivate and evaluate employees and communicate business performance to concerned parties [12], [13]. We can find elements of the systems approach even in this definition of performance measurement.

When applying the systems approach, it is essential to define the system being examined. It is possible to comprehend a system as Checkland [14] does – as a group of elements connected into a whole that embodies characteristics of the whole rather than characteristics of each individual element. Blanchard and Fabrycky [15] expand further on this statement; they consider a system to be a group of mutually interconnected components having specific characteristics and aiming collectively towards realizing a demarcated goal or fulfilling a certain purpose.

[16] understand the concept of a system to be any type of functionally defined set of elements (components, elements, parts, features) connected by mutual relationships in space and time. With the help of the mutual interconnection of individual elements, this system behaves differently with regards to its surroundings than another group of the same but not interconnected elements would behave. He also mentions the positive action of the synergetic effect between elements.

[5] talk about a system as an abstract object that is purposefully defined by a "conceptor" (a person who wants to understand, create or change a specific object or solve a problem) and which embodies specific functional characteristics as a whole, with the basic functional characteristic being the behavior of the system or the dependence of system outputs on system inputs. A system input is understood to be a depiction of a subject that acts on the original object of the "conceptor's" interest. It is then possible to express the set of these inputs with the help of variables by which the system is influenced. The system output is understood to be a depiction of the reaction of the original object to a specific stimulus. The set of these system outputs is expressed with variables by which the system influences other objects in its surroundings. Thus, most authors define systems differently; [15] for example, tried to unify these opinions and established 9 common criteria for defining a system.

The nature of the elements included in a system is varied; therefore, we differentiate systems, e. g., into technical, biological, economic, social and formal; these are homogenous types of systems. The combination of these results in the creation of heterogeneous or mixed systems; organizations or businesses can be considered heterogeneous systems [17]. The set of ties between elements of a system creates its structure. The system can be seen as structured, enabling optimization of internal system activities and the analysis of individual elements, and unstructured, in which only the behavior of the system as a whole is observed [5]. It is not possible to regard the system only in a static way – either from the perspective of its structure or from the perspective of its behavior and changes of state in dependence with the system's surroundings.

The following principles are applied in the systems approach [16], [18]:

- the principle of abstraction (overlooking non-essential features),
- the principle of proceeding from simple system characteristics to more complex features of behavior and to creating a more in-depth system structure,
- the principle of systematically investigating systems,
- the principle of team work (specialists from various fields),
- the principle of the process of investigating from top to bottom (from the highest level of structure down to the details of the system's structure),
- the principle of dividing systems (breaking down into simpler elements).

These mutually interconnected principles are characteristic for seeing reality with the help of the systems approach. Prorok [19] lists other principles which describe specific processes that take place in a given reality – not only processes of structure but also of hierarchy, feedback and the mutual dependence of a system on its surroundings.

On the basis of the relationship of a system to its surroundings, it is possible to divide systems into three basic types [5], [17], [18]:

- a closed system – it does not react to stimulus from its surroundings,
- a partially open system/relatively closed system – it reacts to stimulus but only specific elements,
- an open system – it reacts to stimulus from its surroundings.

For creating a system for performance measurement and management, it is important to apply a systems approach that is able to give these systems' form a clear structure as well as flexibility. It is possible to divide the implications of applying the systems approach to measuring business performance into two broad categories [20]:

- implications for process,
- implications for results.

The following table shows how it is possible to use the systems approach when designing a system for measuring performance (see Table I). [11]

Table I using the Systems Approach When Designing a System for Measuring Performance, updating according

Features of the Systems Approach	Implications
The Top-Down Approach	Build on what the business is already using and the rules governing it. Focus on seeing the whole as well as its parts.
Life Cycle Orientation	Focus on the transition from concept to realization – on development from the beginning of the process. Take into consideration all relevant aspects of the organization's performance.
The Initial Definition of System Requirements	Conduct an analysis of needs and deficiencies at the beginning of the process. Establish the scope of the system of measurement, and make sure the requirements are realistic.
The Interdisciplinary Approach	The systems concept cannot be a task for the company's management only. It is necessary to cooperate with primary internal and external stakeholders.

A well designed system for measuring performance is explicitly accompanied by a set evolutionary cycle with these triggers [21]:

- Process – the existence of a process, its review and modification and the implementation of measures.
- People – the availability of the required skills, their utilization, to reflect on the business requirements, employees, fulfilling requirements, implementing measures.
- Systems – the availability of flexible systems that enable the collection, analysis and proof of pertinent data.
- Culture – the existence of a culture that ensures that measuring performance with pertinent and appropriate tools will not be perceived negatively.

III. Methodology

The goal of this research is to describe a systems approach to measuring and managing the performance of a specific manufacturing company and, on the basis of facts resulting from the analysis of the company's internal material and a managed interview that was conducted, to establish a set of recommendations for increasing the effectiveness of the system of performance measurement and management in use.

The internal materials of selected manufacturing company were analyzed. This company falls within the group 12.00 according to the classification of economic activities (NACE CZ) [22]. According to Commission Regulation (EC) No. 800/2008 [23] the manufacturing company can be characterized as large companies (over 250 employees, over 50 million Euro). It is a Czech joint-stock subsidiary, which is a part of a large foreign holding company/group.

Furthermore, the semi-structured interview was conducted with managers on the middle level management, based on the methodology and rules presented by [24].

IV. The Features of the Systems Approach to Performance at a Specific Company

In the context of theoretical background on the systems approach to measuring and managing business performance, this approach was subsequently identified in the manufacturing company that was studied.

The system for managing performance at the manufacturing company that was studied is founded on the company's four basic principles:

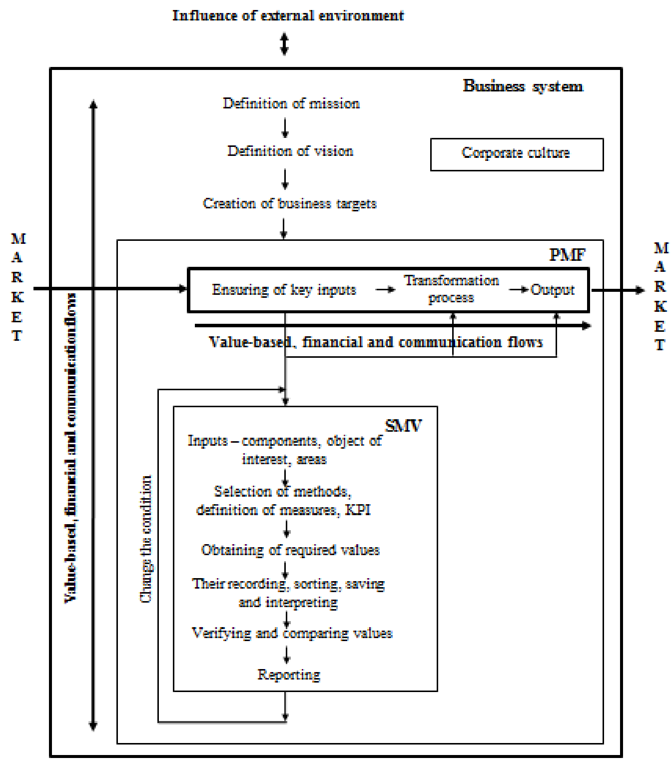
- Optimize all company activities with the goal of achieving added value.
- Identify problems and seek to resolve them.
- Learn and continually improve all company activities.
- Innovate and streamline all company activities. [25]

It is possible to describe the system of performance management from the studied manufacturing company on the basis of the nine criteria for defining a system established by Checkland [14] including the use of these criteria for creating structures and the content of the system for measuring and managing performance in the following way [20]:

1) The system has a long-term mission resulting from the strategy and established measurable goals that is set three years in advance.
2) It is able to measure its own performance using set goals (these goals fulfill the conditions of SMART (specific, measurable, achievable, realistic, time-dependent), which should be attained in individual areas of the company/company activities. Criteria and KPI have been established. KPI are always calculated and reported on a monthly basis. At the same time, there are established data sources, methods of data collection, methods for calculating KPI and roles and responsibility for data collection and KPI calculation. The company has a total of six KPI. Performance is determined using customer satisfaction, audits of the overall system (internal and external), monitoring and measuring processes, the product, investigating incidents and monitoring and measuring key environmental criteria.
3) It includes the decision-making process. Moreover, the PDCA cycle has been applied to the system in order to implement the principle of continual improvement.
4) It is composed of individual sub-systems – the main sub-system is the system of performance measurement.
5) The system elements, e. g., customers, employees, technology, IT, etc., engage in mutual interaction.
6) The system exists in the framework of a wider system, i. e., the company, and engages in mutual interaction with it.
7) The system has boundaries – they are those of the factory/manufacturing company.
8) It has resources available as part of the decision-making process assigned by the company's top management.
9) The system guarantees continuity by applying the PDCA cycle. [25], [26]

A graphic depiction of the system for managing and measuring performance of the studied manufacturing company – its position in the company, including an expression of mutual relationships and flows, is evident from the following illustration (see Fig. 2).

Fig. 2 depiction of the System for Managing and Measuring Performance in the Company's System



The business system described above currently includes two systems – PMF (performance management framework) and PMS (performance measurement system). As a system, the company includes a range of inputs, e. g., infrastructure, equipment, technology, people, capital, know-how, output materials, etc. With the help of various documents/document-tation connecting to the system, the system also has established requirements for these inputs, resources for acquiring inputs, responsibility, etc. System outputs are defined in various ways – a product, semi-finished product, profit, goal fulfillment, achievement of strategy, satisfying customers, employees, etc. It is possible to consider PMF a significant part/subsystem of this business system. The configuration of this system plays a key role, e. g., the configuration of the reporting structure, ways of using data from the PMS, establishing responsibility, etc. This system is located at the top of strategic management in the company. The SMV is a subsystem of the PMF. This system serves as a basis for managing performance in the company; performance is then managed on the basis of measuring the performance of individual company areas/activities. Inputs – the subjects investigated in this system are, for example: work performance (individual and group); processes (their configuration and quality); and products (semi-finished products, products). Quality, fulfilling the product requirements/specifications; key traits of the environment; investigation of incidents; the satisfaction of customers, employees, owners and stakeholders; the performance of suppliers, etc. are all measured. In the

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manufacturing company studied, the balanced scorecard model was applied for measuring and managing performance as well as financial analysis and benchmarking, which is used mainly for comparing individual factories around the globe. Financial and non-financial criteria and six KPI (key performance indicators) have been established for measuring performance [25], [26].

The systems approach concerns all processes in the company, categorized here into four basic groups:

- management processes – the strategic framework is defined here,
- processes concerning protecting the environment as well as ensuring the safety and protecting the health of all company employees while at work,
- manufacturing processes – where inputs are transformed into outputs,
- subsidiary processes – they provide support for the manufacturing and management processes. [25]

The functioning and development of the overall system is ensured using the processes listed above. There is a regular process of criteria review as part of the system that takes place twice yearly. The company has installed software support that was developed specifically for the company.

The most important driving forces for the overall business system are value-creating, financial and communication flows. The transformation of inputs into outputs as part of the manufacturing process results in the creation of a final product intended for sale on the market – this overall process represents the value-creating flow. Financial and communication flows are present in all business activities. Communication flows can be considered of key importance for the overall business system. Communication occurs across the whole company – from establishing the mission, vision, strategy and key goals through to their delegation, monitoring the manufacturing process, measuring and managing the performance of company activities and providing feedback information for strategy revision. Establishing a company culture where all of the company's concerned parties significantly participate in accepting the system and perceiving it positively is fundamental for implementing and applying the system. [25], [26]

The evolutionary development of a system for measuring and managing performance is dependent on a number of basic factors as stated by Kennerly and Neely [21]. The following table lists these factors in the context of the observed manufacturing company (see Table II).

Table II factors Influencing the Development of a System of Measuring and Managing Performance at the Studied Manufacturing Company

Processes	**Systems**	**People**	**Culture**
The continual process of criteria review aimed at monitoring performance in individual areas, establishing a regular measurement schedule, responsibility and resources	The existence, provision, maintenance, updating and usability of IT systems	The availability of assigned human resources for facilitating the revision and modification of criteria and processes	The culture contributes to understanding the advantages of measurement, the provision of easy system implementation and understanding changes
The integration of measuring with initiatives for improving system management and the revision or formulation of a new strategy	The flexibility of IT systems that enable the modification of data collection, analysis and provide suitable tools for reporting	Providing internal self-examination of the system with the help of a human agent	Accepting the need for development
It was possible to ensure a consistent approach to continuity using measuring	The integration of IT, strategy, operating goals and resources for attaining these goals	The availability of appropriate abilities for effective use of the entire system (including in-depth knowledge of operation and the requirements of the participating parties, the ability to develop systems, etc...)	Effective communication across the system for using the established medium or media
Processes identify internal and external triggers for change, a study of these triggers leads to quicker reaction to change	Having sufficient financial resources available for providing IT systems	Creating and developing a community of system users for the transfer of tested practices (e-mail, user groups, etc.)	Using outputs from the system or its subsystems for quick action, correction, reflection on the strategy and processes
Providing the mechanisms for the transfer of tested practices, quicker information flow	Maximizing the accessibility of data, minimizing reporting		The transparency of processes and activities of the entire system

CONCLUSION

The systems approach for both measuring and managing performance and for the company as a whole has been applied

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at a relatively sophisticated level within the studied manufacturing company. This fact is testified to by the sophistication of the business system, which includes systems for measuring and managing performance and establishing value-creating, financial and communication flows. In connection with four factors influencing the system of measuring and managing performance – processes, people, systems and culture. It is possible to state that the problematic factor/place in the system for measuring and managing the performance of the studied manufacturing company is in fact people; this emerged from a managed interview that was conducted. The biggest problem for this company is securing enough qualified people. One recommendation for acquiring qualified people could be, for example, building on the company's existing cooperation with universities and "nurturing future talent" while individuals are still engaged in studies. This could take the form of organizing internships for students, inviting students and the option of engaging in "practice" hiring processes, interviews, and assessment centers, the options of writing theses and dissertations with the company, etc.

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On Modelling the Relaxational Impact of Water Pollutions in System of Flow-through Reservoirs

Sevara Kurakbayeva, Marina Saprygina and Dzhumagali Kurakbayev

Abstract**—** The mathematical model of pollutants propagation in the system of three connected water reservoirs has been submitted. The case of volley pollution of any substance into the one of reservoirs has been numerically investigated. As a result of numerical experiment the peculiarities of pollutants concentration dynamics in everyone reservoirs have been obtained. It is shown the possibility of temporary increasing the pollutant concentration in some of reservoirs even if the volley pollution ended.

Keywords**—**Volleypollution, pollutant propagation, connected reservoirs, mathematical model, numerical study.

I. Introduction

NOWADAYS, the study of all effects linked to processes of pollution propagation in the water reservoir systems is of great practical interest. The results of these investigations find an extensive use in a solution of different environmental problems [1-3].

In general, industrial wastes are propagated through the network of interconnected water reservoirs and form rather complicated scene of pollutions [4, 5]. So, a subject of the investigation in our paper is systems of three flowing reservoirs. A source of pollutions of a specified intensity $I(t)$ is situated on a coast of one of these reservoirs (Fig. 1).

The paper deals with the problems related to dependence of such indexes as a relaxation period in each of the reservoirs on duration of the discharges and water filtration coefficients in a soil.

S. Kurakbayeva is with the Information Systems Department, M.Auezov South Kazakhstan State University, Shimkent, 160019, Kazakhstan (phone: +7-725-250-6039; e-mail: ksevam2014@gmail.com).

M. Saprygina is with the Medical Biophysics, computer science and Mathematics Department,South - Kazakhstan State Pharmaceutical Academy, 160000, Shimkent, Kazakhstan, (phone: +7-725-250-6039; e-mail: marinaiv@mail.ru).

D.Kurakbayev is with the theory and technique of teaching of computer science Department, M.Auezov South Kazakhstan State University, Shimkent, 160019, Kazakhstan (phone:+7-725-240-1780; e-mail: kurakbayev@mail.ru).

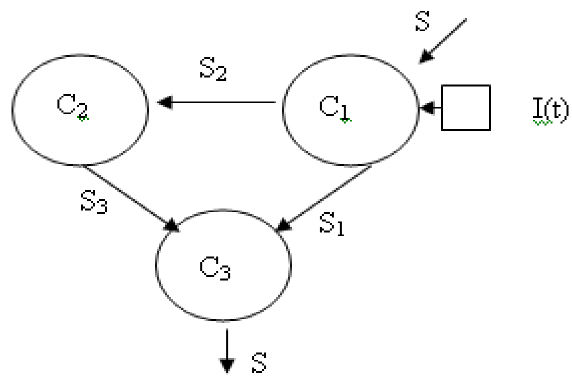

Fig.1 A diagram of flows in the system of three interconnected water reservoirs

II. MODEL

Under neglect condition by filtration of waters in a soil, the next system of differential equations for the water reservoirs pollution balance by a stable impurity may be written:

$$\begin{cases} V_1 \dfrac{dc_1}{dt} = I(t) - sc_1 \\ V_2 \dfrac{dc_2}{dt} = (s - s_1)c_1 - \quad (s - s_1)c_2 \\ V_3 \dfrac{dc_3}{dt} = s_1 c_1 + \quad (s - s_1)c_2 \quad - sc_3 \end{cases} , \qquad (1)$$

Let's take into consideration, that the next conditions are characteristic for our system:

$$s_1 + s_2 = s;\ s_2 = s_3;\ s_1 + s_3 = s, \qquad (2)$$

conforming with a total flows balance.

A dynamic model (1) of the water reservoirs pollutions by the stable impurity taking into account the filtration process can be transformed to the next form:

$$\begin{cases} V_1 \dfrac{dc_1}{dt} = I(t) - s_0 * c_1 \quad = I(t) - (s_1 + s_2) * c_1 & (I) \\ V_2 \dfrac{dc_2}{dt} = \varphi_1 * s_1 * c_1 - \quad \varphi_1 * s_1 * c_2 & (II) \\ V_3 \dfrac{dc_3}{dt} = \varphi_2 * s_2 * c_1 + \quad \varphi_3 * \varphi_1 * s_1 * c_2 \quad - (\varphi_1 * \varphi_3 * s_1 + \varphi_2 * s_2) * c_3 & (III) \end{cases} \quad (3),$$

where c_1, c_2, c_3 are mean impurity concentrations respectively in the 1st, 2nd and 3rd reservoirs, kg/m^3; s_0, s_1, s_2, s_k are water flows, m^3/s; V_1, V_2, V_3 are water volumes, m^3; I is intensity of discharges, kg/s; t is time, s; $\varphi_1, \varphi_2, \varphi_3$ are filtration coefficients.
The next conditions were accepted for the system:

$$s_1 + s_2 = s_0; \;\; s_k = \varphi_1 * \varphi_3 * s_1 + \varphi_2 * s_2 \qquad (4)$$

The concentrations of impurities in the initial discharge moment in the water reservoirs were respectively:

$$c_1(0) = c_{1(0)}, \; c_2(0) = c_{2(0)}, \; c_3(0) = c_{3(0)} \qquad (5)$$

Let's consider a dynamics of the impurities concentrations in each of the water reservoirs, in a case of a volley discharge, i.e. the discharge with sharply rising intensity during short period of time, then continuing with constant intensity during some period of time $I(t) = I = const$ and then with sharply dropping intensity during some period of time T.

III. NUMERICAL EXPERIMENT RESULTS

Figures 2, 3, 4 show a temporal dynamics diagrams of the impurity concentration both during and after the discharge in the situation possible to neglect the water filtration in a soil under the next conditions $c_1(0) = 0, \; c_2(0) = 0, \; c_3(0) = 0$.

These diagrams testify that the mean impurities concentrations in each of the reservoirs after beginning of the discharge begin to rise and stabilize after achievement of defined values.

It is clear that the constant common concentration $c_\infty = I/s$ is established in each of the reservoirs in sufficiently long duration of the constant intensity discharge. However, in the short discharge duration, the concentrations dynamics in each of the reservoirs can significantly vary.

Lets' pay attention that the impurity concentration in the first reservoir after beginning of the discharge begins to rise more intensively in comparison with the second and third reservoirs. For example, the next three temporal periods were chosen: $4{,}65 \cdot 10^5$ s, $4 \cdot 10^5$ s and $1 \cdot 10^5$ s. For example, in the course of experiment in $T = 4{,}65 \cdot 10^5$ with the impurity concentration in the water reservoirs during the discharge in $c_1(0) = 0, \; c_2(0) = 0, \; c_3(0) = 0$ in the first, second and third reservoirs were respectively 99,991 kg/m^3, 99,653 kg/m^3, 99,413 kg/m^3.

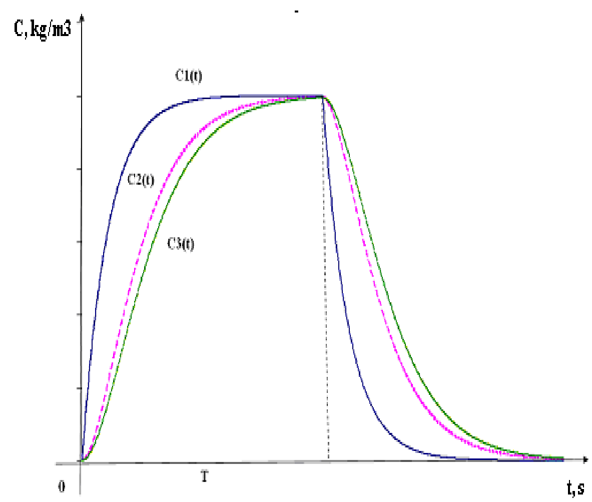

Fig.2 Diagrams of the impurity concentration temporal dynamics in 3 water reservoirs during and after the discharge in **T=4,65·10^5 s**

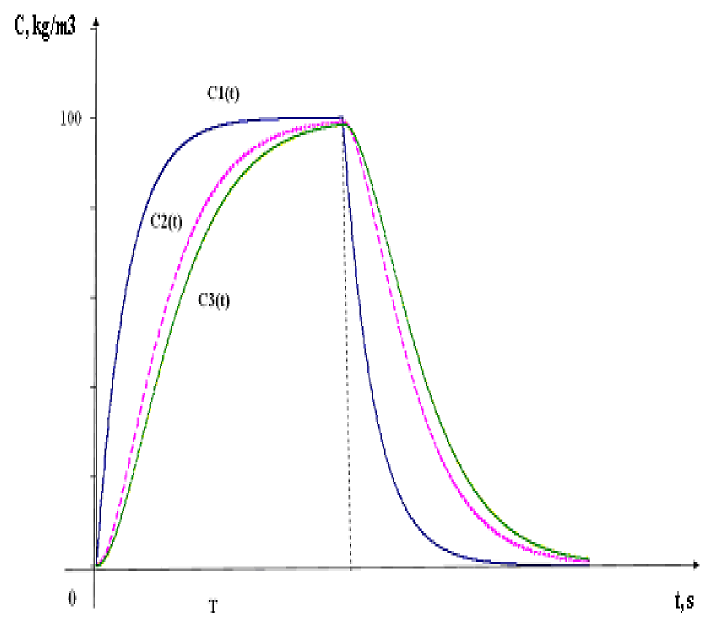

Fig.3 Diagrams of the impurity concentration temporal dynamics in 3 water reservoirs during and after the discharge in **T=4·10^5 s**

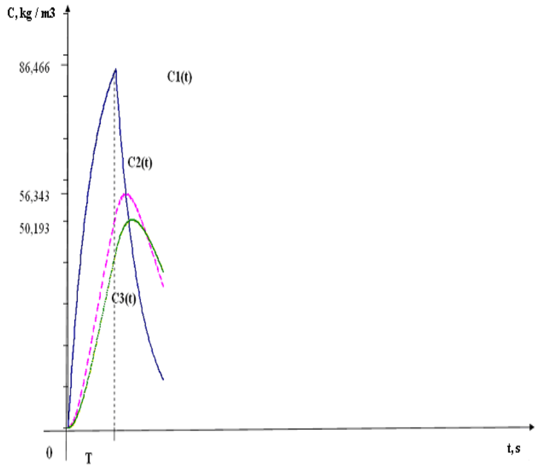

Fig.4 Diagrams of the impurity concentration temporal dynamics in 3 water reservoirs during and after the discharge in **T=1·10 ^{5} s**

A calculation of the impurity concentrations curves in each of the reservoirs (C_1, C_2, C_3) in a some specified set of filtration coefficients was also carried out. Particularly, below there is example for the next filtration coefficients: **1.** $\varphi_1 = 0{,}2$, $\varphi_2 = 0{,}6$, $\varphi_3 = 0{,}8$; **2.** $\varphi_1 = 1$, $\varphi_2 = 1$, $\varphi_3 = 1$; **3.** $\varphi_1 = 0{,}2$, $\varphi_2 = 0{,}2$, $\varphi_3 = 0{,}2$; **4.** $\varphi_1 = 0{,}8$, $\varphi_2 = 0{,}8$, $\varphi_3 = 0{,}8$; **5.** $\varphi_1 = 0{,}2$, $\varphi_2 = 0{,}8$, $\varphi_3 = 0{,}6$; **6.** $\varphi_1 = 0{,}8$, $\varphi_2 = 0{,}6$, $\varphi_3 = 0{,}2$.

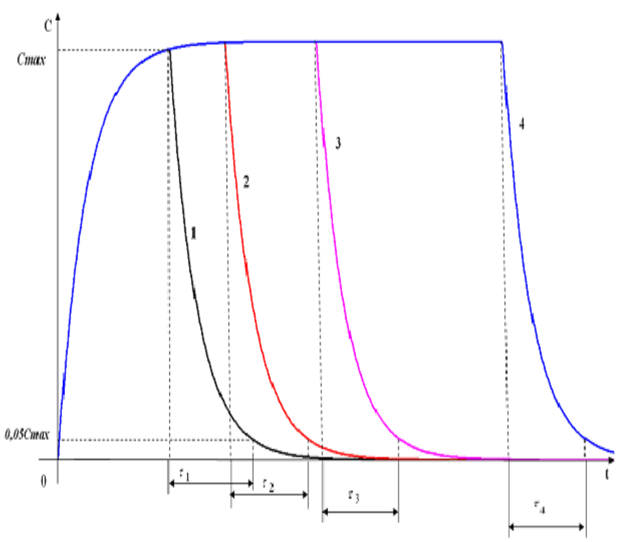

Fig.5 "$C - t$" curves of the impurity dynamics in the first reservoir in different discharge durations T_1, T_2, T_3, T_4 **(** $\varphi_1 = $ **0,2,** $\varphi_2 = $ **0,8,** $\varphi_3 = $ **0,6)**

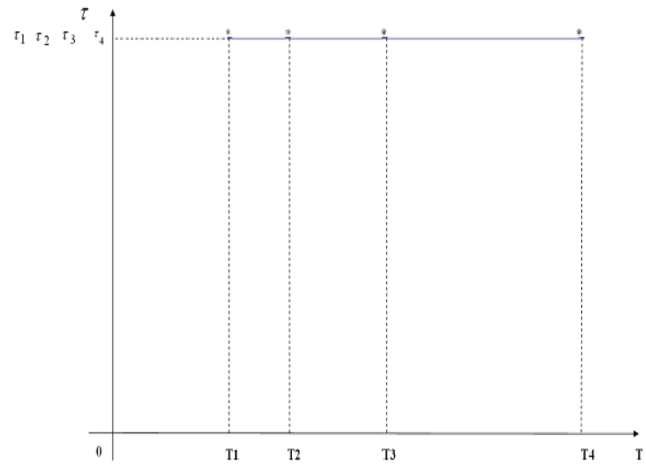

Fig.6 Diagram for dependence of relaxation time on the discharge duration in the first reservoir at $\varphi_1 = $ **0,2,** $\varphi_2 = $ **0,8,** $\varphi_3 = $ **0,6**

The discharge duration varied from 200000s to 800000s. Below, some results obtained in the course of a numerical experiment. Figures 5 and 6 show diagrams for dependence of concentration on time in the reservoir I at

$\varphi_1 = 0{,}2$, $\varphi_2 = 0{,}8$, $\varphi_3 = 0{,}6$ in different T_1, T_2, T_3, T_4.

Then, the relaxation periods τ , i.e. periods during which the concentration drops after the discharge completion from $C_{\max}$ to $0.05C_{\max}$, were determined at each discharge duration.

The numerical experiments showed that in different discharge durations the relaxation periods in the first reservoir are equal and consist approximately 150000 s in the given discharge amplitude.

The second reservoir was considered similarly with the same filtration coefficients and the same discharge duration values. Investigating the third reservoir in the similar way, we obtained another picture (Fig. 4).

It is seen that the relaxation period in the third reservoir at $\varphi_1 = $ **0,2,** $\varphi_2 = $ **0,8,** $\varphi_3 = $ **0,6** achieves the largest value at the discharge duration in 800000s. and consists 641000. The relaxation period here rises with increase in the discharge duration.

Analysis of these diagrams allows make the next conclusions:

1) the filtration does not influence on the discharge duration dynamics in the 1st reservoir;

2) the relaxation periods in the 1st and 2nd reservoirs are not depend on the discharge duration in any filtration sets;

3) the relaxation period in the 3rd reservoir depends on the filtration coefficients set and the discharge duration.

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IV. Conclusion

The calculations show that for the impurity concentration in each reservoir we obtain dependence of concentration on time with certain delay along the time axis. We also established that at the small discharge duration this delay in reservoirs, remote from the direct discharge place, can be accompanied by the impurity concentration temporal increase even after the discharge completion [6].

The developed model allows calculate the stated effects and, by the same token, correctly forecast the impurity concentration dynamics in different interrelated reservoirs of the system. Such approach allows to calculate the maximal values of concentrations, and to forecast also the time, during which, after the discharge, the impurity concentration in water reservoirs will exceed the maximum permissible concentration [7].

The further development of the model should be focused on analysis of the impurities concentration dynamics in the system of interconnected water reservoirs taking into account the impurity diffusion process in reservoirs and filtration in a soil, i.e. characteristic propagation periods of the impurity within the limits of each reservoir should be foreseen in the dynamic model.

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A Comparison Study of Fuzzy Control versus Fuzzy Cognitive Maps for Energy Efficiency of Buildings.

Vassiliki Mpelogianni, Peter P. Groumpos

Abstract—An intelligent software tool in order to achieve the energy efficiency of buildings is developed. The Building Energy Management System (BEMS) which is a system of outmost importance for the control of buildings is reviewed and briefly discussed. Two methods are being examined, that of fuzzy logic and that of the Fuzzy Cognitive Maps (FCMs). These methods are then being compared in order to choose the more suitable regarding the needs of the user and the purpose of the system. For this comparison a system regarding the heating system of a building is being simulated and controlled. Discussion of the results and future challenging research topics are provided.

Keywords—Building energy management system, energy efficiency, fuzzy cognitive maps, fuzzy logic

I. Introduction

THE energy consumed by buildings represents a large part of the world's total energy consumption with a total share of 40%. This is the reason that energy efficiency of buildings becomes an issue of outmost importance. Many scientists have turned their attention to the development of new methods of taking advantage of renewable energy sources, as well as control the existing technologies, to achieve the aforementioned goal. These efforts have led to the appearance of a new research field; that of the Intelligent Buildings (IBs). Many definitions have been given in order to describe what an IB really is, in our research the more suitable definition is the one given be the European Intelligent Building Group (EIGB) which states that "intelligent is a building which offers its users the most effective environment and on the same time uses and manages its resources in a manner that ensures the reduction of the cost due to the use of equipment and facilities" [1]. Various methods have been used to control the operation of a building our research we focus on the methods of Fuzzy Logic and Fuzzy Cognitive Maps (FCMs).

In this paper both Fuzzy Logic and FCMs are used to control the heating production system of a model building and then are compared to choose the one that better serves our purpose.

The structure of the paper is as follows:

In section two the control methods used in our research are being presented.

In section three we present the model that is going to be controlled.

In sections four and five the proposed control algorithms are being developed.

Finally in section six the two methods are being compared, conclusions are being summarized and future research topics are being proposed.

II. Control Methods

A. Fuzzy Logic

Fuzzy Logic is based on the classic Aristotelian Logic which states that a sentence can be true with a certain degree of truth and not just true or false. It extends our way of thinking and proposes that we should not perceive concepts as black or white" but rather as "shades of grey". This idea raised a revolution in the field of logic theory, as it surpassed the model that prevailed for 2500 years, i.e. the true of false model, and allowed us to describe one or more sets which do not have clearly defined boundaries. The concept of Fuzzy Logic was introduced for the first time by L.A Zadeh in the 1960 and it is extensively analyzed in his book "Fuzzy Sets" published in 1965. According to Zadeh a value can on the same time participate on more than one sets, at each one with a different membership degree [2].

Fuzzy models can use uncertain and vague information without requiring precise figures of the system parameters. What Fuzzy Logic essentially does is that through a set of simple verbal rules can model the knowledge and experience of an experienced user. Thus, forming a system based on knowledge, which leads to simpler models, more manageable

$$f = \frac{1}{1+e^{-\lambda x}}$$

and closer to human reason. This made possible to control systems even under operating conditions where conventional methods fail.

The point of departure in Fuzzy Logic is the concept of a fuzzy set. Fuzzy is a set that allows its values to have different membership degrees in the interval [0,1] [3].

For every fuzzy set a membership function can be defined. The membership function (MF) indicates the degree to which the set x belongs to the set A.

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$$\mu_A(x): X \rightarrow [0,1] \quad (1)$$

There are various types of membership functions; triangular, generalized bell, Gaussian, sigmoid e.t.c.

The fuzzy sets as they were described above constitute the inputs and outputs of the system. After defining the I/O of the system in order to extract the value of each output we need a set of rules which will combine the various inputs [4].

The fuzzy rules have the following form:

If x is A ***then*** y is B.

Where “if x is A” is the premise part

And “then y is B” is the consequent part.

The product of Fuzzy Logic when used to control a system is a fuzzy controller, which consists of five parts [5].

- The **knowledge base** where all the rules for the control of the system are saved.
- The **fuzzy sets** used for the representation of the input and output variables with linguistic values.
- The **fuzzifier** which turns all the crisp values of the input to fuzzy sets.
- The **inference engine** which processes the outputs of the fuzzifier and with the use of the knowledge base extracts the fuzzy inference sets.
- The **defuzzifier** which translates the results, from fuzzy to crisp values, so that the control action can be implemented.

The flow chart of a fuzzy controller is shown in Figure 1.

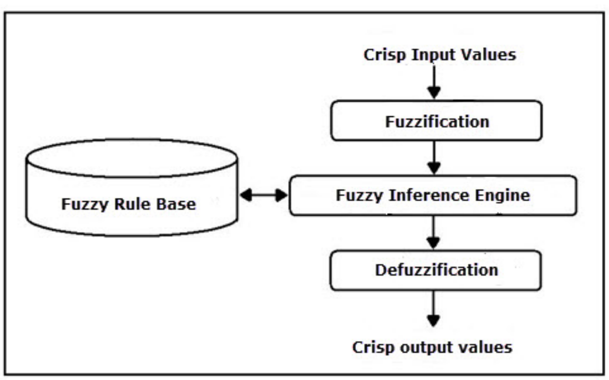

Fig. 1: Flow Chart of Fuzzy Controller

B. Fuzzy Cognitive Maps

Fuzzy Cognitive Maps came as a combination of the methods of fuzzy logic and neural networks. They constitute a computational method that is able to examine situations during which the human thinking process involves fuzzy or uncertain descriptions. An FCM presents a graphical representation used to describe the cause and effect relations between nodes, thus giving us the opportunity to describe the behavior of a system in a simple and symbolic way. In order to ensure the operation of the system, FCMs embody the accumulated knowledge and experience from experts who know how the system behaves in different circumstances. In other words they recommend a modeling process consisting of an array of interconnected and interdependent nodes Ci (variables), as well as the relationships between them W (weights) [6].

Concepts take values in the interval [0, 1] and weights belong in the interval [-1, 1]. Fig.2 shows a representative diagram of a FCM [7].

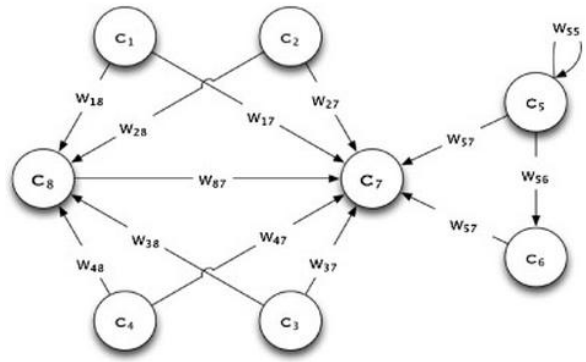

Fig. 2: Fuzzy Cognitive Map

The sign of each weight represents the type of influence between concepts. There are three types of interconnections between two concepts Ci and Cj:

- **wij>0**, an increase or decrease in Ci causes the same result in concept Cj.
- **wij<0**, an increase or decrease in Ci causes the opposite result in Cj.
- **wij=0**, there is no interaction between concepts Ci and Cj.

The degree of influence between the two concepts is indicated by the absolute value of wij.

During the simulation the value of each concept is calculated using the following rule:

$$A_i(t) = f\left(A_i(t-1) + \sum_{\substack{j=1 \\ j \neq 1}}^{n} A_j(t-1) w_{ji} \right) \quad (2)$$

Where t represents time, n is the number of concepts and f is the sigmoid function given by the following equation:

$$f = \frac{1}{1+e^{-\lambda x}} \quad (3)$$

Where $\lambda>0$ determines the steepness of function f.

The FCM’s concepts are given some initial values which are then changed depending on the weights; the way the concepts affect each other. The calculations stop when a steady state is achieved; the concepts’ values become stable [7]-[11].

As causal patterns change and experts update the causal relationships between concepts, the use of Non Hebbian Learning (NHL) procedure helps the FCM to modify its fuzzy causal web [12].

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Due to the non-linear structure of the FCM the NHL can contribute to its training and consequently to the prediction and control of the BEMS function.
In this algorithm the learning rule for FCMs integrates a learning rate parameter ηk, weight decay parameter γ, and the input/output concepts. The value of each concept changes through Eq. (2) whereas weight value is calculated using Eq. (4) i.e. the centroid deffuzification method.

$$u' = \frac{\int_u u \mu_{B'}(u) d(u)}{\int_u \mu_{B'}(u) d(u)} \quad (4)$$

Through the NHL algorithm, the only weights that change are the non-zero ones, all the other weights of the weight matrix Wji keep their initial zero value. [13]

III. Building Energy Management System

The Building Management System (BEMS) is a system of outmost importance for the control of the building. As heating, cooling and domestic hot water production are three operations that consume great amounts of energy we designed a system in order to reduce it. The system is shown in Figure 3,

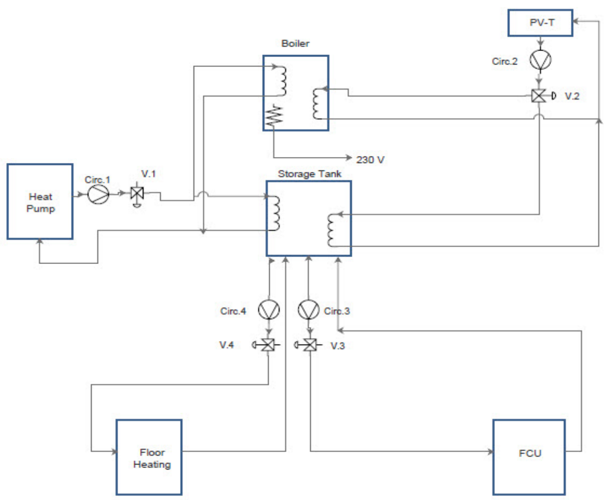

Fig. 3: Building Energy Management System

and consists of :

- A boiler for the domestic hot water storage.
- A storage tank for the storage of water for the heating and cooling of the building.
- A Photovoltaic Thermal Unit for the production of electricity and hot water.
- A Heat Pump (air to water) for heating and air conditioning needs of the building.
- A Floor Heating unit which can reduce the fuel needed by 30%.
- A Fan Coil Unit (FCU) to cover the rest of the cooling and heating needs.

Four circulators and triode valves are used to distribute the water to the various parts of the automation.
The control algorithm will focus on these valves and circulators in order to achieve the maximum energy savings.

IV. Fuzzy Inference Tool

In this section of the paper we are going to present the fuzzy logic controller created to manage the BEMS. Once integrated into the building it is going to lead to substantial energy savings [14].

The aim of the algorithm presented in this section of the paper is to combine the various parts of the building heating system to ensure the most economical and efficient heating and cooling. As mentioned in section 3 the heating/ cooling system comprises of a heat pump , a boiler, a water storage tank , the PV-T modules, the floor heating and a fan coil unit [15]-[16].

In order to efficiently control our system we have to know the temperature of its various parts and whether we want to operate on a cooling or heating mode. Finally because of the danger of certain bacteria growing into the water, to avoid a possible contamination of the water the temperature of the boiler should be raised once a week above 90 degrees C [17].

These parameters are going to constitute the inputs of our system. So the FLC inputs are will be the Boiler Temperature (boilerT), the storage tank temperature (STANKT), the water temperature of the PV-Ts (PVWT), temperature of the floor heating (FLOORT), the temperature of the Fan Coil Unit (FCU) and finally the contamination flag (CFLAG) and the mode of the system (MODE). Each one of the first five inputs is described by triangular membership functions which corresponds to 4 linguistic variables. The other two inputs consist of two states.

The outputs of the FLC will be the function of the heat pump (HeatPump) and the resistance which will raise the water temperature and decontaminate the water (resistance) and the function of each one of the of the four valves and circulators used to control the flow of the water to the various parts of the system (VALVE, CIRC).

The results of this algorithm are presented in Figure 4. This algorithm plays the most important role in the buildings energy management as it controls the way the heating, cooling and production of DHW is done. It is designed so that most of the energy needs are covered from the PV-T. This algorithm acts in cooperation with those that control the HVAC system and DHW production and contributes greatly to the purpose of our study.

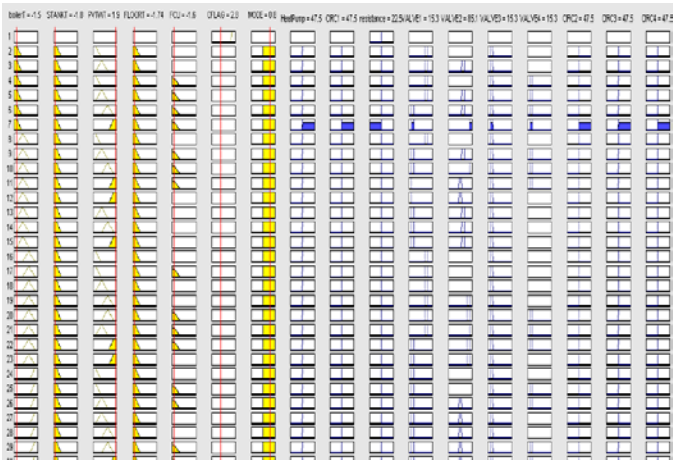

Fig. 4: Results of FLC for BEMS Control.

V. Fuzzy Cognitive Map Development

In this part of the paper we are going to develop the Fuzzy Cognitive Map which can also be used to control the BEMS as it was described in section 3 of the paper.

A. *Concept definition*

In order to have an accurate comparison we used as concepts the inputs and outputs of the previous algorithm, properly adjusted to meet the requirements of this control method.

The concepts were divided into three categories; the input concepts, the medium output concepts and the final output concepts of the FCM.

The concepts as well as the category they belong to, are listed below.

Inputs:

- C1: PV-T Temperature
- C2: FCU Temperature
- C3:Floor Heating Temperature
- C4:DHW Demand
- C5:Contamination Flag

Medium Outputs:

- C6:Storage Tank Temperature
- C7:Boiler Temperature
- C8:Valve 1a
- C9:Valve 1b
- C10:Valve 2a
- C11:Valve 2b
- C12:Valve 3
- C13:Valve 4
- C14:Circulator 1
- C15:Circulator 2
- C16:Circulator 3
- C17:Circulator 4

Final Outputs:

- C18:Resistance Operation
- C19:Heat Pump Operation

Concepts 1-4 and 6-7 take values from 1to 4 (low, medium low, medium high and high). Concepts 5, 14-19 take OFF-ON values. Concepts 12-13 take the value AC which is the position of the value. Finally due to the fact that the valve position is a discrete value, valves 1 and 2 were divided to two separate concepts; the first having the one way positions and the second having the two way position.

B. *Interconnections' Specification*

Continuing the interconnection weights between nodes will be defined. This process will be undertaken by experts who in cooperation with each other will decide the interconnection weights. As part of this work the interconnections between the nodes emerged from an extensive study of the building's simulation based on real weather data. The values positive or negative will vary between the following ones:

W (weak): Very weak interconnection between the nodes C_i, $C_{j.}$

M (medium): Medium interconnection between the nodes C_i, C_j

S (strong): Strong interconnection between the nodes C_i, C_j

VS (very strong): Very strong interconnection between the nodes C_i, $C_{j.}$

These values will then be defuzzified [18]-[19] and a corresponding numerical value will be assigned to each one of them.

The Fuzzy Cognitive Map is presented in Figure 5.

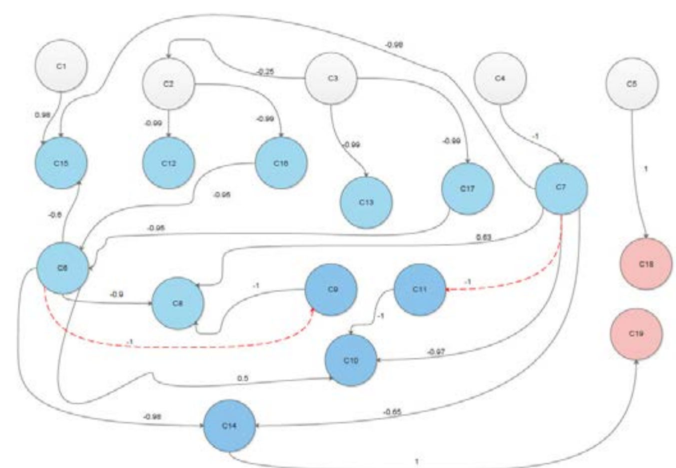

Fig. 5: Fuzzy Cognitive Map

The red dashed lines represent the relationship between the boiler and storage tank temperature with the concepts regarding the common position of the valves and acts only when it is necessary to send water to both directions.

C. *Results of the algorithm*

To understand this process we will give the following example, which is the same example we gave with the previous fuzzy logic controller.

C1=4
C2=1
C3=1
C4=1
C5=0
then after only six iterations the system reaches equilibrium. So the final vector A will occur after the repetitions and it will be:
Afinal
[Columns 1 through 7
0.6591 0.6128 0.6590 0.6590 0.6590 0.3856 0.4571
Columns 8 through 14
0.4419 0.6590 0.3795 0.6590 0.4745 0.4602 0.4526

Columns 15 through 19
0.6501 0.4745 0.4602 0.8074 0.7495]
ie the outputs will be C18=0.8047, C19 = 0.7495 and the way they reaches the equilibrium point is shown in the Figure 6 with the bold green and black lines, respectively.

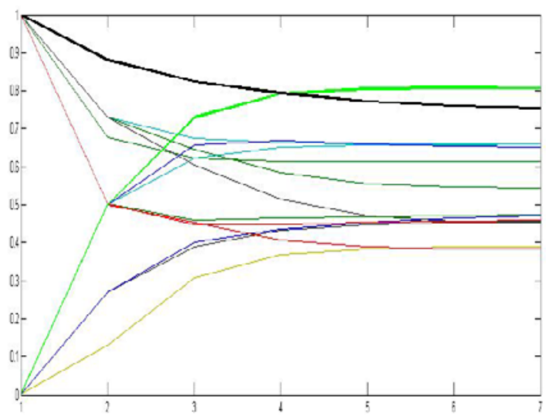

Fig. 6: System Output

VI. Conclusion and Future research

A. Discussion

Summarizing this paper it becomes obvious how the application of Information Technology can help control a building automation and increase its energy efficiency. It became clear how the use of both Fuzzy Logic and Fuzzy Cognitive Maps can contribute to this end. The Fuzzy Logic and Fuzzy Cognitive Maps are two different but very interesting methods, each one has its positives and negatives. This paper was a demonstration on how to use these two methods to achieve the objectives outlined above. In particular by means of Fuzzy Logic we were able to create a control algorithm that can easily handle discrete values such us the position of the valves but requires a lot of rules and as the inputs increase so do the rules needed to correlate the inputs. With the use of FCMs we do not need the rules; except for those required for the definition of the initial values, so the algorithm can more easily implemented into the system but other difficulties emerge. First of all we cannot describe discrete values with one concept. Secondly FCMs lay a lot to the experts solution, which even though helps us describe the system and include situation which otherwise would be left out, creates a lot of problems especially regarding the interpretation of the results.

B. Future Research

In the near future the fuzzy logic algorithm is going to be integrated in the buildings used in our simulation thus giving us real data about the energy savings effort using fuzzy algorithms. Data that can and will be used in future research of moving from high energy consumption to Net-Zero Energy Buildings (NZEB).

Also we will focus our efforts on new learning techniques for the FCMs to be able to take advantage of all of their abilities and advantages regarding the control of complex, non-linear systems.

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V. Mpelogianni is with the Laboratory of Automation and Robotics, Electrical and Computer Engineering Departement , University of Patras, Greece (e-mail: v.mpelogianni@ ece.upatras.gr).

P. P. Groumpos, is with the Laboratory of Automation and Robotics, Electrical and Computer Engineering Departement , University of Patras, Greece (e-mail: groumpos@ ece.upatras.gr).

Design Aspects of Autonomous Advanced Metering Infrastructure

Ivaylo I. Atanasov

***Abstract*—**Self-healing and self-optimization features become a key factor for effective and efficient management of Advanced Metering Infrastructures (AMIs). AMIs exploit the benefits of machine type communications and allow collection and distribution of information to customers, energy suppliers and distributors. The paper presents design aspects of autonomous AMI in the context of fault and performance management. Semantic information is abstracted and structured as domain-specific resources.

Keywords— Machine type communications, Smart metering, Performance management, Fault management Machine type communications.

I. Introduction

SMART metering is aimed at improving energy efficiency and thus contributing to reduction of energy consumption. Advanced Metering Infrastructure (AMI) is defined as integrated system that encompasses smart meters, communication networks, and utility data management systems. It allows collection and distribution of information to customers and other parties such as energy supplier and energy distributor, in addition to providing it to the utility (service provider) itself [1]. AMI gives the customer control on their energy bills providing information they require. AMI is helpful in monitoring the power supply system, providing real time data useful for electric loads, and reducing power outages, enabling dynamic pricing, and optimizing income with existing resources. Effective and efficient AMI management becomes a key survival factor for utility companies as it can reduce operation costs. The increased amount of equipments calls for incorporating of autonomic features in order to maintain operational costs under control. This needs features like self-optimization and self-healing. Currently, there is a lot of research work been carried out on autonomics that proposes different autonomic framework architectures or specific solutions [2], [3], [4], [5], [6].

A generic, conceptual architectural reference model intended to serve as guideline for the design of networks exhibiting autonomic characteristics or capabilities is defined in [7]. Autonomic behaviour is characterized by self-management capabilities such as self-configuration, self-healing, self-optimization, self-organization and self-protecting. It consists of a set of actions triggered by a Decision making Element (DE) on a Managed Entity (ME) and follows policies to achieve a goal. The DE drives a control loop to regulate the behaviour of the ME exposing features like learning, reasoning, planning and cognition.

This paper focuses on AMI self-healing and self-optimization functionality at function and node levels of the GANA reference model. It studies the semantic information structure required to support AMI autonomic features. Next sections provide mapping of the Generic Autonomic Network Architecture (GANA) reference model defined in [7] onto AMI autonomic behaviour at function and node levels, and present the abstracted smart meter information related to self performance and self healing in a structured manner.

I. I. Atanasov is with the Faculty of Telecommunications, Technical University of Sofia, Bulgaria (phone: +359 2 965 2050; e-mail: iia@tu-sofia.bg).

II. Autonomic AMI Functionality

Fig.1 shows the control loop specific to the smart meter performance management (PM) functions.

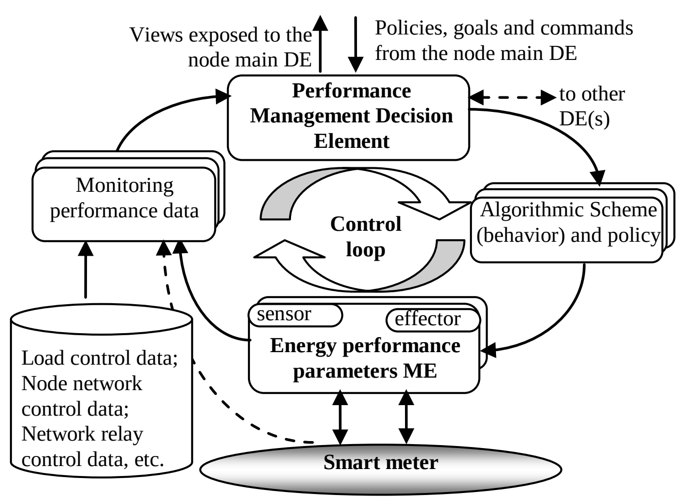

Fig.1. A control loop specific to smart meter performance management function

Residential single phase, self-contained smart meters can measure both revenue billing data and operational data. The minimum revenue billing data include the apparent power, reactive power, power factor and load profile. The operational data include information about outages/restorations, min/max voltage during reporting period, average voltage for period, instantaneous voltage, network interface monitoring data,

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voltage and current phase angle measurements. All these measurements represent monitoring information and specific type of knowledge that is supplied to the Performance Management (PM) DE. The PM DE is responsible for managing, analyzing, controlling and reporting on the energy performance. If the analysis identifies an energy performance violation or potential performance violation, a report is passed to the Fault Management (FM) DE. The latter is responsible for deciding on and caring out the appropriate action/response. This may include requests to the PM DE to install control to optimize the energy performance. The PM DE continues tracking the energy performance problem, ensuring that energy performance is restored to a level required to support services. PM DE is able to activate/deactivate and reschedule the load control, perform direct load control, activate/ deactivate quality of service monitors, perform network interface control, validate the internal clock with an external time source, automatically synchronize it, etc. Smart meters are able to limit service to customers upon a remote utility request, cancel or update scheduled service limiting events prior to their completion.

The horizontal interaction between the PM DE and the FM DE facilitates the distributed decision making. For example, when the PM DE identifies energy performance problem, it may notify the FM DE about performance problem and request discovering the cause of the alert and possible impact on the service performance. In addition, smart meters are responsible for tamper detection and management.

The FM DE is responsible for tracking and monitoring of smart meter fault management, extracting and analyzing of fault reports, performing fault localization analysis, correcting and resolving faults, assigning and tracking fault testing and repair activities. Smart meters perform at least daily self tests having predefined fatal and non-fatal errors that can be detected. They diagnose a variety of self-test results and determine if failures are critical or non-critical to determine what kind of notification should be provided. Typical problems include inconsistency of recording data, program or memory failure, communication link failure etc. Smart meters can be remotely disconnected/ reconnected on demand, detect duplicate service switch disconnect/reconnect, and execute service switch connect/ disconnect commands.

At GANA node level, the autonomous behavior of smart meter management DE is responsible for performing pro-active maintenance and repair activities, analyzing availability and performance over time, including trend analysis and fore casting. The trend analysis and forecasting may be based on predictive data mining, which includes three steps: initial exploration, model building and validation and deployment.

III. Smart Meter Resource Structure

To enable AMI autonomous management, it is important to abstract and structure the meaningful information in the context of energy performance management and smart meter fault management. REST (Representational State Transfer) architectural style is adopted for Machine type communication. In REST, the information is structured as resources which can be uniquely identified. Each resource has a state. The resource state may be manipulated using the following primitives: create, retrieve, update and delete. The proposed information model used for autonomous AMI is based on ETSI resource structure defined in [8].

Fig.2 shows the smart meter resource structure oriented to energy performance management and smart meter fault management. Common attributes defined in [8] are represented by “attribute”.

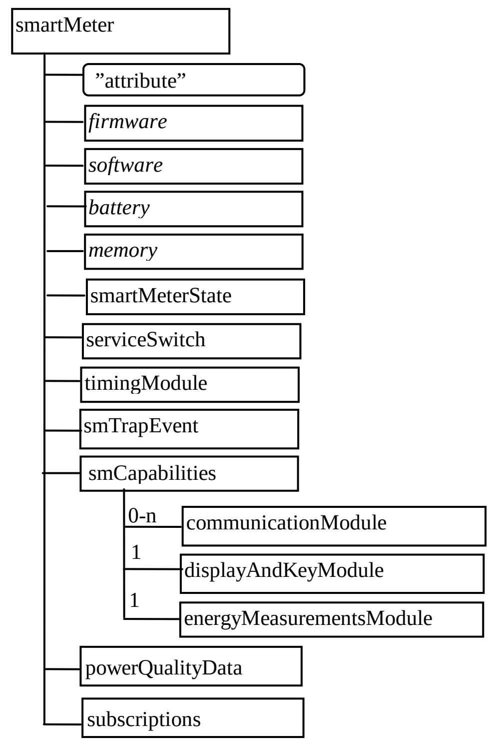

Fig.2. Smart meter resource structure (resources defined in [8] are depicted in Italic)

The smart meter’s heart consists of low power microcontroller coupled with an analog front end, that senses the current and voltage, converts the sensed values into digital form, and sends the digital values to the microcontroller. The microcontroller is data processing and storing unit. The description of the smart meter resources like *firmware*, *software*, *battery* and *memory* may be found in [8]. The structure of the *smartMeterState* resource is shown in Fig.3 (not all of the attributes and resources are presented).

The *smartMeterStatus* attribute indicates the operational state of the smart meter. The smart meter is able to continuously perform self test and has predefined fatal and non fatal errors that can be generated.

Fatal errors indicate that a critical meter error is detected. The fatal error types varies with vendor, and the typical fatal errors can be caused by MCU flash error, RAM error, data flash, metrology, communications error, file system error, OS error etc. [9], [10]. Fatal error recovery functionality creates a process for the smart meter to try to recover after a fatal error condition has occurred, while still maintaining as much data as possible.

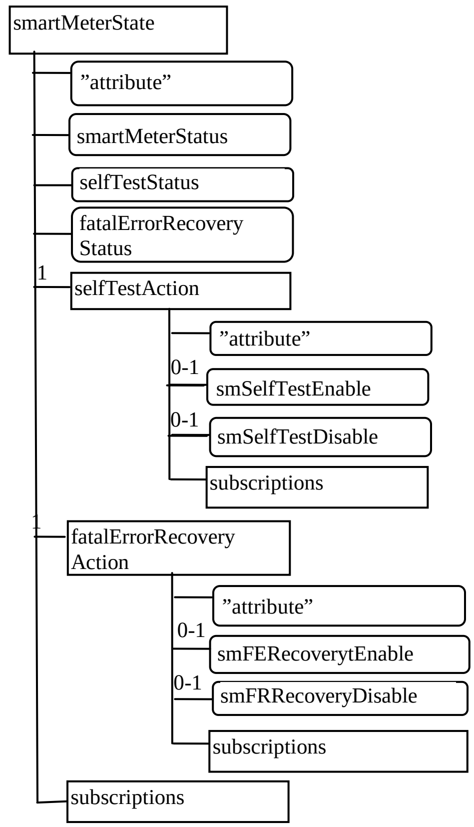

Fig.3. Stricture of *smartmeterStater* resource

The *selfTestStatus* attribute indicates the status of the self test, and the *fatalErrorRecoveryStatus* attribute indicates the status of the fatal error recovery. The *selfTestAction* resource and *fatalErrorRecoveryAction* resource contain the actions to be executed and have attributes that enable and disable the self test and fatal error recovery.

The specific characteristics of the *serviceSwitch* resource, defined as a sub-resource of the *smartMeter* resource, are the *serviceSwitchState* attribute with values connected or disconnected, the *serviceSwitchAction* resource and *switchStatusTrapEvent* resources. The smart meter can remotely be disconnected/reconnected on demand from the service switch, and the *serviceSwitchAction* resource has attributes that allow service switch connecting and disconnecting. The smart meter is able to detect and log different service switch related events such as attempts to operate the service disconnect/reconnect switch remotely or on-site at customer premise. For this purpose the *switchStatusTrapEvent* resource is defined which follows the definition of *etsiTrapEvent* resource [8]. The *timingModule* resource defined as a sub-resource of the *smartMeter* resource represents the smart meter internal clock/time keeper. It has attributes that indicate the time and date, and a *synchronizationAction* sub-resource that contains the action to be executed. The smart meter's clock has to be validated with an external time source at least once per day and automatically synchronized. The *smTrapEvent* resource is used to set trap events for fatal error that can occur. When the meter enters fatal error recovery mode, it stores core dump and sends an exception notification, an error recovery job is performed (e.g. three times), which may clear the meter from the fatal error recovery [10]. Fig.4 shows the simplified process of smart meter self testing and fatal error recovering.

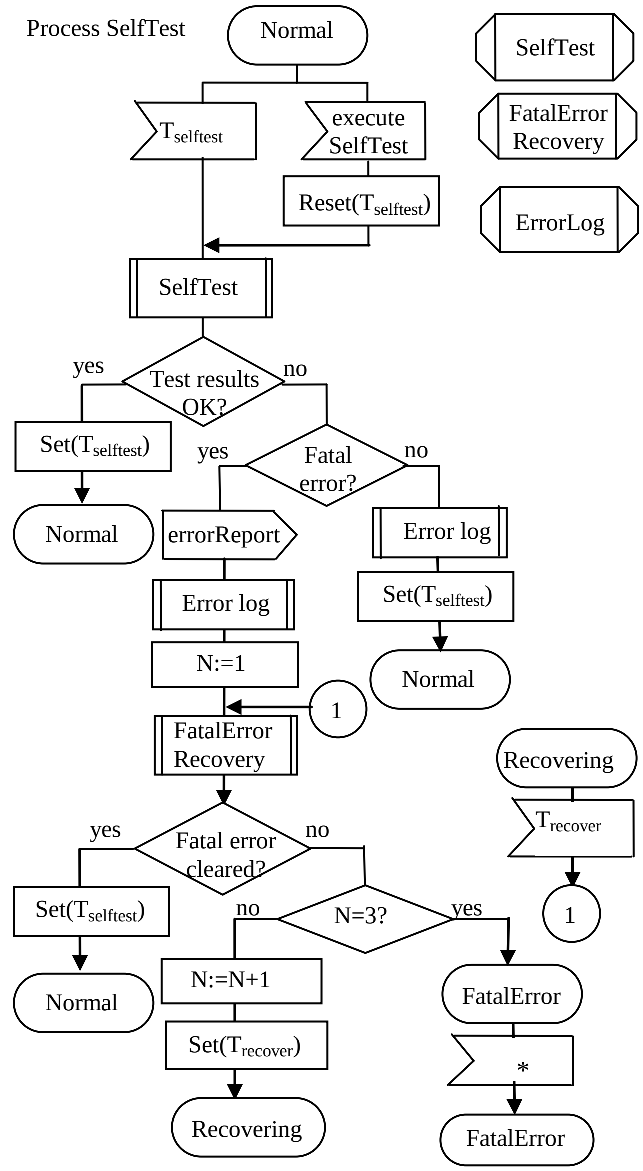

Fig.4. Simplified process of smart meter self testing and recovery

The *smCapabilities* resource represents the smart meter capabilities such as the communication module, display and key module, and energy measurements module.

The *communicationModule* is a collection resource representing the smart meter's communication functionality. The smart meter has communication interfaces to the utility and to the home area network.

The smart meter design supports different types of communication functionalities based on the following methods: UART, RS485, Z-Wave, wM-bus, Zigbee, Bluetooth, 2G/3G/4G cellular, WiFi, Ethernet and PLC. The smart meter checks the communication connection status

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during the self testing and it is able to “ping” and obtain network interface and link information, network association status, signal level status. Both *utilityNetworkInterface* resource and *hanNetworkInterface* resource are structured as to ETSI <capabilityInstance> resource.

As to ANSI C12.19-2008, smart meters include sensors for power quality monitoring, phasor measurements and can record disturbances [12]. Typical disturbances causing power quality degradation may include interruption, under voltage/ over voltage, voltage/current unbalance, voltage sag and swell, outages etc. The *powerQualityData* resource is a container resource that represents the measurement functionality related to the power quality. Fig.5 shows the concise *minVoltage* resource structure as a part of monitored power quality data.

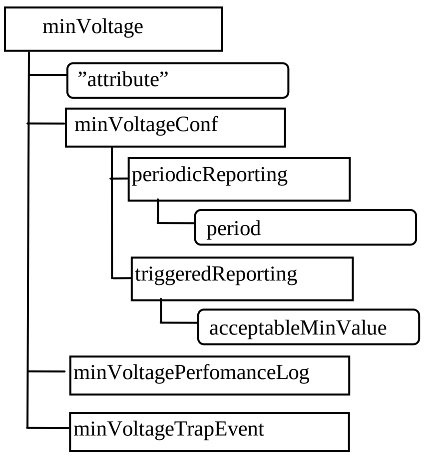

Fig.5. Stricture of *minVoltage* resource

The *minVoltageConf* resource has attributes *periodicReporting* and *triggeredReporting*. The *periodicReporting* attribute is used to configure remotely the smart meter to report the min voltage value within a specified period defined with the *period* attribute. The *triggeredReporting* attribute is used to configure remotely the smart meter to report when the min voltage magnitude is below the acceptable value defined with the *acceptableMinValue* attribute (e.g. below -5% to -15% of 220V). The *minVoltagePerformanceLog* and *minVoltageTrapEvent* resources are used to collect the statistical performance data and to set diagnostic trap event notification about measured minimum voltage values.

IV. Implementation Issues

Resources can be addressed using HTTP URI. The HTTP method determines the action to take and the host, port, and path part of the URI are used to locate the resource. The HTTP POST method is used to create resources, the HTTP GET method is used to retrieve the resource attributes, while the HTTP PUT method is used to update the resource attributes or to notify the subscriber about occurrence of events.

Fig.6 shows examples of HTTP requests that manipulate the resources.

The first request is used to set the period for measuring minimum voltage, the second one is used to retrieve the outage data log file and the third one notifies about a drop in minimum voltage magnitude under acceptable tolerance value.

```
POST
http://SmartMeteringREM.utilityY.com/slcs/meterXXXX/powerQualityDa
ta/minVoltage/minVoltageConf/periodicReporting/period HTTP1.1
duration=30 sec

GET
http://SmartMeteringREM.utilityY.com/slcs/meterXXXX/powerQualityDa
ta/outagePerfLog HTTP1.1

PUT
http://SmartMeteringREM.utilityY.com/slcs/meterXXXX/powerQualityDa
ta/minVoltageTrapEvent/trapInstance HTTP1.1
```

Fig.6. Simple requests for resource manipulation

V. Directions for Future Work

Detection of unusual or undesirable behaviors in order to address issues like fault diagnosis and problem resolution is extremely difficult in wireless environment. It is based on the idea that problems like anomaly detection, fault prediction or intrusion detection follow patterns, which upon recognition, can be used to predict the fault's occurrence. Autonomic behavior includes actions that can be taken beforehand in order to achieve smooth system operation. The future work will be partly dedicated to short term prediction of key performance indicators regarding AMI operational metrics.

The operational metrics evaluate the systems and processes deployed to support AMI and dynamic pricing, and how these support business needs. They also track whether the systems and processes are being used as intended [13]. Fig.7 illustrates the approach to the modular internal structure of the Fault and Performance Decision Element.

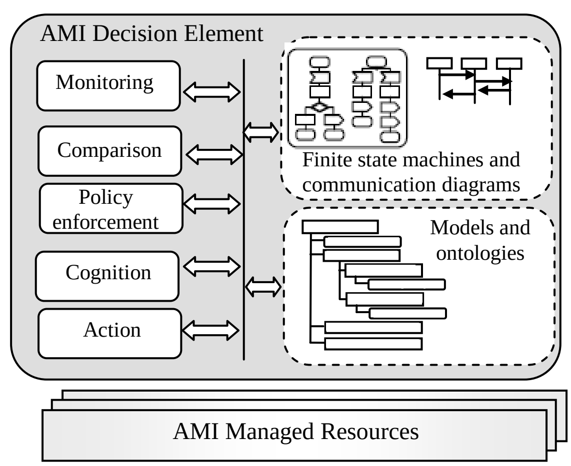

Fig.7. Modular structure of an AMI DE

The proposed data models will be used for continuous monitoring of selected features in the prediction model in order to provide a view of AMI internal functions as well as its environment. Appropriate mechanisms like those illustrated in Fig.4 take part to associate the current situation with the

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patterns recognized and depicted in the prediction model. Unsupervised artificial intelligence methods contribute to the training process by identifying unknown alarms or attacks. This would enable the cognitive capability of detecting previously "unseen" attacks or faults.

The AMI self-awareness autonomic functionality which facilitates self-protection and self-healing will be based on policy management. The actions taken by the DE in some cases can be enforced by a policy on the managed resources. Policy areas include open operation of AMI systems, communication and interface protocols, metrology and meter reading, management of load control, data security, access, storage and transportation, provision of customer displays and home area interface, premises disconnection/reconnection and prepayment etc. [14]. For example, a policy related to pricing of services allows AMI owners to charge a different price to users of their system that are using the same functionality, and a meter reading policy states that AMI systems should provide a minimum of six general accumulating registers to allow the service user to accumulate energy usage data during previously defined time periods.

The cognition module retrieves relevant knowledge from data and allows the cross-control loop interactions accordingly. Cognitive mechanisms allow the system to self-describe, increase the system self-awareness and improve the decision-making process. There is a wide spectrum of approaches to represent knowledge in the intelligent systems with an associated range of reasoning mechanisms over these knowledge forms. There are also different approaches to machine learning that are applicable to the process. The trend analysis and forecasting may be based on predictive data mining in its three steps: initial exploration, model building and validation, and deployment. There exist different predictive data mining techniques [15]. Artificial neural networks consist of information processing units (neurons) connected systematically and structured in multiple layers, and use effective learning algorithms. Support vector machines use supervised learning methods to classify data with different class labels by determining a set of support vectors. Classification and regression tree is a method used for classification and prediction that constructs a classification or regression tree according to its variable type. The multiple linear regression model is an extension of simple regression model built from two or more predictor variables. Another data mining method used for classification is Chi-squared automatic interaction detector which can handle both qualitative and quantitative dependent variables.

VI. Conclusion

The paper presents design aspects of autonomous AMI that features self-performance and partial self-healing functionality. The main contribution is the M2M data model of AMI fault and performance management which applies to detecting faults pertaining to smart meter components (be software or hardware), as well as monitoring of power quality performance indicators. Aiming to support the application interworking, the proposed data model defines the structure of data exchange between M2M applications.

Abstract models at function level and node level are presented. Smart meter semantic information is abstracted and structured as resources which can be addressed uniquely. The resources can be used for collecting statistical performance/ fault data as well as for setting diagnostic trap events. Following the REST architectural style, resource state can be manipulated by the use of standard primitives like create, retrieve, update and delete.

The proposed data model facilitates the deployment of a standardized management interface and it is a step toward autonomous AMI system that features self awareness in knowledge building process of assessment operational statistics and finding of patterns, proactively overcoming of foreseen events, and reactively responding to failures and providing corrective actions.

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Stochastic Optimization and Numerical Simulation for Pumping Management of the Hersonissos Freshwater Coastal Aquifer in Crete

P. N. Stratis[‡], Z. A. Dokou[†], G. P. Karatzas[†], E. P. Papadopoulou[*] and Y.G. Saridakis[‡]

Abstract—In the present study, the well known Princeton Transport Code (PTC), a groundwater flow and contaminant transport simulator, is being used to simulate the dynamics of the freshwater coastal aquifer located in Hersonissos area of the Greek island of Crete, and guided by the Algorithm of Pattern Extraction (ALOPEX), a real time stochastic optimization method, to optimally manage area's main pumping activities and prevent saltwater contamination. Main objective of this hybrid coupling of the PTC's finite-element (FE)/finite-difference (FD) routines to the ALOPEX stochastic optimization technique, is to create an optimal pumping management plan, for the Hersonissos aquifer, that maximizes the total extracted freshwater volume from the aquifer and, at the same time, keeps all pumping locations safe from saltwater intrusion. For this, we utilize the recently adopted version of the ALOPEX unconstrained optimization algorithm accompanied by an efficient penalty system designed for the aquifer pumping management problem. The numerical simulations conducted led to summer and winter pumping plans that considerably improve the total extracted freshwater volume from the aquifer while the active pumping locations remain safe from seawater even if a 2% increase of the proposed pumping plan is applied.

Keywords—ALOPEX stochastic optimization, penalty system, PTC code, finite elements, coastal aquifers, saltwater intrusion, pumping management.

I. Introduction

Saltwater intrusion is a phenomenon that poses a significant threat to the quality of groundwater reserves in coastal aquifers. This phenomenon is mainly affected by unrestrained groundwater withdrawals that disturb the natural balance of freshwater - saltwater in groundwater systems. To protect groundwater reserves and design a sustainable water management strategy in coastal aquifers, researchers have been focused on the combined use of mathematical models, numerical simulations and optimization algorithms.

The objective of this work is to assess the saltwater intrusion and then extend and provide sustainable management alternatives for the Hersonissos aquifer, located in Crete, Greece. The saltwater intrusion phenomenon at this aquifer has been studied previously by a number of researchers. In [15] (see also [16]), the finite difference MODFLOW and the finite element PTC models are employed to simulate saltwater intrusion and compare the numerical results to the ones obtained by geostatistical techniques (Kriging). In [10] the PTC simulator is coupled by a differential evolution (DE) algorithm to maximize the total extracted freshwater volume from five preselected pumping locations (production wells) while satisfying minimum hydraulic head constraints at specified locations, ensuring no further intrusion of seawater. The same approach was followed in [4] using sequential linearization in order to reduce the computational cost. The Hersonissos aquifer has been also studied in [20] by making use of geostatistical techniques (Kriging and Ordinary Kriging).

ALOPEX stochastic unconstrained optimization originates at the area of neurophysiology (cf. [8]) and, since then, has been applied with success in many real time applications (see for example [21] and the references therein). Recently, in [18], the dynamics of the algorithm were studied in depth for the problem of saltwater intrusion of coastal aquifers. The determination of the algorithm's feedback and noise amplitudes and the introduction of an effective penalty system, to enforce problem's constraints, revealed its potential to successfully treat the problem of pumping management in coastal aquifers.

The approach employed, thus, here is to combine the groundwater simulation model PTC with the newly introduced constrained version of the ALOPEX stochastic optimization technique. The objective is to maximize groundwater withdrawal in the existing pumping well network while precluding saltwater to enter a safe zone around the active wells in the region.

II. Methodology

A. Groundwater simulation model - PTC

PTC (Princeton Transport Code [3]) is a well known three-dimensional groundwater flow and contaminant transport simulator that uses a combination of finite element and finite difference methods to solve the groundwater flow Boussinesq equation which, for the heterogeneous isotropic unconfined case, takes the form (cf. [7])

$$\nabla \cdot (Kh\nabla h) + W = S_y \frac{\partial h}{\partial t} \tag{1}$$

where h denotes the hydraulic head, K is the hydraulic conductivity (considered to be heterogeneous and isotropic), W is the volumetric flux per unit volume representing sources and/or sinks of water, S_y is the specific yield and t denotes time.

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[‡]School of Production Engineering and Management, Applied Math & Computers Laboratory, Technical University of Crete, 73100 Chania, Greece
[†]School of Environmental Engineering, Geoenvironmental Engineering Laboratory, Technical University of Crete, 73100 Chania, Greece
[*]School of Mineral Resources Engineering, Applied Math & Computers Laboratory, Technical University of Crete, 73100 Chania, Greece
Email of the corresponding author : y.saridakis@amcl.tuc.gr

PTC employs a hybrid splitting algorithm for solving the fully three-dimensional system. The domain is discretized into approximately parallel horizontal layers, within each of which a finite element discretization is employed allowing accurate representation of irregular domains. The vertical connection of the layers is represented by finite differences. This hybrid finite element and finite difference coupling provides the opportunity to divide the computations into two steps during a given time iteration (splitting algorithm). In the first step, all horizontal equations are solved while in the second step, the vertical equations which connect the layers are solved (cf. [3]).

B. Sharp interface approach

In this work, the PTC model is used in conjunction with the sharp interface approach and the Ghyben-Herztberg approximation in order to estimate the saltwater intrusion extent. The sharp interface is a hydraulic approach, thus only the hydraulic head values on the model domain are needed in order to approximate the saltwater intrusion extent, as opposed to other approaches that utilize chloride or electrical conductivity measurements. The main assumption is that the mixing zone between the two immiscible fluids (fresh and saline water), that have different densities, is limited into an interface of a small finite width. The location of the sharp interface between the two fluids is determined by the difference between the hydraulic heads of the saline and fresh water and the volume of freshwater flowing towards the shoreline from inland (cf. [19]). The location of the seawater intrusion front is approximated using the Ghyben-Herzberg relationship:

$$\xi = \frac{\rho_f}{\rho_s - \rho_f} h_\xi \approx 40 h_f, \tag{2}$$

where, ξ is the interface depth below the sea level, h_f the hydraulic head of the freshwater above the sea level, ρ_f =1000 kg/m^3 the density of freshwater and ρ_s =1025 kg/m^3 the density of saline water. This approach has been applied and extended by many researchers in the literature (e.g. [1], [10], [11], [12], [16] among many others).

C. Study area and numerical model development

The study area of Hersonissos aquifer is located on the north coast of Crete, 25 km from the city of Heraklion in Crete, Greece. The Hersonissos basin covers an area of about 18 km^2, and stretches for 3.8 km in W - E direction and almost 4.7 km in N - S direction. During the summer period water demand is high due to extensive touristic and agricultural activities, leading to significant drawdown in the area, intensifying the problem of seawater intrusion. The region of interest has five pumping wells that are active all year, especially during the dry period, in order to meet the irrigation needs and the increased population during the summer period due to tourism.

The basin is covered mainly with karstified limestones of variable hydraulic conductivity and marls, whereas along the coastal line alluvial deposits with high permeability can be found (cf. [15]). The hydraulic conductivity values used for each geologic formation were 12.96 m/d for limestones and dolomitic limestones, 5.2 m/d for bioclastic limestones, 0.15 m/d for marl formations, 0.6 m/d for clay and 430 for alluvial deposits located near the coastline (cf. [10]).

Initially, a six month groundwater flow simulation, representing the dry season, when saltwater intrusion is more intense, was implemented. This was followed, in the sequel, by a six month wet season simulation in order to study the aquifer's response to saltwater intrusion during conditions of increased fresh water inflow to the basin. A Dirichlet boundary condition of fixed head equal to 100 m was applied along the coastline to simulate the sea boundary, assuming a change in the reference level from the sea level to the bottom of the aquifer (the aquifer bottom elevation was set to zero thus the sea level was set to 100 m). Various Neumann conditions were applied at the southern boundary of the region during the calibration process, in order to simulate groundwater inflow from connecting basins and match the measured hydraulic head values at the wells (see Fig. 1).

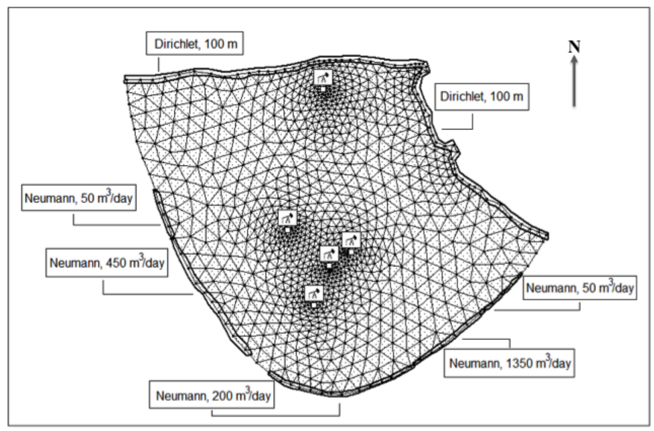

Fig. 1. Hersonissos aquifer. Sideways water recharge values.

Regarding the saltwater intrusion toe location, according to the Ghyben-Herzberg relationship, h_f was estimated at 2.5 m, given that the depth of the studied aquifer is about 100 m (based on Boring Log information). Thus, the contour of 100+2.5 = 102.5 m represents the hydraulic head isolevel limit below which a zone is considered intruded by saltwater.

D. Pumping management

To fix notation, let M be the number of active wells in the region and let the vector $\boldsymbol{Q}$ be defined by

$$\boldsymbol{Q} = (Q_1 \ , \ \cdots \ , \ Q_M) \tag{3}$$

where Q_i , $i = 1, \ldots, M$ denotes the pumping rate of the i-th active well with coordinates (x_i, y_i). The objective, to maximize groundwater withdrawal while precluding saltwater to enter a safe zone around all active wells, may then be described by the following nonlinear optimization problem (cf.

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[18]):

$$maximize: \quad P \equiv P(\boldsymbol{Q}) = e^{-\left[S(\overline{\boldsymbol{Q}})-S(\boldsymbol{Q})\right]^2/S^2(\overline{\boldsymbol{Q}})} \in [0,1]$$

$$under\ the\ constraints: \quad 0 \le \underline{Q_i} \le Q_i \le \overline{Q_i} < Q_A,$$

$$S(\boldsymbol{Q}) = \sum_{i=1}^{M} Q_i \le Q_A \qquad (4)$$

$$x_{\tau,i} \le x_i - d_s,\ i \in \{1,..,M\},$$

where P denotes the profit (objective) function, $\underline{Q_i}$ and $\overline{Q_i}$ are the minimum and maximum, respectively, pumping capabilities of the i-th well, Q_A is the total discharge capability of the aquifer, $x_{\tau,i}$ is the x-coordinate of the saltwater's front in the neighborhood of the i-th well and d_s is a pre-specified safety distance (set equal to 180m in the present implementation).

E. Constrained ALOPEX for pumping management

For the solution of the nonlinear optimization problem (4), described in the previous section, we employ ALOPEX stochastic optimization algorithm coupled by a penalty system to enforce problem's constraints.

To be more specific, in each iteration step, ALOPEX updates simultaneously the values of all control variables Q_i , $i = 1,\ldots,M$ by means of the following vector rule:

$$\mathbf{Q}^{(k)} = \mathbf{Q}^{(k-1)} + c_k \Delta\mathbf{Q}^{(k-1)} \Delta P^{(k-1)} + \mathbf{g}^{(k)}, \qquad (5)$$

with

$$\begin{aligned} \Delta\boldsymbol{Q}^{(k)} &= \boldsymbol{Q}^{(k)} - \boldsymbol{Q}^{(k-1)} \\ \Delta P^{(k)} &= P(\boldsymbol{Q}^{(k)}) - P(\boldsymbol{Q}^{(k-1)}) \end{aligned} \qquad (6)$$

where c_k is a real parameter controlling the amplitude of the feedback term, while $\mathbf{g}^{(k)}$ is the noise vector, with values uniformly distributed in an appropriately chosen interval, in order to provide the necessary agitation needed to drive the process to global extrema avoiding local problems. The methodology for determining a near optimal set of values for c_k and $\mathbf{g}^{(k)}$ is thoroughly discussed in [18].

In each ALOPEX iteration step all control variables Q_i , $i = 1,\ldots,M$ are being rectified, if needed, via a two-phase penalty system. Phase one refers to the enforcement of the first two constraints described in (4), and precedes PTC's implementation, while phase two refers to the enforcement of the third *toe-constraint* described in (4), needs the trace of the saltwater interface and, thus, follows PTC's implementation. While the algorithms of implementing said penalty system are described in detail in [18], it is worthwhile to point out that:

- In both penalty phases, the values of those Q_i needed to be rectified, are being, ultimately, reduced or increased by a percentage, which in our implementation (as in [18]) has been set to 5%.
- In phase two, the enforcement of the toe-constraint is being achieved in two cycles. In cycle one only the pumping rates of the active wells at risk are being rectified, while, if necessary, in cycle two the pumping rates of all active wells that affect the endangered wells are being rectified.
- The efficiency of the standard-deviation/mean-value stopping criterion, introduced in [18], is also reported in the present work through all numerical simulations included in the next section.

Finally, in Fig. 2 that follows, the whole ALOPEX/PTC pumping management methodology, described in the above paragraphs, is being depicted via the flow chart of the whole process.

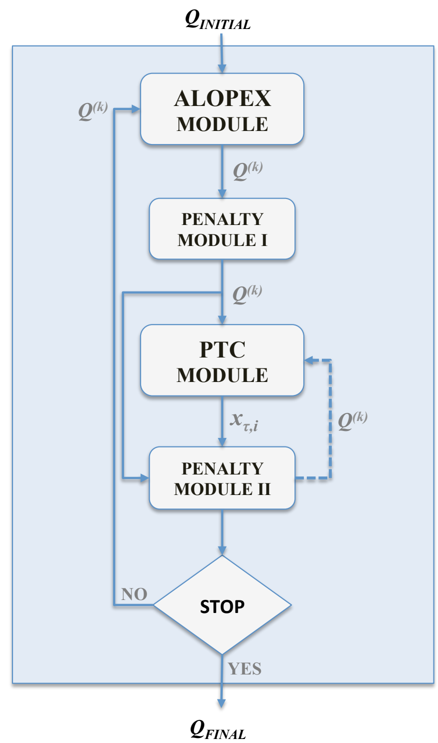


Fig. 2. Flow chart of the ALOPEX/PTC pumping management methodology.

III. Numerical simulations

In this section we include the results from characteristic numerical simulations performed for the freshwater aquifer located at Hersonissos, Crete, Greece.

To characterize the simulation profiles included, recall the main governing flow equation from (1) and let the volumetric flux W satisfy

$$W = N - Q$$

where N denotes the recharge rate distributed over the surface of the aquifer and Q denotes the discharge rate distributed over the active pumping area. Then, the simulations included refer to a *dry case* scenario as well as to a *wet case* scenario characterized by

- *Dry Case*: $N = 0$ mm/year, while the sideways (subsurface) recharge, characterized by the Neumann boundary conditions, is as defined in Fig. 1,
- *Wet Case*: $N = 500$ mm/year with percentage of infiltration set at 30%, while the sideways recharge is as described in Fig. 1 increased by 20%.

Both case scenarios consider five active public pumping locations, the coordinates of which (see Fig. 1) have been assigned via a geographical information system. From the five active wells the top one, located close to the north coastline of the aquifer (see Fig. 1), is always flooded by seawater, independently from the pumping activities in the region. This is due to the fact that the *natural* saltwater intrusion, namely the hydraulic head isolevel at 102.5m when $Q = 0$ (the thin light-blue contour line included in all figures that follow), is far beyond the well's location. The water extracted from this location is always unsuitable for human consumption or land irrigation and, therefore, may as well considered to be inactive. Nevertheless, to comprise with relevant results in the literature, we consider active all five pumping locations despite the fact that we are able to protect only four of them from saltwater intrusion.

In Table I we have included the maximum $\overline{Q}_i$ pumping capabilities of all five active locations, while the corresponding minimum ones have been set to satisfy $\underline{Q}_i = 0.3 * \overline{Q}_i$.

TABLE I
PUMPING CAPABILITIES (m^3/d) OF ACTIVE LOCATIONS

i	1	2	3	4	5
$\overline{Q}_i$	1850	2550	600	2550	200
$\underline{Q}_i$	555	765	180	765	60

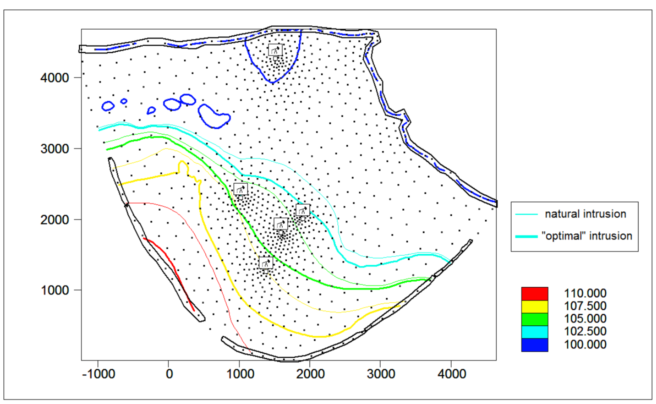
Finally, we note that in all numerical simulations the pumping rates Q_i , $i = 1, \ldots, M$ are considered to be numbered in a top-to-bottom fashion, namely $y_1 \geq \ldots \geq y_M$.

A. Dry Case

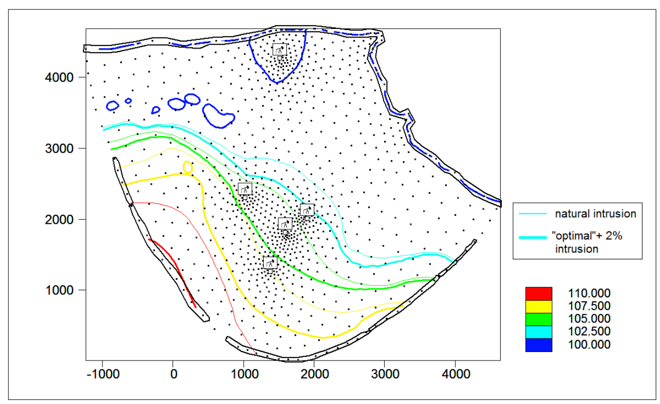
All results, pertaining to the dry (summer) case ($N = 0$) scenario, from the ALOPEX/PTC pumping management performance, during a typical cycle of 500 iterations, are summarized in Table II and Fig. 3 that follow.

TABLE II
ALOPEX/PTC PERFORMANCE: DRY CASE

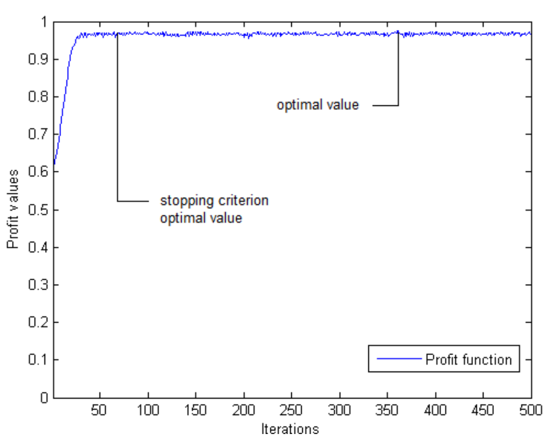
Problem Parameters	*Total Optimal Values*	*Stopping Criterion Optimal Values*
k (# iter.)	362	59
$P(\boldsymbol{Q}^{(k)})$	0.97424	0.97033
$Q_1^{(k)}$	1839.06	1783.77
$Q_2^{(k)}$	1375.14	1338.24
$Q_3^{(k)}$	558.96	546.16
$Q_4^{(k)}$	2525.95	2539.59
$Q_5^{(k)}$	198.78	197.14
$S(\boldsymbol{Q}^{(k)})$	6497.89	6404.90



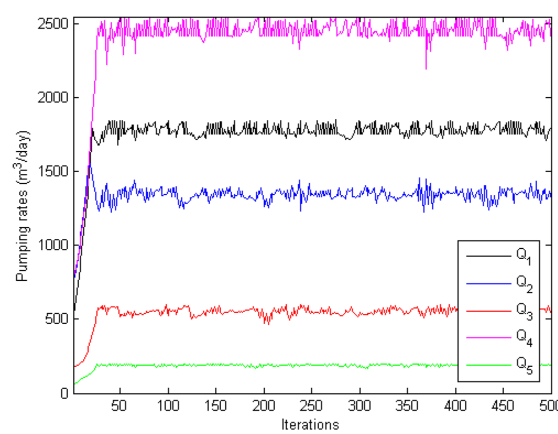
(a) Hydraulic head isolevel curves using the optimal pumping rates. The countour line at 102.5m denotes the saltwater interface.



(b) Hydraulic head isolevel curves using the optimal pumping rates increased by 2%. The countour line at 102.5m denotes the saltwater interface.



(c) Values of $P(\boldsymbol{Q}^{(k)})$ during a cycle of $k = 500$ iterations.



(d) Pumping rates Q_i during a cycle of $k = 500$ iterations.

Fig. 3. *Dry Case*: ALOPEX/PTC performance for five (5) active pumping locations in a typical run of 500 iterations

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Inspecting, now, Fig. 3a it can be easily verified that all pumping locations, except naturally the top one, remain safe from saltwater intrusion, since we kept the saltwater interface (contour line at $h = 102.5$m) at a distance of at least d_s=180m away from all protected active locations. It is also significant that, as Fig. 3b suggests, increments of 2% - 5% on all optimal pumping rates Q_i (reported in Table II) do not expose the protected active pumping locations to saltwater intrusion due to the carefully chosen value of the safety distance d_s. As it pertains now to the ALOPEX performance notice that (see figure 3c) the algorithm drives the objective function to a narrow neighborhood of its constrained maximum in less than 50 iterations and remains close to it, for the rest of the process, within relatively small amplitude fluctuations. Similar behavior may be observed, in Fig. 3d, for the process's control variables Q_i.

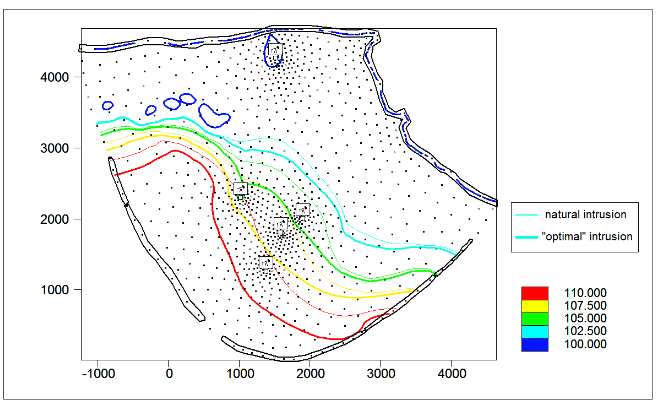
B. *Wet Case*

All results, pertaining to the wet (winter) case ($N = 500$) scenario, from the ALOPEX/PTC pumping management performance, during a typical cycle of 500 iterations, are summarized in Table III and Fig. 4 that follow. By inspection only of the reported results one may easily verify that this is an untroubled case in the sense that the active pumping locations may perform at maximum pumping rates without any threat from saltwater intrusion.

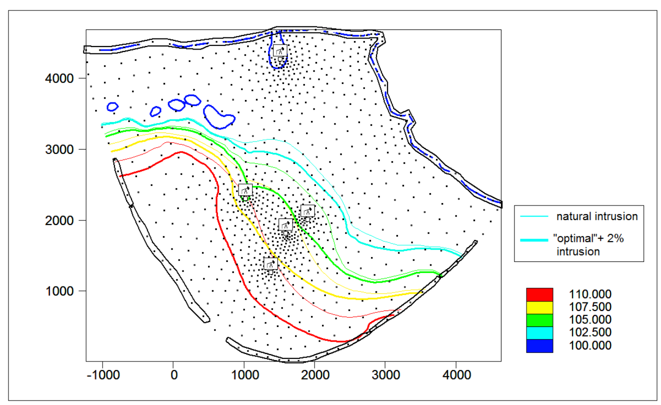
TABLE III
ALOPEX/PTC PERFORMANCE: WET CASE

Problem Parameters	*Total Optimal Values*	*Stopping Criterion Optimal Values*
k (*# iter.*)	476	59
$P(\boldsymbol{Q}^{(k)})$	0.97424	0.97033
$Q_1^{(k)}$	1807.49	1683.33
$Q_2^{(k)}$	2539.68	2537.39
$Q_3^{(k)}$	598.70	578.29
$Q_4^{(k)}$	2545.65	2534.73
$Q_5^{(k)}$	193.98	186.96
$S(\boldsymbol{Q}^{(k)})$	7682.40	7520.70

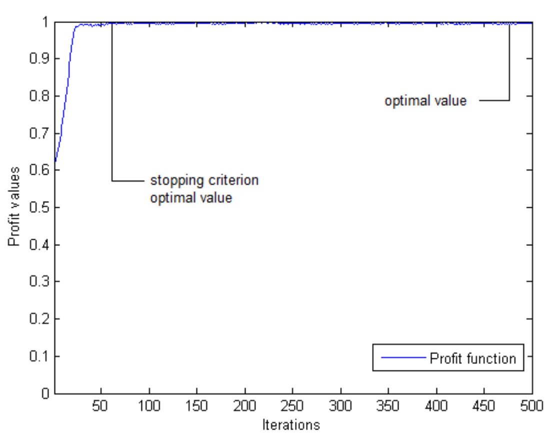
Indeed, as both Figs. 4a and 4b suggest, all pumping locations, except naturally the top one, remain safe from saltwater intrusion, since the saltwater interface (contour line at $h = 102.5$m) is not even close to the safety distance of d_s=180m from all protected active locations. ALOPEX drives in less than 50 iterations (see figure 4c) the objective function to its global maximum and remains close to it, for



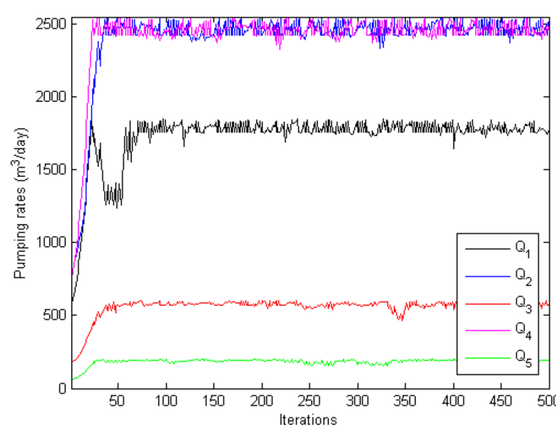
(a) Hydraulic head isolevel curves using the optimal pumping rates. The countour line at 102.5m denotes the saltwater interface.



(b) Hydraulic head isolevel curves using the optimal pumping rates increased by 2%. The countour line at 102.5m denotes the saltwater interface.



(c) Values of $P(\boldsymbol{Q}^{(k)})$ during a cycle of $k = 500$ iterations.



(d) Pumping rates Q_i during a cycle of $k = 500$ iterations.

Fig. 4. *Wet Case*: ALOPEX/PTC performance for five (5) active pumping locations in a typical run of 500 iterations.

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the rest of the process, within very small amplitude fluctuations. Similarly, inspecting Fig. 4d, it can be noticed that all control variables Q_i reach within a few iterations maximum performance.

IV. Conclusion

In this study, we combined the PTC groundwater simulation model with the newly introduced constrained version of the ALOPEX stochastic optimization technique, in an attempt to maximize groundwater withdrawal in the existing pumping well network while avoiding saltwater to enter a safe zone around the active wells in the region. The results, for both dry and wet case scenarios considered, revealed that the recently introduced constrained version of the ALOPEX stochastic optimization method cooperates effectively with PTC and, operating on pumping locations in both local and global range, is capable to produce considerably improved results. We strongly believe that the reported results justify and encourage further investigation on the performance of the method.

Acknowledgment

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Analysis of Noise Level Exceedances by Exponential Rate Function in Non-Homogeneous Poisson Model

Claudio Guarnaccia, Joseph Quartieri, Nikos E. Mastorakis and Carmine Tepedino

***Abstract*—** The study of the impact of acoustical noise on human activities is a very important issue in cities and areas in which relevant noise sources are present. The effect on health, both auditory and non-auditory is largely documented in literature and several models have been developed to take care of this problem. Since almost all the national regulations fix a maximum acoustical level, according to the area and to the kind of buildings and activities that occur in that, a model based on threshold exceedances study is suitable. In this paper, a non-homogeneous Poisson model is presented and applied to a large dataset of noise measurements. The parameters probability distributions estimation, based on Monte Carlo Markov Chains and Gibbs algorithm, will be described. The posterior distributions of the parameters will be shown and their mean values will be used to plot the cumulative mean function. This function, that represents the number of surpassings of the threshold as a function of the time, can be compared with the observed exceedances.

***Keywords*—** Acoustical Noise Level, Cumulative Rate Function, Exponential Rate Function, Goel Okumoto Function, Non homogeneous Poisson Process, Predictive Model, Threshold Surpassing.

I. Introduction

Acoustical noise pollution is one of the major problems in urban areas [1]. Together with air pollution, in fact, it is a relevant risk for human health. In [2], [3] some of the effects related to the exposure to acoustical noise are resumed, focusing on the auditory and non-auditory effects.

The most important source of noise are transportation infrastructures and industrial areas, such as documented in [1], [4], [5]. Many models, with different approaches, have been developed to predict the noise levels produced by trains (for instance [6]-[11]), road traffic (for instance [12]-[23]), airport (for instance [24], [25]), industrial settlements (for instance [3], [26]), etc..

In this paper, the approach that will be pursued is based on the implementation of a non-homogeneous Poisson process [27], [28] to study the probability of surpassing of a certain noise threshold. Similar models have been presented in [29], [30] for air pollution and [25], [31] for noise level. The introduction of changepoints is discussed in [25] for airport noise, while in [32] the comparison between various models, with a different number of changepoints, is discussed on four large dataset of noise levels.

In this paper, one of these datasets will be adopted to test the implementation of a different rate function, that is exponential instead of power law. In particular, the Goel Okumoto (GOP) rate function [33] will be implemented instead of the Weibull Power Law (PLP) rate function, adopted in [25] and [31].

The dataset is related to acoustical noise equivalent level measured in Messina, Italy, in the framework of the long term monitoring campaign promoted by the Department of Urban Mobility of the city. The levels considered here are measured during the night and are evaluated on a 8 hours range, from 10 p.m. to 6 a.m..

Since some data were missing, both single and group of data, a Time Series Analysis model, such as the ones developed in [34]-[37], has been used to fill the gaps. This will be the same procedure adopted in [32] to make the datasets continuous.

The results will be presented in terms of comparison between observed and estimated exceedances, i.e. cumulative mean function.

In addition, the evaluation of the probability of observing a certain number of threshold surpassings will be presented in the last section, showing how the model can be helpful in decision processes by policy makers.

II. Model Presentation

The Non-Homogeneous Poisson Process (NHPP) is a stochastic model able to count occurrences of a certain event, in our case the surpassing of a chosen noise level threshold.

Let $N^{(\theta)} = \left\{N_t^{(\theta)} : t \in [0, T]\right\}$ be a NHPP with mean value function $m(t|\theta)$ and θ the parameters vector. The function $m(t|\theta)$ represents the cumulative function of the expected number of events registered by $N^{(\theta)}$ up to time *t*. In this paper, the events are represented by the surpassing of a certain acoustical noise threshold (68 dBA). In order to fully characterize the process, the functional form of $m(t|\theta)$, or

C. Guarnaccia, J. Quartieri and C. Tepedino were with Department of Industrial Engineering University of Salerno, via Giovanni Paolo II 132, Fisciano (SA) (corresponding author to provide phone: 0039 089969596; cguarnaccia@unisa.it, quartieri@unisa.it, ctepedino@unisa.it).

N. E. Mastorakis was with Military Institutes of University Education (ASEI), Hellenic Naval Academy, Piraeus – GREECE (http://www.wseas.org/mastorakis).

equivalently, of its rate function $\lambda(t|\theta)$, must be achieved. In fact, the relation between the two functions is:

$$\lambda(t|\theta) = \frac{d}{dt} m(t|\theta) \quad . \qquad (1)$$

The probability to observe k exceedances in the time range [*t; t+s*] is given by:

$$P(N_{t+s}-N_t=k) = \frac{[m(t+s)-m(t)]^k}{k!} \, e^{-[m(t+s)-m(t)]} \qquad (2)$$

where Nt is the number of times a threshold is surpassed in the time range from 0 to *t*.

The model adopted in this paper is based on the Goel-Okumoto (GOP) [33] process defined by the following mean value function:

$$m(t|\theta) = \alpha[1-\exp(-\beta t)], \quad \alpha,\beta > 0 \,, \qquad (3)$$

where $\theta = (\alpha, \beta)$. The rate function associated with this process is given by

$$\lambda(t|\theta) = \alpha\beta \exp(-\beta t). \qquad (4)$$

In the Messina dataset considered in this paper, the epochs of occurrence of noise level threshold violations up to time *T* are included in the dataset $D_T = \{n;\ t_1, \dots, t_n\ ; T\}$, in which *n* is the number of observed threshold overruns times which are such that $0 < t_1 < t_2 < \dots < t_n < T$.

The likelihood function for θ is:

$$L(\theta|D_T) = \left(\prod_{i=1}^{n} \lambda(t_i|\theta)\right) \exp\left(-m(T|\theta)\right) \qquad (5)$$

A. *Parameters estimation*

In this work, in order to have the estimation of the model parameters, an empirical Bayesian analysis is applied. The choice was to use approximately non-informative prior distributions, in particular uniform U[*a*,*b*] distributions, with *a* and *b* chosen in an appropriate way.

The software OpenBugs has been used to obtain simulated samples from the posterior distribution of θ. In this software framework, only the distribution for the data and prior distributions for the parameters need to be specified. This software adopts standard Markov chain Monte Carlo (MCMC) methods. For further details, one may refer to [25], [29]-[32].

III. Analysis and Results

The model presented above has been tested on a dataset of 1341 noise measurements, collected in Messina, Italy, in a monitoring station placed in Boccetta street, during night time (from 10 p.m. to 6 a.m.). The time range goes from the 11th of May 2007 to the 10th of January 2011. The observed exceedances of the threshold (68 dBA) are 900. The statistics of the data are resumed in Tab. 1.

Table 1: Summary of the statistics of the 1341 noise data

	Mean	Std.dev	Median	Min	Max
1341 data	68.25	1.31	68.50	63.5	72.0

Five chains have been chosen in the two runs, with 100000 iterations each and different starting points. The parameters have been evaluated after a burning period of 50000 iterations and thinning every 10 steps. The choice of the prior distributions is crucial in the Bayesian approach. In this paper, a uniform distribution U[*a*,*b*] has been chosen both for α and β, with opportune boundaries *a* and *b*. An initial strongly informative distribution choice, in general, should be avoided but, once the first iteration has been run, more informative distribution can be used.

The uniform prior distributions, with *a* and *b* parameters (boundaries), are:

$$\alpha \rightarrow U[1000\ ,\ 3000]$$

$$\beta \rightarrow U[0.0001\ ,\ 0.00055].$$

The starting points of the five chains have been choosing in all the interval [*a*, *b*] and are:

1. α = 1100 ; β = 0.0005 ;
2. α = 1800 ; β = 0.00045 ;
3. α = 2500 ; β = 0.00012 ;
4. α = 2100 ; β = 0.00035 ;
5. α = 2900 ; β = 0.0003 .

The convergence of the five chains is achieved quite soon, independently from the starting points resumed above, as shown in Fig. 1 and Fig. 2.

The resulting posterior probability density functions of the parameters are reported in Figg. 3 and 4, while the statistics are resumed in Tab. 2.

With the mean values of the parameters, the mean function can be plotted versus time and compared with the observed surpassings of the threshold. This comparison is reported in Fig. 5.

As it can be noticed, the agreement between the two curves is very good, except for a region that goes approximately from 800 to 1150. In this time interval, a lower number of exceedances is observed but the model is not able to follow this pattern. A possible solution is represented by the introduction of a suitable number of change-points, such as in [25], [30], in order to evaluate the parameters in different ranges and with a better agreement. This improvement of the model is part of an ongoing work [32].

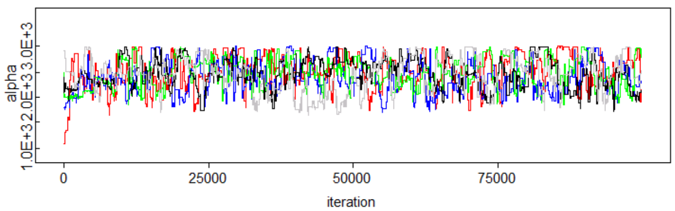

Fig. 1: Time history of the 100000 samples generated in the MCMC procedure used to estimate alpha parameter

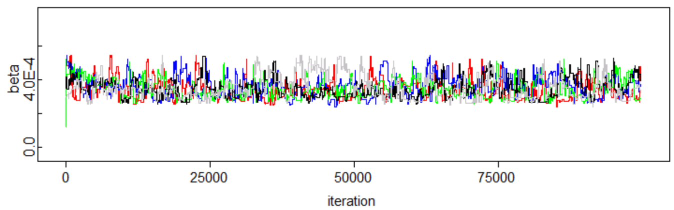

Fig. 2: Time history of the 100000 samples generated in the MCMC procedure used to estimate beta parameter

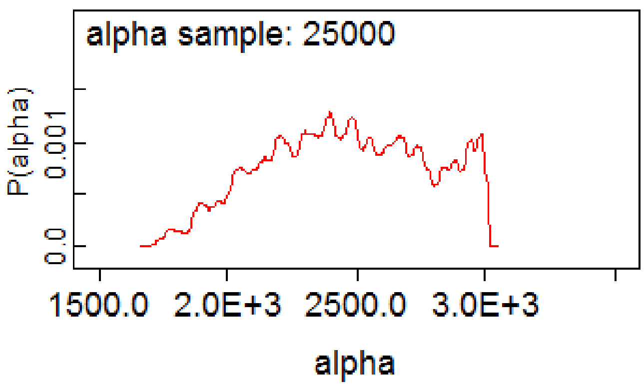

Fig. 3: Density plot of the alpha posterior distribution

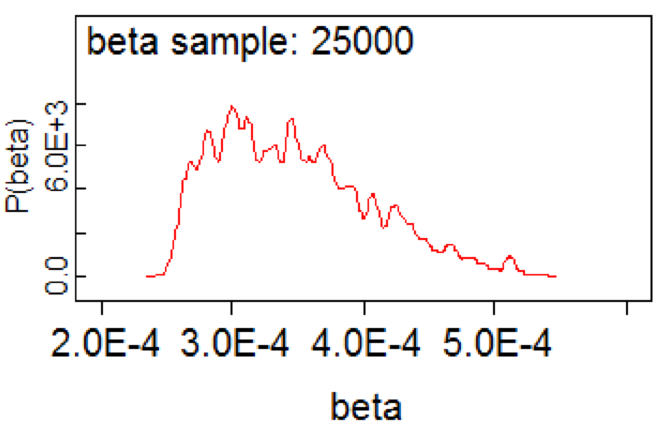

Fig. 4: Density plot of the beta posterior distribution

Table 2: Summary of statistics of the α and β parameters

	Mean	Std.dev	Median	val 2.5%	val 97.5%
α	2462.0	310.0	2460.0	1884.0	2989.0
β	$3.5\ 10^{-4}$	$5.9\ 10^{-5}$	$3.4\ 10^{-4}$	$2.6\ 10^{-4}$	$4.8\ 10^{-4}$

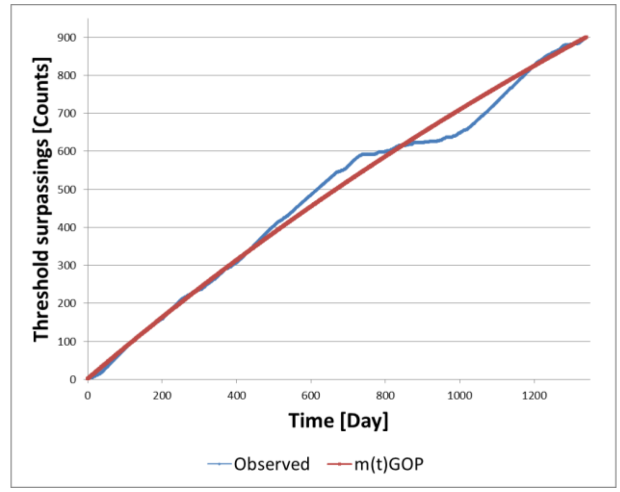

Fig. 5: Observed (blue line) and predicted by the GOP model (red line) threshold surpassings plotted versus time

IV. Probability of Threshold Surpassings

In this section, the authors will present how the Poisson distribution can be used to evaluate the probability of observing a certain number *k* of events of noise level threshold surpassings, in an interval of *s* periods, starting from the period *t*. Let us remind that the time base for the equivalent level is 8 hours, from 10 p.m. to 6 p.m. (night level), thus each period corresponds to a night measurement.

In order to define a suitable Poisson distribution, the mean values of the parameters of the GOP model rate function are needed. These parameters have been evaluated in the previous section and their statistics are reported in Table 2.

The simulation reported here is based on an interval of 30 periods (*s*), i.e. 30 days, starting from period 1200 (*t*), i.e. the 22nd of August 2010, in the case of 68 dBA noise level threshold. The actual observed exceedances are 23.

Figg. 6 and 7 report respectively the probability to observe *k* threshold exceedances and the cumulative probability of observing up to *k* threshold exceedances in the 30 periods time interval.

Table 4, instead, presents the following data:

1) probability of observing exactly the real number of threshold surpassings;
2) cumulative probability of observing up to 10 threshold surpassings;
3) cumulative probability of observing up to 20 threshold surpassings.

It can be noticed that the probability of observing the real number of exceedances is quite low (about 3%), that means that looking for the exact value of threshold surpassings is not the most useful way to use this tool.

On the contrary, the other two results are more relevant. The cumulative probability (*p*) of observing up to 10 surpassings is very low, i.e. there is a high probability (1-*p* is about 95%) of having more than 10 exceedances in the 30 periods (days) that follow the 22nd of August 2010 (t = 1200).

Finally, the cumulative probability of observing up to 20 surpassings is about 81%, stating that there is an almost low

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probability (1-p is about 19%) of observing more than 20 surpassings of the threshold. These results show that the model is able to give strong indications about the range of the threshold exceedances. In the case presented here, the indication is that the site is affected by many threshold surpassings and it is critical from the noise pollution point of view.

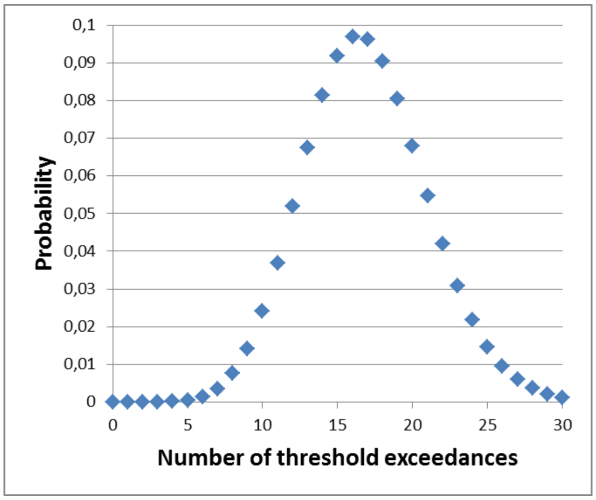

Fig. 6: Probability to observe k exceedances in an interval of 30 days from the period 1200, as a function of k

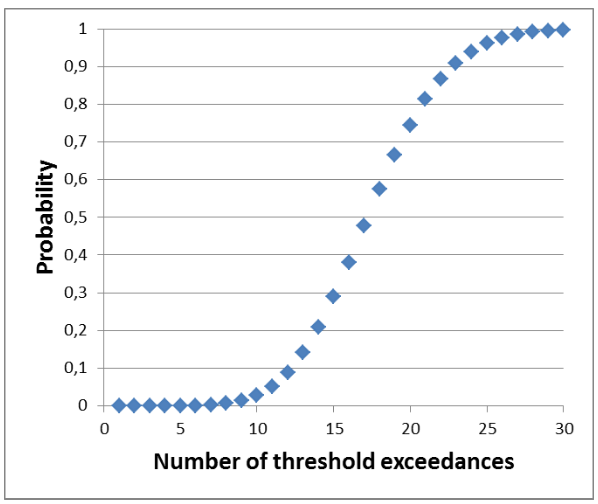

Fig. 7: Cumulative distribution function of observing up to k exceedances in an interval of 30 days from the period 1200

Table 3: Probability of observing the actual number of exceedances (k=23) and cumulative probabilities of observing up to 10 and up to 20 threshold surpassings

Probability $P(k = 23)$	Probability $p(k \le 10)$	Probability $p(k \le 20)$
0.030815	0.051557	0.812575

V. Conclusions

In this paper, the problem of predicting the probability of surpassing of a certain noise level threshold, on a given time range, has been considered.

The problem has been attached by means of non-homogeneous Poisson process and the key point of the presented work has been the choice of the rate function form. An exponential rate function has been introduced, according to Goel Okumoto (GOP), instead of the Weibull Power Law (PLP) rate function, adopted in previous papers.

The model parameters estimation has been performed in the OpenBugs software framework, adopting a MonteCarlo Markov Chain technique. The uniform prior distribution choice for parameters probability density and the chains starting points resulted in an almost quick convergence of the chains. The posterior distributions have been presented and the mean values used to calculate and plot the mean function, i.e. the cumulative function of the surpassings predicted versus time.

The comparison of the model results with the real observed exceedances is good, except for a region of the plot in which a lower number of surpassings is measured, with respect to the prediction of the model.

The evaluation of the probability of observing a certain number of threshold surpassings has been presented in the last section, showing that the model is able to give strong indications about the range of threshold exceedances.

The implementation of more informative prior distributions and of different rate functions in the Poisson process represent the future steps of this work, in order to achieve an always better prediction of the probability of noise level threshold surpassings.

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Solar Energy Resources of Uzbekistan and Peculiarities of Their Mapping

Kh. Egamberdiev[1], Yu. Petrov[1], B. Kholmatjanov[1], U. Rakhmonov[1]
[1]*Department of Astronomy and Atmosphere Physics, National University of Uzbekistan named after Mirzo Ulug-Bek, Uzbekistan*

Abstract — The desert and semi-desert areas of Uzbekistan emerge at present as zones of intensive economic activity that is closely connected to economic progress of the country. The following priority areas of the development should be emphasized. First, the bulk of this territory is occupied with Karakul sheep pastures, where 5 million heads of Karakul sheep. Second, mining industry (gold, uranium, marble etc. excavation) is expanding there, and broad scale geological prospecting is underway there. Third, ecotourism and some kinds of health care activities are capable of being developed in the territories.

In the arid areas in absence of natural sources of potable water, all the above kinds of activities, including people living and working in arid conditions experience acute need in water supply. Life such territories intended for development can be secured such non-traditional sources of energy as the solar and wind power installations. With this regard, work has been done on estimation of solar energy resources of Uzbekistan and the methodology of their mapping has been developed as well.

Keywords — solar energy, solar energy resources, methodology of solar energy mapping.

I. Introduction

Present development of civilization requires expansion of power generation. Use of traditional methods of power generation (coal, oil, and shale) yet in the nearest future will not allow for generation of necessary amount of energy, it means that crisis is threatening. This is a solid argument in favour of non-traditional power generation. Many experts in power generation reckon that the only way to overcome this crisis is large scale utilization on renewable sources of energy sources (solar, wind, ocean, or non-traditional, as they are termed) [2, 4]. Besides, it should be born in mind that employment of traditional energy resources besides consuming oxygen leads to significant pollution of the environment, which is one more reason for developing non-traditional energy sources.

At present, the problem of utilization of the solar energy moves from the sphere of scientific research to area of practical application the broad spectrum: from solar cell batteries to solar power plants (SPP) [6]. In 2016, it is planned to put commission of the first SPP in Samarkand Region with rated poser 100 MW. Annual power generation is capable of raising to 220 million KW per hour [5]. In total, according to the opinion of experts equals approximately 50 million tons in oil equivalent, which makes 99% on all the renewable of all renewable of all the renewable energy soccer in Uzbekistan.

Purpose of the work: first to provide estimation of solar energy resources in the territory, to provide estimation of the solar resources in the territory Uzbekistan.

II. Solar Energy Resources

The number of clear and cloudy days allows us to estimate the efficiency og utilization of the solar energy in the territory of Uzbekistan. While counting clear and cloudy days, common methodology has been applied: the days when relative duration of sun shining (RDSS) exceeds 80%, and cloudy were the days when RDSS was less than 20% of maximum possible duration of sun shine (DSS) in the particular day. The interval between these two indices characterizes average conditions of cloudiness. As RDSS has been defined on records from heliograph the obtained data on quantity of clear and cloudy days should be considered more objective as compared with number obtained as a result of normal climatic processing of cloudiness.

According to the data from actinometric measurements in the territory and border areas of the neighbouring countries (Kazakhstan, Turkmenistan, and Kyrgyzstan) the map of territorial distribution of number of clear days had been constructed, fig. 1. As it is seen from the Figure that the number of clear days in maximal in the southern areas of the country (207 days), minimal on the Ustyurt Plateau and Fergana Valley (142-148 days), and 170-190 days in the rest of territory. The maximum of completely cloudy days is observed on Ustyurt and Fergana Valley (70-75 days), minimum is in the southern areas – 51 days, and that in the rest of territory it is – 60-70 days.

The DSS has its maximum in the period of May to September (300-350 hours a month), which makes 64-69% of the annual amount. The maximum number of DSS is observed in the desert zone and the South of the country (over 3000 hours), fig. 2.

Possible sums of direct insolation on a perpendicular surface, i.e. sums of radiation that would be obtained at constantly clear sky, for all the areas of Uzbekistan exceed 11000 MJ/m2 a year. Sums of summary solar radiation at average conditions of cloudiness in the warm half year are below the possible sums by 1.1-1.25 times. In the rest of year, the real sum of the solar radiation is below the possible by 1.9-2.3 times depending on geographical location of actinometric observations. These sums, as a rule, within the range of 5860-6755 МДJ/m^2 a year.

The sums of solar radiation at clear sky in April through August make over 700 MJ/m^2 a month. At presence of moderate cloudiness, these sums drop down for the same period by 1.1-1.3 times.

III. Mapping Solar Resources

The existing methods of mapping various kinds of solar energy have on essential fault it is they do not take into account location of the actinometric stations. In the lower half-kilometer layer of the atmosphere at equal other conditions, input of direct insolation on the upper border of this layer increases by 10-12% [1]. As actinometric stations of Uzbekistan are located within the range: from 75 m (Takhyatash) to 2000 m (Qyzylcha) at mapping altitudinal change of radiation flux of the solar energy. In this respect, a new methodology of solar radiation record depending on altitude of the points of actinometric observation has been developed. As it is known, the flux of solar radiation in clear days depends on optic condition of atmosphere in the point of observation, i.e. on its transparency, elevation of the Sun over the horizon that is defined by the longitude of the point as well as on elevation of the point over the sea level [1]. We have used these patterns for development of methodology of mapping monthly, seasonal, and annual sums of direct insolation in clear days.

The diagrams have been drown where sums of the solar radiation of all the actionometric stations or Uzbekistan as well as the adjacent territories of Turkmenistan, Kazakhstan, and Tajikistan have been plotted with consideration of elevation of these spots over sea level. The total of 15 stations have been chosen.

Inter-seasonal variations of the sums of direct radiation has allowed to identify four typical periods: winter (XI-II), summer (V-VIII), and two transitional (III, IV), and (IX, X) ones. With respect of longitudes, the data from all the stations have been summarized for intervals 37.5-41°, 41-44° north latitude. The curves of vertical distribution of direct radiation have been drawn for the points characterizing the background transparency of the atmosphere, i.e. for those stations, for which the anthropogenic pollution could be considered negligibly small. To this category of stations, we have attributes Karakalpakstan, Takhyatash, Tamdy, Akmolla, Akkum, and Kyzylcha. While constructing the profiles, the patterns of vertical variations of direct insolation in unpolluted atmosphere obtained as a result of experimental sensing of the lower layers of atmosphere with aid of air-balloons and specially equipped plane [1, 3].

Based on the obtained vertical profiles, the smoothed profiles of direct insolation sums have been built for separate seasons and the year as whole. Based on these profiles, a table of monthly mean sums of direct solar radiation has been built depending on altitude and longitude of the territory , table 1. The data of the table has been used for mapping the monthly, seasonal, and annual sums of direct radiation on the perpendicular surface by means of their putting on hypsographic map of Uzbekistan. We have used a similar methodology as the basis for constructing maps of sums of the direct insolation on horizontal surface, fig. 3.

The maps of distribution of the scattered and sum solar radiation show the inhomogenuity of input of these kinds of radiation in the territory of Uzbekistan depending of lay-off-the-land. We point out as well that in the conditions of heavy dustiness of the lower layers of atmosphere in the warm half year the sums of scattered radiation increase that entails the comparable order of magnitude with direct insolation on the perpendicular surface.

IV. Estimation of Human-caused Pollution on Solar Energy Resources

The mapping methodology we offer of the direct and sum solar radiation on clear days allows to estimate to what extent human-caused exhausts into atmosphere entail weakening of the solar radiation. Deviations of sums of direct insolation on the perpendicular surface as compared with its values in the winter time show that in winter time weakening of sums of the direct radiation reach 32% (Fergana) in south-eastern part of Fergana Valley, 20% in its western part (Kayrakkum). In Tashkent, weakening of direct insolation makes 18%.

The least weakening of the direct radiation is observed at the points, first, fairly open and, second, with smaller industrial production capacity. These include Termez and Charjou, where weakening of the direct radiation in winter season makes 5-6%.

In the transition seasons in the south-eastern part of Fergana Valley, weakening of the direct radiation makes 23-25%, that in Termez is 13% and in Tashkent it is 14%.

In the summer season, these indices tend to diminishing over all the listed periods.

V. Conclusion

The developed mapping methodology of sums of the direct and sum solar radiation allows to estimate potential values of the solar energy resources of the individual areas of Uzbekistan. From this point of view, these resources are the most significant in the following territories of Uzbekistan: the South Aral Sea area, the desert part of Bukhara and Navoi Regions, Karshi, Surkhan-Sherabad, and Mirzachol regions.

Based on climatic and statistical and trend analysis as well as estimation of the solar radiation weakening by means of calculation, it has been shown that close to large industry centres of Uzbekistan conditions for operating solar installation worsen as a result of weakening of the solar radiation by human-caused exhausts into atmosphere as well as the temporal variability of the radiation characteristics. With this regard, utilization of the solar installations capable of transforming scattered and sum radiation is more expedient in such areas.

For efficient deployment of the natural resources in the desert areas of Uzbekistan, it is reasonable building of SPP of small capacity.

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Table 1: Monthly Average Sums of Direct insolation on Perpendicular Surface in Clear Days Depending on the Altitude and Longitude (MJ/m^2).

Longitude, φ°	seasons									
	XI-II		III-IV		V-VIII		IX-X		год	
	MJ/m^2	h, m	MJ/m^2	h, m	MJ/m^2	h, m	MJ/m^2	h, m	MJ/m^2	h, m
41-44	<700	0-100	<1000	0-200	<1100	0-100	<900	0-200	<11100	0-100
37-41	<750	0-100								
41-44	700-750	100-300	1000-1050	200-400	1100-1150	100-350	900-950	200-750	11100-11400	100-200
37-41	750-800	100-300								
41-44	750-800	300-600	1050-1100	400-850	1150-1200	350-900	>950	>750	11400-12000	200-550
37-41	800-850	300-700								
41-44	800-850	600-1200	1100-1150	850-1600	1200-1250	900-2000			12000-12300	550-800
37-41	850-900	700-1600								
41-44	>850	>1200	>1150	>1600	>1250	>2000			12300-12900	800-2000
37-41	>900	>1600								
41-44 37-41									>12900	>2000

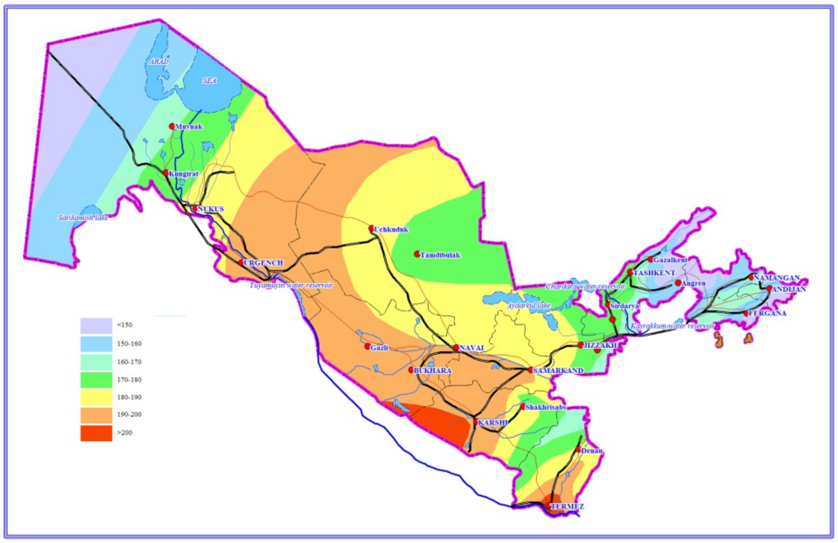

Figure 1: Geographic Distribution of the Number of Clear Days in Uzbekistan (days).

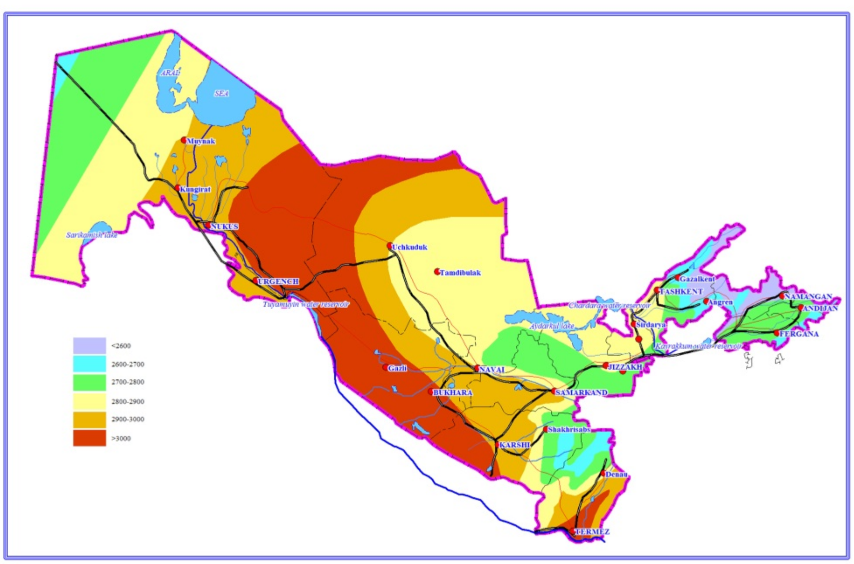

Figure2: Geographic Distribution of the Yearly Sums of Duration of Solar Shine in Uzbekistan (hours).

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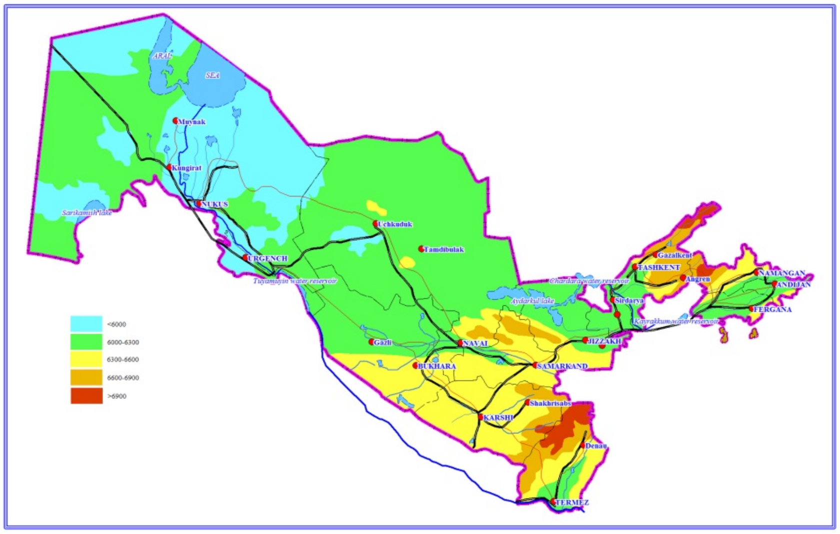

Figure3: Geographic Distribution of the Yearly Sums of Direct insolation on Horizontal Surface on Clear Days in Uzbekistan (MJ/m^2).

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Mixing of flu-gas stream by local acceleration in channel of biomass boiler

Jiri Pospisil, Martin Lisy, Michal Spilacek

***Abstract*—**The paper introduces the carried out study focused on mixing process of flu-gas stream in rectangular duct within a biomass boiler. The CFD code StarCD was used for numerical investigation of mixing process. A built up numerical model represents the afterburner channel in a two-chamber biomass boiler with capacity 200 kW. The boiler is designed for combustion of very moist biomass. The trace gas was used for identification of mixing quality. The trace gas was virtually distributed in separate points in front of the duct. 3D concentration fields in the duct were computed. 2D concentration fields in the cross section led in the end of the duct was used for evaluation of mixing quality. Target of carried out parametrical studies was to find out an optimum shape of an afterburner channel which could provide maximum mixing of combustion air flow with a flow of flue gas and combustible components in volatile matter. Adjustments to the channel shape can help to increase combustion efficiency and decrease emission production (especially CO, particulate matter and organic gaseous compounds). A local acceleration of the flow was used for encouragement of mixing process in the duct. Different size of cross section windows was tested and compared from the view of mixing quality.

***Keywords*—**CFD analysis, flue-gas, mixing, emissions

I. Introduction

INCREAS in use of renewable energy sources goes hand in hand with requirements on improvements of relevant technologies. Technologies for energy from biomass very often use poor-quality fuels that are fuels with high water content. Improper fuels cause many troubles in the control of combustion process, and require advanced combustion equipment designs. Besides low quality of the fuels, the industry has to face growing requirements on boiler and combustion technology efficiency, and decrease of emitted pollutants. Development of combustion technologies is commonly supported with computational simulations which stimulate fast development and savings in development of prototypes.

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Jiri Pospisil is with the Brno University of Technology, Faculty of Mechanical Engineering, 61669 Brno, Czech Republic, e-mail: pospisil.j@fme.vutbr.cz.

Martin Lisy is with the Brno University of Technology, Faculty of Mechanical Engineering, 61669 Brno, Czech Republic, e-mail: lisy@fme.vutbr.cz.

Michal Spilacek is with the Brno University of Technology, Faculty of Mechanical Engineering, 61669 Brno, Czech Republic, e-mail: spilacek@fme.vutbr.cz.

II. Conditions of Combustion Process

All combustion is a chemical reaction which provides thermal energy from energy chemically bound in the combusted fuel. Combustion is a process of burning a fuel where the fuel burns and produces heat and light. Active combustible matter in the fuel (C, H, and S) reacts with atmospheric oxygen (O2). Combustion reactions occur under convenient temperatures and the temperature is the main factor affecting the process speed (the higher the temperature, the faster the reaction). Combustion is called burning, if accompanied by light effect, such as flames [4, 5].

As already stated above, combustion is a reaction of fuel and oxygen contained in the combustion air. Combustion equations provide simplifications for the so called stoichiometric amount of oxygen necessary for the reaction. However, this amount of oxygen is never sufficient in reality, and the combustion process takes place with certain amount of excess air, which increases probability of the reaction. On the other hand, amount of excess air cannot rise too much. First, it increase production of NOx, and second, it reduces temperature in the furnace, which worsens conditions for combustion of the fuel.

When describing conditions necessary for optimum course of combustion reactions, the so called 3Ts are usually mentioned: time, temperature, and turbulence. Combustible components of the fuel must be in contact with oxidizer so that the combustion reaction is optimum. The contact must occur under optimum temperature conditions and must last for a specific period of time. Specific parameters are affected by various factors, such as type of fuel, furnace design, pressure in the furnace, etc. Optimization of the three parameters, that is temperature, time, and turbulence, helps decrease surplus of combustion air [4, 5].

Biomass contains high share of volatile combustible matter (75-80 %) and therefore it is vital to comply with the optimum conditions during combustion of biomass. Volatile combustible matter is released from the fuel at temperatures exceeding 150 °C; intensive release occurs at 200-250 °C. Further increase in temperature causes burning of first components of the fuel. Hydrogen and hydrocarbons are ignited at temperatures exceeding 450 °C, and the temperature of the flame steeply rises to 900-1,400 °C (depending on fuel moisture content and excess combustion air). Solid combustible components in charcoal are ignited at temperatures around 600 °C. Flame temperatures must be kept at above 900 °C and sufficient amount of oxygen must be supplied in order to achieve complete burn out of the combustible [6].

All “3T” parameters were considered and analyzed during development of the technology discussed below. The original combustion chamber had a rectangular cross section with an inclined grate and no built-in internals. The fuel was supplied from one side above the grate and flue gas flow left through the opposite outlet branch. Primary air was supplied under the grate, secondary air was supplied above the grate. Major problem of operating the original technology was a minimum mixing of flue gas flow containing significant share of combustibles and combustion air flow that is a minimum mixing of the flow under low temperatures in afterburning and exchanger sections of the chamber. Insufficient mixing resulted in high emissions, especially CO.

Instalment of inclined partition inside the combustion chamber significantly helped increase temperature in the chamber and retention time of the flue gas at high temperature levels (see Fig. 1). The partition in the chamber further helped improve mixing of air and released combustible; however, the mixing was insufficient. It was necessary to improve mixing of the gaseous mixture, especially mixing with the supplied secondary air. There are various technical solutions to this problem.

The simple solutions include reduction of the channel cross section by using built-in internals with an orifice; the more complicated ones use the so called static mixer, which is a device for continuous mixing of liquids. Energy necessary for the mixing come from pressure drop of the liquid flowing in the static mixer.

Thorough assessment of available options resulted in opting for the instalment of built-in internal with an orifice. Following procedures helped optimize the shape and location of the orifice so that the mixtures of flue gas and secondary air may be sufficiently mixed.

III. Computational Modelling

Computational modeling based on the control volume method was used for parameter study testing the impact of local reduction of the cross section of a flue gas duct on mixing of the flue gas.

Computational model of an afterburner channel in 150 kW boiler for combustion of wood was built up for the purposes of the study. Geometry of the combustion channel was transposed into a mesh comprising hexagonal volume elements, see Fig. 1.

Flue gas flowing in an unobstructed flue gas duct of a rectangular cross section (0.72 x 0.4 m), no local reduction, was modelled as the initial, basic geometrical configuration. Other geometrical configurations resulted from modifications of the basic configuration of the flue gas duct that is by installing a thin partition with one rectangular orifice of the size corresponding to 70 %, 50 %, and 30 % of the original unobstructed duct, free cross section of the duct.

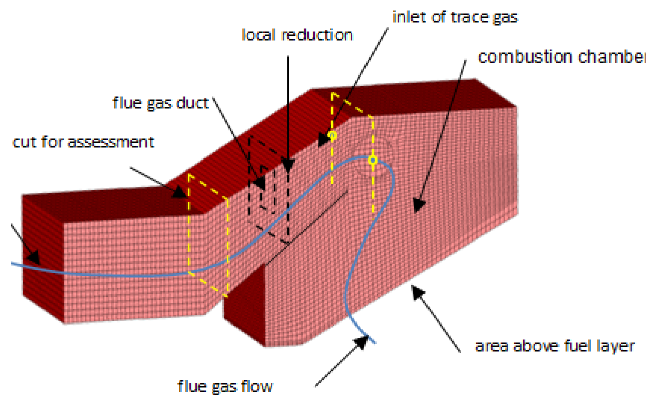


Fig. 1 Geometry of the area – mesh of control volumes

Flow of a gaseous mixture comprising 5 % hydrogen and 95% nitrogen, the so called trace gas, was supplied into the flue gas flow from the side walls of the boiler, 0.4 m before the local reduction of the duct (see Fig. 1 – yellow dots). There were two sources of trace gas, located at the same horizontal line, in the middle of the duct height. Mixing of the flue gas was assessed using concentration maps of the trace gas which were acquired in a vertical cut of the combustion duct 0.5 m beyond the reduction.

Boundary conditions

Inlet boundary conditions – Inlet was identified at a lateral cross section at the bottom part of the boiler where flue gas enters the relevant section of the boiler. Flue gas velocity was set to 10 m/s, temperature to 750 °C, and flu-gas density to 0.24536 kg/m^3 (at the given surface).

Similar boundary condition was used for trace gas injected from the boiler wall. The trace gas entered the flow from the wall level at velocity 5 m/s in the direction perpendicular to the boiler wall.

Outlet boundary condition “PRESSURE”- was set to the outlet surface at the end of the combustion duct in the computational model.

Boundary condition WALL - was set to other surface areas of the model. The solution considers a wall with friction.

Turbulence model - Solution used a k-epsilon turbulence model.

IV. Results and Discussion

3D trace gas concentration in the combustion equipment was calculated in the parametrical study. Similar model setting was used for all analyzed geometry. Examples of concentration fields are given in Fig. 2 (no reduction of the flue gas duct).

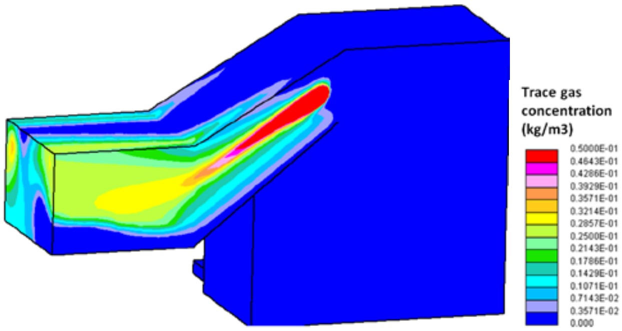


Fig. 2 Trace gas concentration close to the flue gas duct walls

Assessment of distribution of trace gas concentrations in the flue gas was done in the vertical cut led 0.5 m beyond the local reduction of the flue gas duct. Concentration maps of trace gas from the cut are given in Fig. 5. Concentration was evaluated by identifying a minimum concentration, maximum concentration, and average concentration. Obtained values of the assessed parameters are given in Fig. 3 for all researched configurations. Chart in Fig. 4 presents an overview of assessed parameters.

Calculated concentration maps (Fig. 5) clearly show a difference in the trace gas concentration distribution for the particular researched options. Option 1 shows two independent flows of trace gas close to the walls where the gas enters the flue gas flow. Flue gas duct without any reduction does not intensify mixing of gases in the combustion duct. Mixing is thus a consequence of physical and turbulent diffusion. The highest difference between a maximum and minimum concentration at the assessed cut was obtained for the option 1.

	Free cross section in reduction place			Concentration in cut		
	Free cross section	width(m)	height(m)	min. (g/m3)	max. (g/m3)	Avg. (g/m3)
Option 1	100%	0,72	0,402	2,50E-04	6,43E-02	1,52E-02
Option 2	70%	0,602	0,336	3,55E-03	4,98E-02	2,92E-02
Option 3	50%	0,509	0,284	1,79E-03	3,60E-02	1,70E-02
Option 4	30%	0,394	0,22	1,23E-03	2,61E-02	1,56E-02

Fig. 3 Values of trace gas concentrations in the assessed cut

Local reduction tested in the flue gas duct for options 2, 3, and 4 shows a different nature of concentrations, but the decrease in maximum concentration in the cut is almost linear. This proves that reduction of the cross section helps mix the flue gas. Minimum concentrations of all researched options are close to zero. This concentration may be found in parts of the flow which were exposed to the trace gas only minimally.

Average concentration of the trace gas with identical mass of the entering gas should be identical for all options, which Is not true for option 2 (70 % reduction). Deviation from that assumption may be explained by a used flat averaging which does not reflect different mass flows of flue gas in various parts of the cross section.

Quantification of the impact the cross section reduction on mixing of the gases may stem from a linear decrease of maximum concentration related to smaller free cross sections. Boundary states of that linearization may be the option 1 (no reduction in the duct) with maximum concentration 100 %, and option 4 (30 % of the free cross section) where the maximum concentration reached 41 % of the maximum free duct concentration.

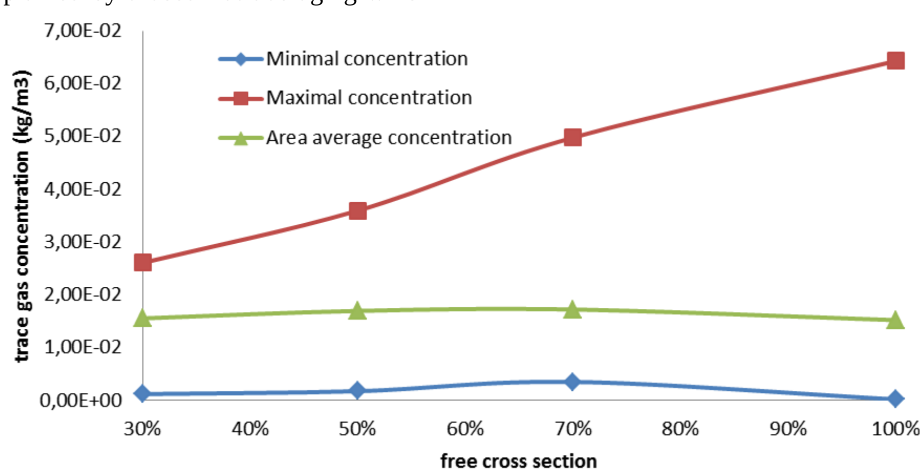
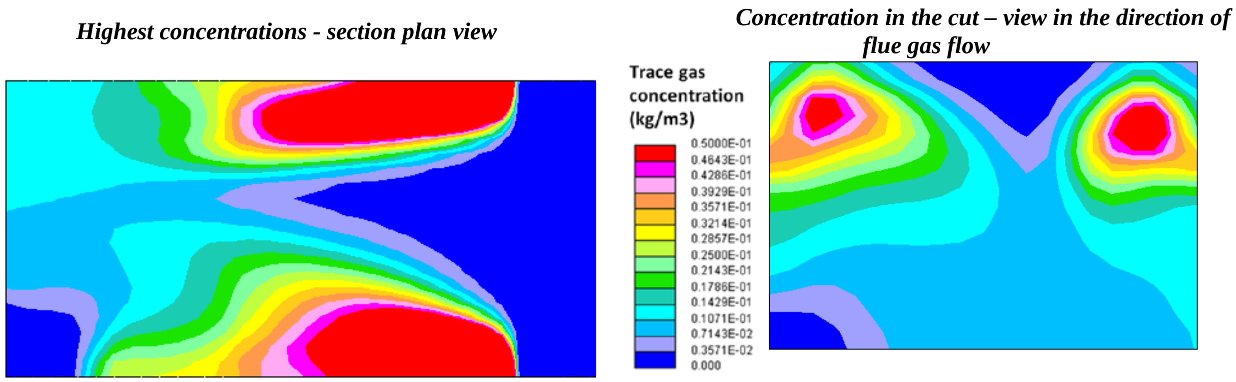
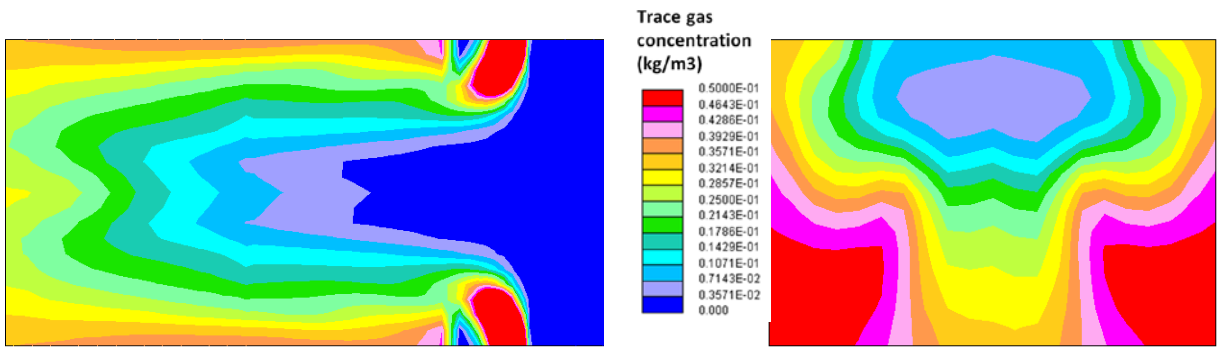


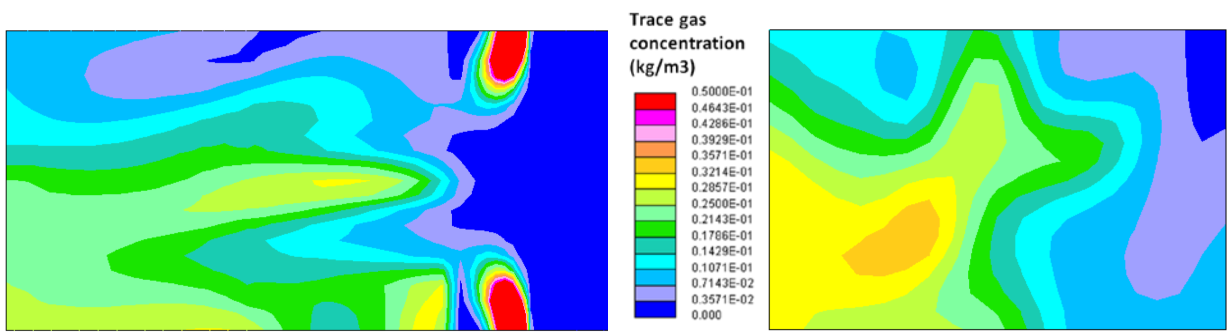
Fig. 4 Graphical display of maximum, minimum, and average concentration



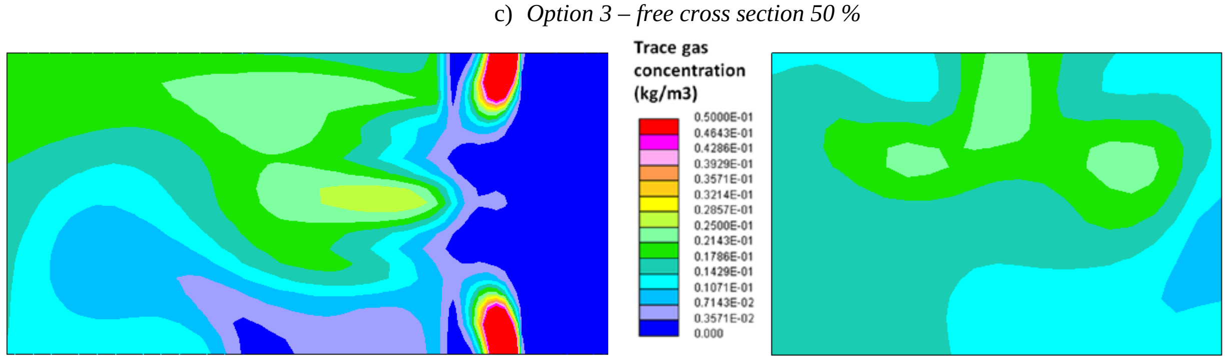
a) Option 1 – free cross section 100 %



b) *Option 2 – free cross section 70 %*



c) *Option 3 – free cross section 50 %*



d) *Option 4 – free cross section 30 %*

Fig. 5 Concentration of trace gas in the cut of maximum concentrations

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Reduction of the free cross section of the channel results in increase of pressure losses. For correct evaluation of pressure losses, the static pressure fields were analyzed. Static pressure values necessary for flowing of flu-gas through the entire boiler were obtained from carried out parametrical study. The relationship between static pressure drop and the free cross section of the duct is presented in the Fig. 6.

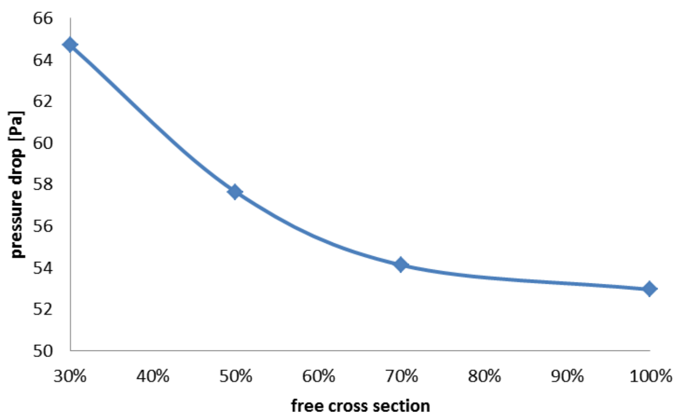

Fig. 6 Relationship between the static pressure drop and the free cross section

Pressure losses and mixing intensity are directly connected with actual value of kinetic energy of turbulence. Corresponding kinetic energy of turbulence was obtained from the numerical calculations in position behind the channel reduction – in position of the evaluating cut. Values of kinetic energy of turbulence obtained from carried out parametrical study are presented in the Fig. 7.

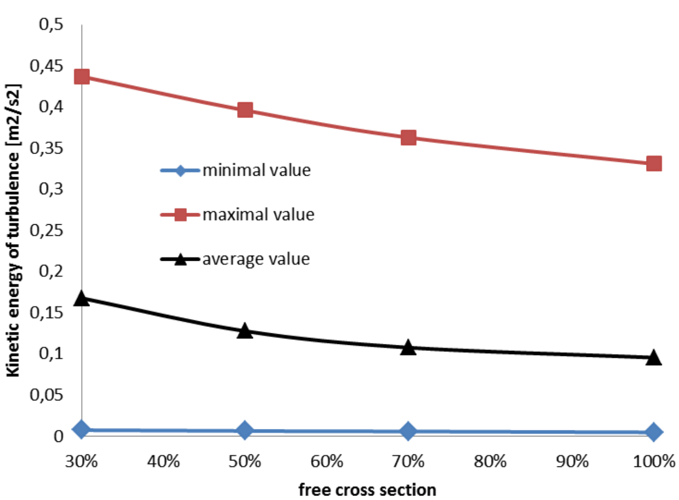

Fig. 7 Relationship between the kinetic energy of turbulence and the free cross section

Kinetic energy of turbulence generally increase with increasing velocity of flu-gas flow. For studied configuration of flu-gas duct we can investigate relation between the velocity of flu-gas in the orifice of the reduction and kinetic energy of turbulence in the evaluated cut. This relation is graphically expressed with utilizing relative changes in the Fig. 8.

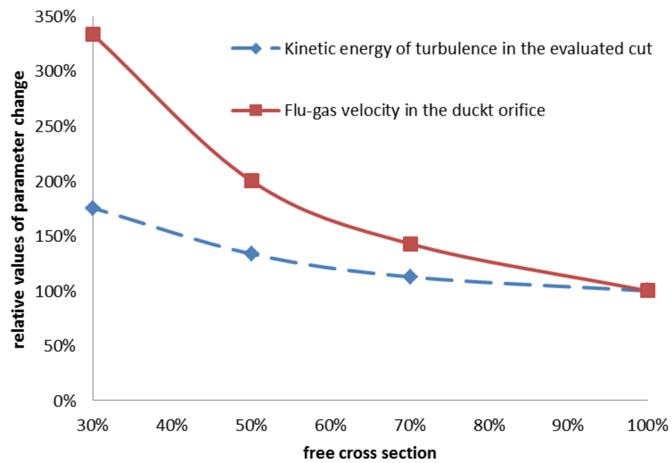

Fig. 8 Relative changes of kinetic energy of turbulence in the assessed cut and flu-gas velocity in the duct orifice

The Fig. 8 shows that increasing flu-gas velocity increases the kinetic energy of turbulence behind the reduction orifice. Significant distance of assessed cut from the reduction orifice causes the less intensive increase of kinetic energy of turbulence in comparison with the observed flu-gas velocity.

V. Conclusion

Carried out parametrical study aimed to increase retention time of flue gas in the gasification chamber and intensify mixing of flue gas flow with secondary air. Using a computational tool StarCD, we designed a system of built-in internals for regulation of flue gas flow in the chamber equipped with a turbulator which significantly helps mix flue gas flow with combustion air. Main task was to identify the impact of reduction of the duct on the quality of mixing of flue gas and secondary air flows. Mathematical modeling clearly shows linear dependency of the duct reduction on flow mixing, and decrease of maximum concentration of secondary air in the duct.

In terms of practical applications, optimum options seem to be the option with 50 and 30 % reduction. Solution with the 30 % reduction of the flue gas duct was performed and tested in practice. Emissions of pollutants comply with emission limits stipulated in the most stringent class 5 according to ČSN-EN 303-5 as well as with emission limits under Regulation No. 405/2012 Sb. providing for operational measurements of emissions. Co emissions were lower than 100 mg/m3n; OGC ranged in 2-3 mg/m3n, interval, and PM reached ca. 30-40 mg/m3n.

In addition to that, the new design greatly enhanced a fuel drying process and the boiler may now combust fuel with max. 55 % moisture content without preheating of the combustion air and grate extensions. Use of computational simulations accelerated the whole process of development of combustion technology for very moist biomass and reduced requirements on subsequent experiments.

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Jiri Pospisil graduated from the Brno University of Technology in Mechanical Engineering in 1997. Then he studied CFD modelling as a PhD student at the same university for four years. His activities include application of CFD for prediction of pollutant dispersion in urban areas. Since 1999, he has participated in the development of a small-scale numerical dispersion model involving influence of moving cars. His activities are focused on the developing of numerical models for different applications in vast field of energy industry.

RIVER CONTRACTS IN ITALY. AN EXPERIENCE FOR RIVER MANAGEMENT

Angioletta Voghera

Abstract— The national and community framework for rivers management plans and experiences outlines the need to adopt a cross-sectoral approach. In this context, “river contracts” (RCs) emerge as a way to reconcile local interests and build integrated strategies in order to redevelop and manage the environmental and landscape quality of a river basin.

Although there is no Italian law on the method or contents of river contracts, the authors initially highlight the strengths and weaknesses that emerge from an analysis of major national experiences.

Given these considerations the article goes on to propose a methodology to elaborate an action plan and strategic territorial scenario based on participation. Using traditional methods and new social networks, the participatory construction of the RCs exploits multiple suggestions by the population to define multi-sector strategies for the Tinella river territory..

Keywords— participation, negotiation, rivers management, local development.

I. Introduction

THE lively international debate that began in the early 1990s has focused on the management and conservation of the world’s natural resources, highlighting the importance of water resources and the need to protect them as crucial environmental elements of a territory. Water management activities have also come under increased scrutiny, not only because they refer to physical elements of natural systems, but because they are strategic for people’s quality of life.

The International conference on water and the environment held in Dublin in 1992 was the first to emphasize the economic role of water resources, environmental disasters, and the importance of institutional and social training and awareness. That same year, the World Water Day (March 22) was established by the United Nations Conference on environment and development in Rio de Janeiro, held as part of the initiatives on sustainability (Rio Declaration on environment and development).

Furthermore, world forums on water were organized from 1997 onwards as international events to discuss the multiple issues involving water resources. There have been a total of five events (one every three years) dedicated to specific themes: in Marrakech (1997), water and sewerage systems, shared management of water resources, conservation of the ecosystem, and efficient use of water; at the Hague (2000), water and nature, water and people, water and sovereignty (Making water everybody's business, 2000); in Tokyo (2003) and in Mexico City (2006), the relationship between water resources and people’s lives (Water for people, water for life, 2006), new policies, integrated resource management, efficient management, and stakeholder involvement; in Istanbul (2009) changes in water consumption policies (especially in the agricultural sector), the struggle against subterranean water pollution, and improvement in sewage treatment plants.

These international initiatives inspired the 2000/60/EC Directive (Water Framework Directive, WFD). The document is presented as "a framework for community action in relation to water resources"; its objective is to maintain and improve the quality of water resources throughout Europe using integrated measures regarding the qualitative and quantitative dimension of waters (Kaika, 2003). The logic behind the Directive is that water should be initially recognized as a crucial resource for the sustainable development of local communities (Kallis, Butler, 2001; Mostert, 2003). Indeed, as emphasized in the Directive, “water does not only […] satisfy the primary needs of the population […] but is vital for all ecosystems” and represents a driving force for development, capable of producing and sustaining collective wellbeing.

Based on these premises, sustainability is achieved - according to the Directive – by focusing on its ecological, economic and social features (Moss, 2004). The Directive emphasizes the need for maximum integration of the disciplines involved in the knowledge process and enhancement of responsibilities, legislation and measures as well as through the involvement of institutions and citizens (Carter, 2007). Furthermore, it also emphasizes the importance of operating according to the principles of effectiveness and transparency (e.g. The HarmoniCOP Handbook -Harmonizing Collaborative Planning and developing guidance for the implementation of the Water Framework Directive; Tippetta et al., 2005). It specifies that all forms of information, consultation and participation of public opinion should be enacted in order to achieve, by 2016, the common objective of “good status" for the quality of waters in a hydrographic district. The role of the Regions is also considered extremely important: fundamental objectives and action priorities are established for basin areas, while more specific projects are established and implemented regionally in order to create a closer relationship with local communities and their needs. The Directive sanctions the transition of water management from

This work is defined in collaboration to the Provincia di Asti and of Valerio Avidano.

government to the territory (Governa, Toldo et al., 2009) thereby overcoming the logic of administrative fragmentation (and consequent restrictions). It also promotes integration between the management of water resources and land use planning (Carter and Howe, 2006; Kidd and Show, 2007).

The entire framework defined by the Directive was assimilated by Italian national legislation with a certain slowness. With the Legislative Decree 152/2006, Italy formally implemented the contents of the WFD: however, formal implementation alone did not provide the technical instruments necessary for the effective realization and implementation of the provisions .

In Italy the subject had previously been governed by Law 183/1989 which defined for the first time the hydrographic basin as the optimal area for soil defense actions. The Basin Authorities have cognitive, programming and planning competencies and are required to draw up the Basin Plan, a sectorial tool for hydrogeological risk assessment, water level management and improvement of its status in a river basin.

Despite the administrative or technical difficulties encountered in putting the new principles into practice, Law 183/1989 contributed to safeguarding local conditions and, at the same time, assigned different responsibilities on various territorial scales (Chicca et al., 2003). It also reinforces integration between various disciplines (environment, land use, urban planning, economy, etc.), with extensive dialogue between the stakeholders involved in the fluvial territory transformation processes.

After twenty years from the introduction of Law 183/1989 and with numerous basin plans undertaken (such as River Po, 2010), in the light of those principles that planning activity has made its own (subsidiarity, sustainability, cooperation), soil defence is interpreted as an integral part of a general environmental planning strategy, related to the requalification of waters, management of the fluvial heritage, protection of natural assets and control of soil uses, separating it definitively from a sectorial approach. Finally, on an institutional level, «the positive legacy is that of having structured a stable form of coordination between Basin Authorities and local institutions […], promoting both the regulatory connection between the Basin Plan and local plans, and the assumption of responsibilities by sharing objectives» (Peano, 2008).

On this basis, Legislative Decree 152/2006 intervenes, updating national legislation in accordance with the principles and objectives of Directive 2000/60/EC. The hydrographic districts and the new District Authorities have been instituted, as a replacement for the Basin Authorities. This innovation reinforces the integration between the land use planning and the management of water resources, and incorporates the need to interrelate the Basin Plan with the territorial plans on the various scales, referring to the contents of Law 183/1989. The administrative reorganisation should experiment a logic of planning of the waters through the definition of more territorialized objectives that include not only hydro-geological risk assessment, but also environmental and landscape preservation and enhancement (Brunetta, 2008).

The implementation of the policies set out by the District Plan progresses through the definition of the Regional Water Protection Plans (WPP), which organise a series of actions, interventions, rules and behaviors aimed at the improvement of qualitative and quantitative water status, while interacting with regional and development policies . The WPP (Water Protection Plan) establishes strategic objectives for the safeguarding of water, starting with the evaluation of the overall status of the ecosystems (river-bed, banks and peri-fluvial areas), the compatibility of land uses and settlement pressures, and of the social and cultural behaviors associated with water, that can directly or indirectly influence water resources. The WPP in the Piedmont Region (2007) introduces the River Agreement as an innovative method of territorial governance, useful in identifying shared strategies, actions and rules for the environmental, landscape and socio-economic enhancement of a river basin.

II- River Contracts. A Tool for Fluvial Management

Inspired by international experiences (i.e. Belgium , France), unlike most territorial planning tools, in Italy the River Agreement is not based on an institutional law. It is more of an experience implemented and developed in the last ten years and constantly consolidated both methodologically and operationally . However, its role in water management and territorial planning is gradually gaining widespread recognition, and as a result the River Agreement is increasingly being inserted in a variety of planning tools (basin or hydrographic district plans, water protection plans, landscape plans, rural development programs). To date there is no unequivocal definition of the River Agreement. The proposal to create a National Charter of River Agreements, discussed during 5th National Round Table on October 21, 2010 in Milan, acknowledges the trends in practices implemented in various Italian regions. The Charter also states that the River Agreement must promote vertical and horizontal subsidiarity as well as participative local development and sustainability. The River Agreement must involve a decision-making process that includes all the actors involved and all pertinent topics (Carter, 2007); this will lead to a change in traditional water management, based on a hierarchical top-down relationship, and overcome its strictly technical and sectoral nature (Eckerberg and Joas, 2004).

In fact, inclusive governance, transparent assessment, and socially robust knowledge are the three pillars of a successful river basin governance processes (Guimarães Pereira, Corral Quintanab, 2009). In this view the River Agreement, a form of negotiated planning, begins with a voluntary agreement mobilizing participation by all major institutional and social actors in a fluvial region in order to define and implement a common strategic framework (Affeltranger, Lasserre, 2003; Antunesa, et al., 2009). The decision-making process should involve several heterogeneous socio-economic actors and different decision-making forums. The objective of this inclusive process is to relate different visions and aggregate them into multi-sectorial policies (soil and water protection, environmental improvement, landscape enhancement, regional development), financing specific projects, as well as influence planning and programming (Kidd, Shaw, 2007).

In this regard it also contributes to rebuilding knowledge and the self-defining skills associated with hydrogeological safeguard, the ecological development of the river and its landscape, and the development of multifunctional agricultural practices; this is achieved by reactivating multi-level management of "basin communities" (Magnaghi, 2011) and enabling people to recover rivers; furthermore, it can help generate new urban and rural territoriality, set up a network of local initiatives, and create integrated territorial enhancement policies.

Studies of some of the more advanced and different projects in Lombardy, Piedmont, Emilia-Romagna and Sicily, discovered certain common characteristics involving administration (of the process), and technical contents.

The public-private concertation process involves heterogeneous groups of stakeholders. Although the organizational structure of each project varies considerably, they all have a small decision-making body (Control Room) with members from the most important stakeholder groups; the Control Room coordinates activities and outlines the strategy of the agreement. A second body (Basin Assembly, Contract Forum) comprises all parties which in one way or another become part of the process. Although generally defined as an “enlarged participative body”, the facts show that there is a widespread tendency to include (through workshops, focus groups, assemblies, etc.) only the most important stakeholders from the economic world, institutions, or representative associations. As regards participation, certain projects do not involve any form of public consultation; others involve only certain age groups (chiefly through projects with schools), and still others involve only specific groups of individuals.

The Italian case studies demonstrate a predominance of technical topics connected with water and soil pollution and a constant attention to the hydrogeological safety of the land. All the experiments have the same objective: the enhancement of the landscape primarily considered, however, as being closely linked to fruition following the construction and/or interconnection of slow mobility routes (cycle-tracks, panoramic routes), and to an attempt to build parts of a local ecological network. Although often not locally perceived or considered as a threat to safety, the river emerges as a driving force behind community development, and the proposed strategies very often are purely technical (especially as regards waters and soil) and relate to ordinary planning measures.

Furthermore, the implementation of planned measures is subject to the presence or otherwise of public funds already earmarked by existing planning instruments (local plans, operational plans, rural development plans, etc.).

The weaknesses related to an inadequate inclusive participation process, to excessively sectoral measures, and the absence of ad hoc financing, were compounded by limited territorialisation of the strategies which had little to do with the physical territory. As a result, the final product is a framework of general objectives for the enhancement of the river and its territory, divided into different technical and sectoral action plans. The experiments do not define the spatial scenario of the strategies in the form of a "large area project general masterplan", that would allow the "spatial" results of the project to be visualised, by directing the contract revision and implementation process, in addition to revealing the physical and functional interactions between the different planned interventions.

Finally, one last critical area was poor evaluation: the most recent experiments use an strategic environmental evaluation tool only after the concertation process (“ex-post” evaluation), but not a program for the qualitative and quantitative monitoring of the contract results. In fact, the quality of the evaluation tool could also play a crucially important role during all stages of the process; it must be considered as a continuous reference tool to verify congruence between current and future planning decisions and the environmental and strategic objectives established by regional planning and programming measures . As a result, it will be necessary for each River Contract to formulate a suitable program for the qualitative and quantitative monitoring of these measures; this program will continually evaluate the results and possibly redesign the method in order to improve final performance.

III- The proposed Method for the Tinella Torrent River Contract

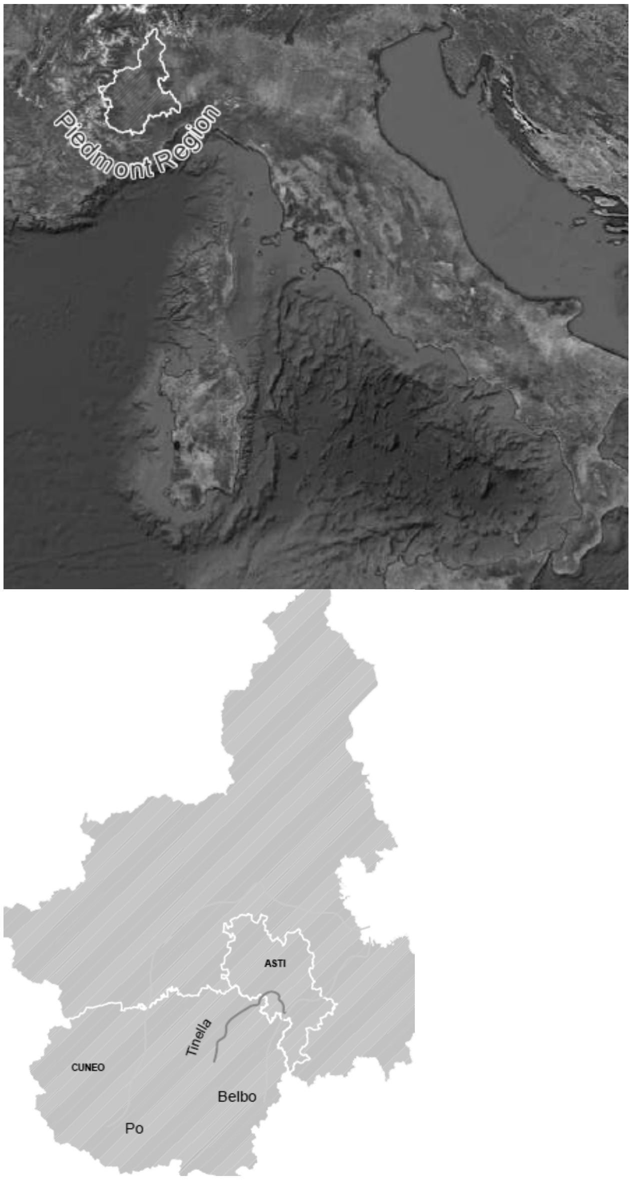


Figure 1. Tinella territory in Piedmont Region.

IIIa Tinella Context

Within the framework of ongoing experiences in Italy and the guidelines of river contracts in Piedmont (Governa and Toldo, 2011), the paper presents a methodological and procedural model to develop the clauses of the River Contract of the Tinella torrent sub-basin, including assessment of the process and monitoring of results; the Tinella torrent sub-basin is located in a region situated on the border between the provinces of Asti and Cuneo (see Figure 1). As part of the bigger basin of the Belbo torrent, the model proposed for the Tinella must satisfy the planning framework established for the Belbo torrent River Contract signed in 2010; as a result, the Tinella is emblematic, insofar as it is considered not just a tool specifying the strategic territorial policies policies, but rather a method for bottom-up construction thanks to widespread involvement of the local population in regional upgrading projects. The specific features of the Tinella region, chiefly characterised by vineyards and excellent agrarian landscape, make it suitable for gourmet and cultural tourism, as well as the drafting of policies to regenerate tangible and intangible relationships which over the years have been established between the agricultural world and the fluvial system. Furthermore, it creates synergies between the integrated upgrading of the fluvial area and economic regional growth based on the development of local resources which have become increasingly important nationally and internationally in relation to the Unesco nominated zones which cover most of the basin.

The work on the Tinella project is part and parcel of the methodological and procedural model of the River Contract, fully integrating the participative process and technical content. As regards the former, the consultation conducted in the region (involving primary and secondary schools, as well as on the web through the social network, Facebook) outlines the objectives of reaching good (impartial, wise, and efficient) decisions and knowledge which are prerequisites required for the start-up of the first activities regarding active participation of the local population (Medaglia, 2012). Technically speaking, the proposed model is a strategic, interdisciplinary and integrated vision expressed in its spatial and design dimension as a theoretical plan.

IIIb. Knowledge of the region

Considering the customary prevalence of ecological aspects, intrinsically linked to water quality and quantity, the Tinella torrent method seeks to achieve a more integrated and multidisciplinary regional vision. The decision stems from the knowledge that the river contract could contribute not only to the integration of individual sectoral tools related to the management of the hydrogeological system (basin or district plan, water protection plan), but also to the possibility of combining and linking different strategies found in regional planning and programming tools. It was therefore considered extremely useful to reflect on a more extensive analytical framework of the fluvial region capable of emphasising a variety of critical issues and values which could be brought into play in the overall project. The proposed interpretation framework is very broad and includes elements traditionally considered in the water management sector, and urban, regional and socio-economic planning.

In this case, a preliminary analytical exercise (status of the waters) initially considered the topics directly associated with water quality, using indicators and procedures established by the Legislative Decree 152/99 to implement Directive 200/60/EC and recently revised by Arpa (Italian Regional Environmental Protection Agency). At the same time, an analysis of hydrographic dynamics and criticalities in river morphology and water balance highlighted potential areas of overflow. Another part of the interpretive framework (regional and landscape system) considered: nature and vegetation, defining the characteristics of the ecological network of the fluvial system along the torrent and its tributaries; anthropic dynamics, starting with the choice of local urban plans;

landscape constraints and assets, including those formally recognised by current national laws (recently collected in Legislative Decree 42/2004 and subsequent modifications and integrations), the ones considered as such by the Regional Landscape Plan, or those still considered elements of cultural importance by Unesco during its studies to establish nominated areas which include a large portion of the Tinella region; perception and fruition system, not just of the fluvial area, but also the more extensive hilly region in the sub-basin. Finally, consideration was also given to the demographic and economic dynamics (socio-economics) of the Tinella region in the last decade, as well as demographic and economic trends (agriculture, industry, trade, services, and tourism).

III.c. Citizens’ participation

In line with the most established Italian and European practices, different approaches can be used in participative experiments. Some authors define them as "models", others "levels", or also "degrees" of participation. In essence, they are different methods used to practically achieve participation. These may relate to four categories: communication, animation, consultation and empowerment (Ciaffi, Mela, 2006), each with its own specific objectives and methods, although they can also be applied separately.

As regards these participation methods, this particular experiment was undoubtedly part of the consultation category and, to a lesser degree, communication; it also paved the way for future participation projects which may develop during implementation of the Belbo torrent River Contract. Accordingly, the objective was to be as inclusive as possible and primarily involve ordinary citizens often unconnected with River Contract formulation mechanisms.

Citizens’ participation was initiated using a "casual selection method"; this involved forming a reference sample representative of the whole community. Casual selection undoubtedly has several advantages: it excludes any a priori filter of admissible viewpoints and, above all, it allows citizens who still haven’t formed an opinion to participate (Bobbio, 2004). In this case, the reference sample was not divided into categories with specific socio-demographic characteristics; however, the method endeavoured to obtain a final sample as representative as possible with respect to the socio-demographic composition of the local population. Consequently, the consultative process was based on three important activities, each aimed at a precise objective: the first targeted younger individuals (primary and secondary school students), the second targeted an intermediate age bracket, while the third targeted the elderly. Each of these activities used its own method chosen according to its (alleged) effectiveness in targeting the reference population. Traditional questionnaires were distributed directly to students and the elderly. Instead, a virtual questionnaire for the intermediate age bracket was circulated to web-based communities. The idea of circulating a virtual questionnaire on the web was initially inspired by considerations regarding sample representativity. Indeed, the idea to include young and old members of society was developed because this made it possible to conduct the experiment all over the territory; instead, given the substantial numbers of participants in the other age brackets this would have been more problematic. This decision to use this tool resulted, on one hand, in widespread regional distribution and, on the other, in the rapid circulation of information, and equally rapid elaboration of the answers. As regards the distribution method, a decision was taken to use one of the best known social networks: Facebook. The choice fell on Facebook because it is a widely used web channel, not only numerically (number of hits), but also temporally (frequency of hits), making it possible to distribute the questionnaire in a relatively short space of time. In addition, using Facebook to distribute information is not an entirely new procedure. In France and Belgium, for example, the social network has recently been used to "advertise" several participative activities associated with river contracts: a number of pages were created (Contrat de rivière Haine, Contrat de rivière Senne, Contrat di rivière transfrontalier du Segre en Cerdagne, etc.) and are used today as a means of interactive communication between administrators and citizens involved in contract management activities. The consultation activities for the Tinella lasted approximately seven weeks; the final sample registered 339 individuals, or 2.1% of the reference population (16,226 inhabitants), fully in line with average participation rates: 1-2% in Spain (Ganuza, 2006) and Italy (Bobbio, Pomatto, 2007).

Figure 2 shows that the most representative sample was the intermediate age category, with decidedly low margins which are of little importance (the highest was 5.4%). On the other hand, for the youngest (0-13) and the oldest individuals (over 60) there was a difference in the gap between the population and the sample. In this case, the younger were more numerous in the sample because, despite an effort to keep the number of questionnaires to students to a minimum, the six school sections (87 total students) actually represented a substantial part of the sample. The elderly represented a second distortion since they are hardly represented in the final sample; as mentioned earlier, this is due to the fact that the elderly find it more difficult to participate using the web; the experiment conducted across the region allowed the questionnaire, within the timeframe available, to be submitted to 33 individuals (while with a more "balanced" sample, this figure should have been more than double).

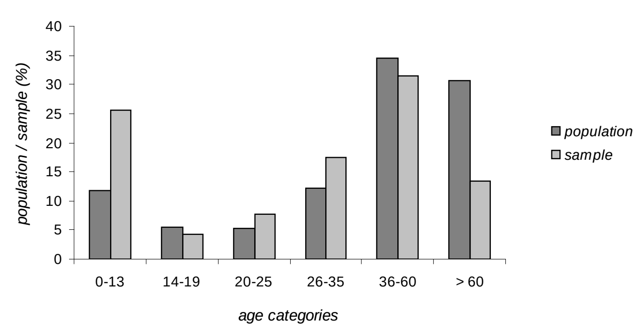


Figure 2 - Percentage distribution of population and sample by age categories.

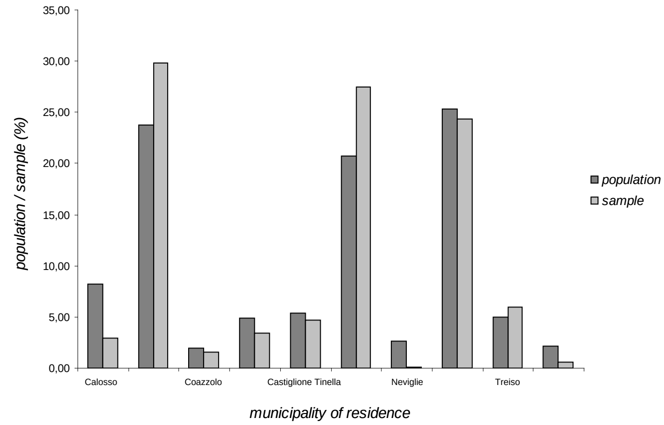


Figure 3 - Percentage distribution of population and sample by municipality of residence.

The final sample is representative of the population also with respect to the spatial distribution of responses (Figure 3). The ratio for the various municipalities of residence in question was definitely positive; the margin between one and the other was roughly 1%. On the other hand, the margin was higher, almost approximately 5%, just for several other municipalities.

A decision was taken to divide the survey content of each questionnaire into three sections; the aim of each section was to understand how citizens - and therefore the local community as a whole - tackle a particularly important topic in the construction of the project. The first part focused on the "perception of the fluvial environment" in order to understand what image the inhabitants associate with the river element in terms of water quality, the cleaning of coastal areas, the genuine nature of the landscape, and risk of overflow. The second section was called "fruition of the fluvial region"; it investigated not only the current levels of regular visits to the fluvial region, but also the possible upgrade pleasure projects which may be implemented by the River Contract. The key objective of the third and final section was to understand "whether" and "to what extent" citizens would be prepared to play an active part in activities to implement the river contract. On the whole, answers indicated the commitment which citizens would be prepared to undertake in the management of specific activities. The answers reflected the "level of commitment" of citizens, in other words, they were willing to participate in activities in the reference region whether or not the prerequisites are in place.

III.d. Planning proposal

The results of the consultation process were closely combined with the technical analyses developed during the expert’s interpretation of the region and then inputted into the proposed strategic and planning proposals (see Table 1) with its five overall objectives: water quality improvement; restoration of water balance; management of hydro-morphological dynamics; regional and landscape upgrade; enjoyment, development and promotion of the region. As regards each planned action, the project implementation methods are indicated in the action plan, as are the individuals to be involved, the relationship between the various actions, and the strategies used to include the population in the process.

The action plan was regionalised in the hypothetical action plan (see Figure 4) allowing experts and citizens to understand the spatial dimension of these actions and how they relate to local planning skills. The same “large area project” could be used as a working hypothesis to complete the process in the next active participation and consultation stage. This may also help to establish the financial and management tools required to implement strategies.

IV- . RESULTS AND CONSIDERATIONS ON PARTICIPATIVE EXPERIMENTATION AND POSSIBLE IMPLEMENTATION

There are two ways to assess the advantages of including social actors in the decision-making process right from the preliminary stages: one is decision content, the other is the relationship with the actors. In actual fact, we refer here to the advantages associated, in a broad sense, with the participative process (Gastil & Levine, 2005; Forester, 2010; Healey, Hillier, 2008; Susskind, 2009; Fung, 2010); however, it is also extremely important to reaffirm them in a contextual framework such as the framework of river contracts.

Participative experiments have been important in urban areas for many years (especially in degraded districts), but the situation is different in rural and suburban regions. In these areas, normally considered by River Contracts, the topics associated with regional planning are discussed - with difficulty - by very diverse individuals. In addition, the strategies proposed by well-known planning tools and regulations are the result of the decisions taken by institutional actors and important social actors directly involved in the processes.

With regard to the relationships between actors, it is logical to think that this first step can bring advantages which are in some ways discernible in the short or medium term (Ciaffi, Mela, 2006). The first advantage is an improvement in the relationship between institutional actors and citizens. Indeed, the start-up of an inclusive process can undoubtedly lead to a rapprochement between all social parties by improving trust between institutional actors and citizens. This process provides two advantages. First of all, it boosts citizens’ trust in institutional actors, while feeling explicitly called upon to express themselves on decisions affecting their territory. On the other hand, institutional actors become increasingly aware that a significant part of the population is attentive to issues relating to a river or, better still, is willing to participate in forms of open dialogue and share ideas about the future landscape of the fluvial region.

Regarding the quality of the decisions concerning large scale and local choices, consultation of citizens primarily means identifying the problems and opportunities of a certain region. It also means making decisions which, in the words of Susskind and Cruikshank (1987), are more equitable by having strong collective visions, wiser by being aware of multiple viewpoints, more efficient due to the reduction in time and costs of the measures, more long-lasting and simpler to implement because they anticipate potential opposition to the measures.

These are characteristics well suited to the objectives proposed by a River Contract. The scope of the contract is to give citizens the opportunity of debating a subject of obvious collective interest, in other words, the management of the water resource, while enabling them to understand the need for the common use of this asset. In this regard, Magnaghi (2006) points out that through participation "it is possible to overcome the dichotomy between "public use" and "private use" of assets, by reintroducing the third concept of "common use". Common use should relate to many components undergoing privatization and removal from collective fruition and management: water, energy, [...], agro-forestry landscapes, urban public spaces, open unbuilt spaces in the sprawling city, the historical road network [...] and so on: in one word, the region (territory?)".

With regard to the advantages brought about by the preliminary start-up of the process, in other words equity and knowledge, the River Contract therefore needs to create close relations between the vision of the experts (always necessary) and that of citizens. This can be achieved through the inclusive process laid down in river contracts, although in practice the process only involves the most influential social and/or economic actors. Starting with sectoral analyses, and the cognitive framework - the basis for dealing with fluvial enhancement with a good technical "conscience" - it is then necessary to evaluate other problems, different viewpoints and alternative approaches which can be identified only through full public consultation.

Furthermore, decisions concerning implementation should be more efficient: in this particular case, opposition to objectives and measures during implementation is less likely if decisions are based on a more inclusive process. It is true, however, that organizing a participative decision-making process requires additional resources compared to ordinary processes, both in terms of time and real costs (for communication or facilitation or accompaniment services). However, potential problems that might occur during implementation should also be considered: these problems might undoubtedly be more likely in the case of traditional processes, and would force decision-makers and experts to abandon some decisions in order to formulate new ones. If on the other hand, as in this particular case, decisions are based on a more inclusive process, these phenomena will be less likely to occur, enabling better management of conflicts. In other words, the time "lost" earlier, is gained later (Bobbio, 2004), and will help to define transformation scenarios that are more long-lasting and simpler to implement.

To increase efficiency and facilitate the implementation of planned measures, focusing citizens' attention on the process and expected results could definitely be an incentive for decision-makers when implementing upgrade measures, also, and above all, the measures which are technically less urgent (Mela, 2002). In this regard it should be said that the river contract is obviously intended as an interdisciplinary tool used to implement measures in an integrated manner. It is clear however that during the process to define specific projects and investments, the most influential decision-makers (the Control Room) will tend to establish a series of intervention priorities which will depend on the financial resources immediately available. It follows that we risk attributing too much importance to the most urgent actions which, needless to say, are those associated with the alleviation of hydrogeologic risk, the cleaning up of water, and management of withdrawals. This is because these aspects are the most pressing at the present time and will be the subject of the "heated" debate which, without a shadow of a doubt, will ensue.

First of all, several institutions (European Commission, Basin Authority, Region) tend to concentrate almost exclusively on these aspects by establishing obligatory standards which have to be implemented before December 2015. Furthermore, since existing organized groups (conservation groups) find it easy to concentrate on ecological issues, they can be moderately influential in the definition of policies when intervening during meetings of the Basin Assembly. Furthermore, ecological aspects should be debated by different categories of individuals (entrepreneurs, farmers, service providers). In other words, there is a risk that the decision-making bodies responsible for the contract focus more on these topics and "postpone" the implementation of certain more remote measures (for example, fruition networks and services upgrades) which in some cases are not included in the action plan schedule. Therefore, if decision- makers are aware that, right from the preliminary phase, a certain number of citizens expect tangible results in the region affected by these changes (cycle/pedestrian paths, leisure areas and equipment, services), then this is an added value for the implementation of the envisaged measures.

However, the small groups of citizens (schools, associations, etc.) involved in the participatory process of the Tinella provided interesting suggestions regarding the enhancement of public services and leisure facilities.

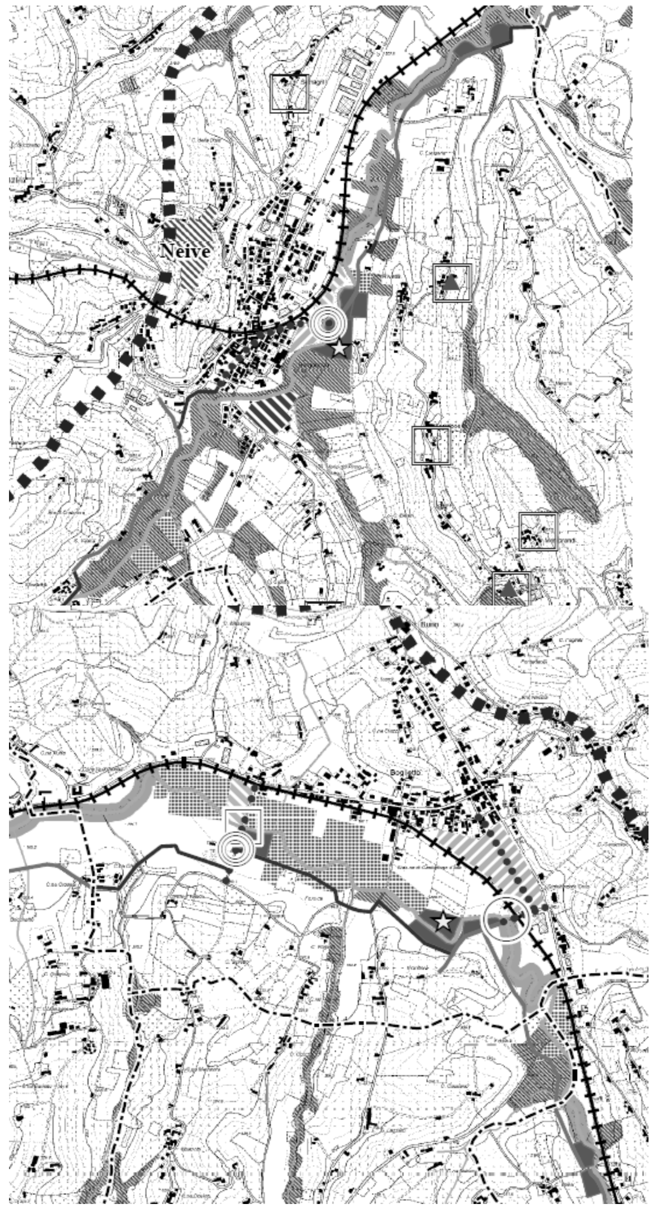
The feasibility of the projects and effectiveness of the measures are further reinforced by a draft plan or general masterplan. Generally speaking, most River Contracts choose not to draft this kind of plan illustrating the effects of the projects and measures on the territory and the outcome of the established objectives. On the other hand, a spatial plan or a masterplan integrating different projects is important during implementation; right from the first ratification of the action plan, it clearly illustrates the technical and economic feasibility of the choices made, and highlights the commitment and responsibility of the institutional actors. It's true that during the drafting phase of the River Contract the masterplan can delay the technical and decision-making process (schedules, agreements), but in the long term it guarantees greater transparency in the decision-making process and also underscores the planning skills and awareness of local administrations. This generates greater awareness of regional resources and also creates synergies between River Contracts and other development proposals such as large scale plans (Voghera, Avidano, 2012). The planning proposal - communicated through a masterplan and translated in several project ideas - also plays an important role in emphasizing the interdisciplinary relationship between objectives, measures and interventions which are not always so obvious in the action plan; this is achieved by facilitating the comprehension of synergies and conflict resolution.

The River Contract only concludes the first stage of the entire planning and spatial design decision-making process. Indeed, it is extremely important that the planned action structure, in addition to the evaluation and monitoring tools, proves to be flexible, in other words, it must adapt to any new requirements that emerge during the process. Certain elements of the cognitive framework may change between the drafting and implementation phase (also due to the updating and adaptation of the Arpa Piedmont analysis system to the European Directive); this includes local urban planning which is experiencing continuous (and rapid) development. The action plan and related project should be a starting point, an opportunity, which each social actor involved in the process can use during consultation in order to establish where and how to proceed. This may include "improving" or radically modifying implementation methods and responsibilities, beginning with the continuation of communication and consultation activities and the start of active participation. In this regard, it is crucial for the process to remain open, flexible, suited to the continuous implementation of strategies, open towards other different urban designs and to the ongoing redefinition of the interests and responsibilities involved. In fact, it is particularly important to define the role of possible territorial scenarios before the following stage of decision-making and shared responsibility with public and private actors (e.g., companies, owners, developers).

Vice versa, too rigid an approach might lead to the formulation of an additional and operationally ineffective planning tool for fluvial regions; this would fuel the skepticism of part of the political and professional milieu in relation to the "usefulness" of the agreements (Susskind, Cruikshank, 1987).

Therefore, the River Contract may produce better results if it is used as a way to create strategies, declare interests, define responsibilities and locate resources (also financial) by interlinking the policies and scenarios of various tools for the management of fluvial regions.

From this point of view, the quality of the evaluation tool also plays a key role – to be used during the entire process - by acting as a continuous reference to verify congruence between the planning decisions (current and future) and the environmental and strategic objectives recognised by the regional planning and programming tools. In view of possible future developments of the proposed model, a suitable programme will be drafted to monitor the quantity and quality of the work still required, to constantly assess the results, and possibly to redesign the way ahead in order to improve final performance.



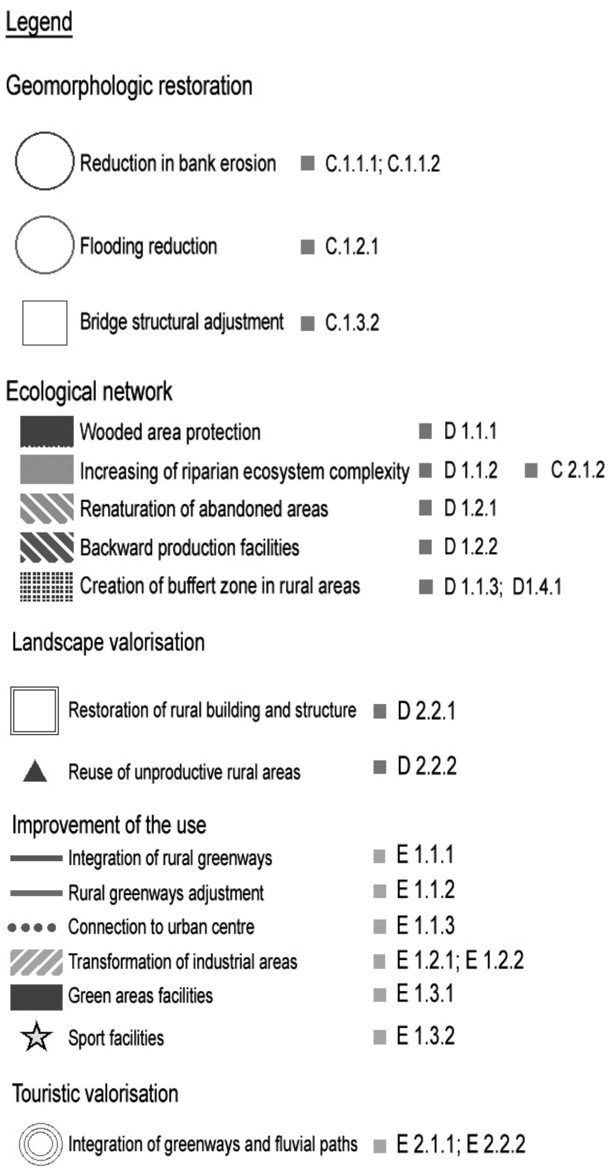


Figure 4 - Planning hypothesis (extracts)

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Author Architect, PhD in Territorial Planning and Local Development, Associate Professor of Urban and Regional Planning - Interuniversity Department of Urban and Regional Studies and Planning (DIST), Politecnico di Torino. Hers main research field and teaching activities deals with Regional and Landscape Planning, and Urban Design with reference to the international and European context. Special attention is focused on sensible environments such as: natural and landscape protected areas, fluvial and rural areas. Author of numerous articles and researches findings in this fields have been published both nationally and internationally; particularly author of the monographs: Culture europee di sostenibilità. Storie e innovazioni nella pianificazione (Gangemi Editore, 2006); After the European Landscape Convention. Policies, Plans and Evaluation, (Alinea Editrice, 2010); with Ingaramo R., Planning and Architecture. Searching for an Approach, (Alinea International, 2012).

Table 1 - Objectives and actions of the action plan (part 1 and 2)

GENERAL STRATEGIES		SPECIFIC STRATEGIES		ACTIONS		SUB-ACTIONS	
A	IMPROVEMENT OF WATER QUALITY	A1	Curb on polluting substances	A1.1	Defionition of specific programs to improve firm works	A1.1.1	Adaptation of the under-sized plants
						A1.1.2	Use of natural depuration techniques
				A1.2	Definition of criteria for the wastewater disposal in case of environmental criticality	A1.2.1	Adaptation of inadequate plants
						A1.2.2	Assessment/mapping of alternative plants in which confer wastewater excess
				A1.3	Definition of criteria for the reduction of vineyard pollutants	A1.3.1	Implementation of regional disposals to reuse wineries effluents in the agricultural
						A1.3.2	Certification of companies operating in the wine trade
B	RESTORATION OF THE WATER BALANCE	B1	Decrease of water taking	B1.1	Management of concessions in relation to water needs	B1.1.1	Revision of issued concessions and assessment of the actual needs
						B1.1.2	Definition of criteria for the issue of new concessions
		B2	Diffused water recovery	B2.1	Stimulation of actions for water recovery throughout the area	B2.1.1	Recovery of natural water storage
						B2.1.2	Collection of rainwater
C	GOVERNMENT OF THE HYDRO-MORPHOLOGICAL DYNAMICS	C1	Geomorphological adjustment	C1.1	Reduction of banks erosion	C1.1.1	Re-immission of sediment in river bed
						C1.1.2	Re-routing of the current
				C1.2	Reduction of the rise of the river bed	C1.2.1	Localized slope adjustment (increase) / sediment removal and transfer of excess sediment
						C1.2.2	Forestation upstream to reduce the supply of sediment downstream
				C1.3	Localized reduction of flood risks	C1.3.1	Strong limit for new buildings within the flooding areas
						C1.3.2	Structural adjustment of the bridges with poor drainage
		C2	Presidium and mainteinance of the region	C2.1	Enhancement of agricultural activity and its role in the management of the river area	C2.1.1	Increase the access to funding channels for environmental good practices
						C2.1.2	Stimulation of riparian manteinance for ecological rehabilitation of the banks

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D	REGIONAL AND LANSCAPE UPGRADING	D1	*Restore of the greenway*	D1.1	Improvement of the vegetation system	D1.1.1	Protection and monitoring of natural woodland
						D1.1.2	Increase of the riparian ecosystems comlexity
						D1.1.3	Mitigation of the impact from intensive agriculture
				D1.2	Recovery of degraded areas	D1.2.1	Renaturation of non-used industrial areas within the river zone
						D1.2.2	Withdrawal of industrial buildings
				D1.3	Reduction of waste in riparian zones and river bed	D1.3.1	Management (programs) of waste in river bed
						D1.3.2	Removal of waste currently found in the riparian zones
				D1.4	Improvement and enhancement of the widespread naturality	D1.4.1	Creation of "green buffers" on the cultivated areas edges
		D2	*Landscape enhancement*	D2.1	Consolidation of the perceptive identity of the river	D2.1.1	Re-forestation of low-density vegetation parts of the river
						D2.1.2	Maintenance (or opening) of small apertures ("holes") for visual enjoyment of the river from rural tracks
						D2.1.3	Maintenance of free visuals between roadway/railway and river
				D2.2	Upgrade of rural villages	D2.2.1	Functional improvement of rural structures
						D2.2.2	Strengthening of the ecological role of farms unproductive surfaces
E	FRUITIVE DEVELOPMENT AND PROMOTION OF THE REGION	E1	*Fruition development*	E1.1	Improvement of the rural trails system for the conscious enjoyment of the landscape	E1.1.1	Adaptation of rural tracks for cycle and pedestrian mobility
						E1.1.2	Interconnection between urban cycle-pedestrian routes and rural trails
				E1.2	Development of town-river relations	E1.2.1	Openings of gates within compact industrial zones (for better accessing to the river area)
						E1.2.2	Adjustment of industrial areas interposed between town and river, according with lanscape compability criteria
				E1.3	Creation of spaces for the enjoyment of the river area	E1.3.1	Creation of small green areas (public or private for public use) in overlookin the river
						E1.3.2	Creation of a area for recreation and sport
		E2	*Tourist enhancement*	E2.1	Tourism development	E2.1.1	Phisical interconnection between the major tourist routes and river trails
						E2.1.2	Realization of a uniform signage system

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Assessment of risks factors in accordance with OHSAS 18001 standard

Adela-Eliza Dumitrascu, and Flavius A. Sârbu

Abstract—In this paper are detailed the theoretically and applicative aspects regarding the risks assessment methodology in order to evaluate the accidents at the work place and occupational health in accordance with ISO 18001. In this respect, in this paper are applied the processes of identification, evaluation, avoidance and control of risk of injury and illness associated to professional activities of the organization. The case study describes the identification and assessment of risk factors specific to the workplace. Also, it is determined the global risk level for analyzed process, and the risks distribution for executant, work task, manufacturing equipment and work environment and it was proposed measures of improvement for the factors to which the risk exceeds the limits of acceptability for the analyzed workplace.

Keywords— Occupational health and safety; Risk factors; Risks assessment; Risk matrix

I. Introduction

ASSESSING the level of security is a systematic examination of all aspects of work undertaken in order to determine the sources that could cause bodily harm, and this forms the basis for substantiation of measures to prevent and control risk. Risk assessment process should be initiated by the management of employment legal person, an individual, in consultation with all concerned at work.

OHSAS 18001:2007 standard is not the solution to all problems of security and health at work of an organization, but offers a practical way to achieve a healthier work and more secure, and continuously improve performance through a comprehensive management [1].

Summary of main changes:

The assessment should be structured to cover all relevant hazards and risks. When risk is identified, the assessment begins by researching primarily the possibility of eliminating it at source.

Assessing the level of security is a systematic examination of all aspects of work undertaken to determine the sources that may cause bodily harm, constituting the basis for substantiation of preventive measures and control risks. The risk assessment work to be initiated by the legal name of the person, in consultation with all those involved in the work.

Assessment should be structured so as to cover all relevant hazards and risks.

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A.-E. Dumitrascu is at the Department of Manufacturing Engineering, "Transilvania" University of Brasov, 29 Eroilor Street, Brasov, Romania (e-mail: dumitrascu_a@unitbv.ro).

F. A. Sârbu is at the Department of Engineering and Industrial Management, "Transilvania" University of Brasov, 29 Eroilor Street, Brasov, Romania (e-mail: sflavius@unitbv.ro).

II. Evaluation Methodology of Risks

• Full identification of risk factors is a form that includes the main categories of risk factors for injury and occupational disease, grouped by Foreground Criterion of the work system (executing task employment, means of production and working environment).

• List of possible consequences of the action of risk factors on the human body is a tool helpful in applying the rating scale of severity of consequences. It includes categories of injury and harm the integrity and health of the body, possible location of consequences in relation with body structure and minimum gravity - maximum generic of consequence.

• Rating scale of severity and likelihood of consequences of action of risk factors on the human body is a grading scale of severity of consequences classes and class probability of their occurrence.

In terms of probability classes, following trials finally chosen the method for adapting standard EU risk assessment on the machine so that it specified intervals instead have considered the following:

- Class 1 of probability: the frequency of the event over 10 years;
- Class 2: frequency of production - every 5÷10 years;
- Class 3: every 2÷5 years;
- Class 4: every 1÷2 years;
- Class 5: once at 1 year ÷ 1 month;
- Class 6: less than once a month.

Rating scale of severity and likelihood of consequences of action of risk factors on human body is presented in table 1.

• Key risk assessment is a table, of which class or classes of severity, and columns - Classes of probability.

With the grid is made effective expression of existing risk analysis system, as the couple gravity - frequency of occurrence.

• Scale of classification of levels of risk / security work, built on the scale of risk assessment is a tool used in assessing the expected risk, respectively the level of security.

In the central area of the form are given explicitly all couples gravity-probability associated risk levels.

• The summary assessment of the workplace is the document summary of all operations by identifying and assessing risks of injury and / or occupational disease.

• proposed measures sheet is a form to centralize the necessary preventive measures implemented, results of job evaluation in terms of risk of injury and occupational disease exist.

There are several variations on this matrix that can be found in the literature [1]–[9]. According to ISO 18001, the scale of risk assessment (risk matrix) presents a combination of severity of consequences and probability of occurrence (table 1). The following risk matrix is used in risk assessment process for analyzed case study, (Table 1).

Table 1. Rating scale of severity and likelihood of consequences

SEVERITY LEVEL		**SEVERITY**
CONSEQUENCES		
1	NEGLIJABLE	– minor consequences reversible disability likely to 3 days calendar (healing without treatment)
2	LOW	– a reversible consequences foreseeable disability 3 - 45 days requiring medical treatment
3	MEDIUM	– consequences reversible disability likely a 45 - 180 days requiring medical treatment and hospitalization
4	HIGH	– irreversible consequences of a reduction of work capacity of up to 50% (Grade III disability)
5	CRITICAL	– irreversible consequences with loss of 50 - 100% of work capacity, but with the possibility of self (disability grade II)
6	CATASTROPHIC	– irreversible consequences with total loss of capacity and capacity for self-employment (disability grade I)
7	HAZARD	– death
LIKELIHOOD LEVEL		**PROBABILITY**
EVENT		
1	EXTREMELY RARE	Probability of producing extremely rare impact **$P < 10^{-1}$/year**
2	IMPROBABLE	Probability of producing very small impact **$10^{-1} < P < 5^{-1}$/ year**
3	RARELY	Probability of producing small impact **$5^{-1} < P < 2^{-1}$/ year**
4	OCCASIONAL	Probability of producing medium impact **$2^{-1} < P < 1^{-1}$/ year**
5	PROBABLE	Probability of producing major impact **1^{-1}/an $< P < 1^{-1}$/ year**
6	FREQUENT	Probability of producing very large impact **$P > 1^{-1}$/ year**

The methodology for evaluation the risks of occupational health and safety consist of following steps:

1. Risk assessment planning;
2. Risks identification;
3. Identification of exposed persons;
4. Identifying types of exposure;
7. Risk assessment (the likelihood and the consequences);
8. Monitoring and control of risks;
9. Setting priorities for action and adoption of security measures;
10. Implementation and application of security measures;
11. Registration of the assessment process;
12. Measurement (assessment) effectiveness;
13. Control (regular or in case of changes in the system):

- Evaluation results retain validity (not required any further action);
- Revision is necessary.

14. Tracking plan for risk assessment.

the unacceptable risks must be treated. The objective of this stage of the risk assessment process is to develop cost effective options for treating the risks.

The options of risk treatment are:

− Avoiding the risk,
− Reducing (mitigating) the risk,
− Transferring (sharing) the risk, and
− Retaining (accepting) the risk.

Avoiding the risk - not undertaking the activity that is likely to trigger the risk.

Reducing the risk: controlling the likelihood of the risk occurring or controlling the impact of the consequences if the risk occurs.

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III. IDENTIFICATION OF RISKS FACTORS

A. *Risk factors own means of production*

• Driver risk factors:

- Tapping the excavator arm during the cutting work;

- The fall of the drum on legs or upper

- Impactor by means of automobiles on during the work in the work area or move to car transport;

- Benches pit work area during the work (vibration, car access, tram, etc.)

- Drop objects, materials, the vehicles moving near the work area or disposed of apartment tenants;

- Project management or particles:

- Stone wheels driven by motor vehicles;

- Particles in the detached concrete or asphalt;

- Recoil caused by the use of drilling tools;

- Jet Oil on accidental breakage of the plant hydraulic excavator - inadequate pressure hoses;

- Direct contact of skin with dangerous areas - cutting, stinging - heads cable, broken glass, sharp objects embedded in the soil;

• Heat risk factors:

- Direct contact of skin with cold metal surfaces to work in winter;

- Working with open flame (lamp and accessories) or development of flame caused by neighboring networks, under pressure - burning heat;

• Electrical risk factors:

- Electrocution by direct touch:

- The absolution cables;

- Achieve accidental remaining blood elements;

- Accidental breaks existing LEA conductors on the same route;

- To maneuver the station and posts TRAFO wrong;

- Electricity:

- Electric indirect touch: the accidental damage to electrical insulation surrounding routes;

- Emergence voltage step: to put down accidental electrical paths in the vicinity of the intervention;

• Chemical risk factors:

- Working with toxic substances (some adhesives sets of sleeves, some grease in sets of sleeves) - chronic intoxication;

- Working with flammable substances: insulation, fuels, lubricants.

B. *Risk Factors own working environment*

• Physical risk factors:

- High temperature air in warm season - work outdoors or in covered pit tent;

- Lowered the air temperature in the cold season - the work may take place until a temperature of -10 ° C;

- Drafts, especially cold season;

- Low level lighting at intervention and high contrast light - dark to work in sunny days;

- Natural disasters - surprise lightning, blizzard, the collapse of trees;

- Dust - dust particles driven by air currents;

• Chemical risk factors:

- Gases, fumes, toxic aerosols in the atmosphere of working environment:

- Gas accessories resulting 3 M and / or RAY CHEM;

- Vapor degreasing of organic solvents;

- Gas density greater than air emissions from transport.

C. *Risk factors own the job:*

• Content:

- Use of existing installation accessories intervention works on the same cable due to advanced state of wear of the plant (there are economic restrictions for the use of new materials);

• Overloading Physical:

- Dynamic Effort:

- Works manual cutting, clearance;

- Manual handling of cables;

- Forced and vicious postures within pits;

• Overloading psychological:

- Rhythm great work and repetitive short cycle operations.

D. *Risk Factors own contractor:*

• Wrongful:

- Removing FUSE MPR on circuits and their connection without the use of devices intended for that purpose;

- Failure distance of 500 mm between the edge of the pit and land result in the cutting;

- Enforcement of connections in memory;

- Use of inappropriate tools (with cutting edge unsharpened);

- There are not indicated and enclose the work areas as required by law in force;

- Travel, stopping in hazardous areas:

- On car access routes;

- Under high load means;

- The way FF and tram;

- Drop the imbalance at the same level, slips, trips - Uneven surfaces covered with ice;

- Falls from height:

- The scale of aluminum;

- The platform telescopic arm;

- The graves of more than 2 m;

- Communications between performer and higher hierarchical steps or between the band members;

• Failure:

- Failure means of protection of equipment (personal protective equipment).

IV. RISKS ASSESSMENT OF OCCUPATIONAL HEALTH AND SAFETY

The process of work which is intended to be examined is the performance of maintenance and repair underground power lines LES 0.4 kV - subscribers, public lighting and L.E.S. medium voltage (6 kV, 20 kV) and operational work of operation (reception facilities in November, check the field construction, putting into service).

The result is specified by “Assessment sheet”, which is observed that the total of 35 risk factors identified (figure 1), only 6 above, as part of the risk, the value of 3, one falling into the category of factors maximum likelihood, one falling into the category of high risk factors and 4 others falling into the category of medium risk factors.

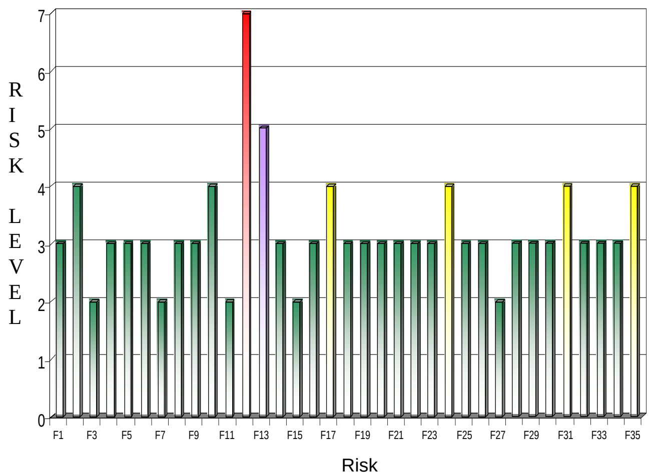

Figure 1. Partial risk levels vs. risk factors

V. Conclusions

The 6 risk factors that are unacceptable are:

• F12 (the partial risk - level 7) by the direct shock: the unlinking cables; achieve accidental elements remaining under tension, the accidental breaking of conductors LEA on the same route, to maneuver the station and wrong positions;

• F13 (partial risk - level 5) electric current:: the electric shock by indirect; emergence voltage step;

• F17 (the partial risk - level 4) lowered the air temperature in cold season;

• F24 (the partial risk - level 4) dynamic effort: work manual digging, clearing, handling and manual cable positions and forced to work in the vicious landfill;

• F31 (the partial risk - level 4) travel, stops in dangerous areas: the ways of auto access; the task of lifting;

• F35 (partial risk - level 4) of non-protective equipment (personal protective equipment).

The percentage of identified risk factors for the work system elements is illustrated in figure 2.

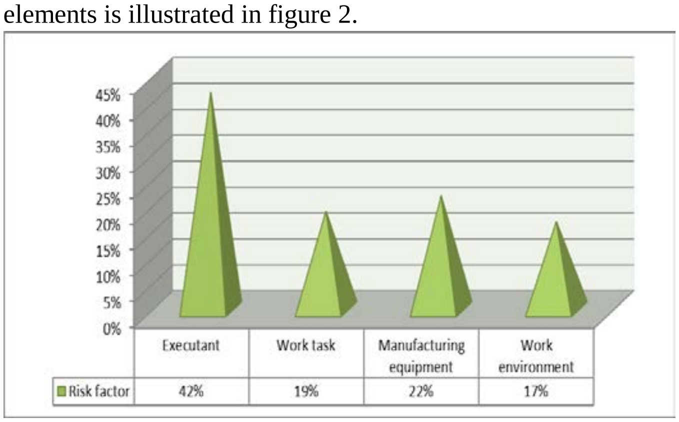

Figure 2. The percentage of identified risk factors

To reduce or eliminate the 6 risk factors (which are unacceptable in the field), are necessary measures presented in the generic "sheet of proposed measures" to workplace. As regards the distribution of risk factors generating sources, the situation is as follows (see figure 3):

- 42.86% of their factors of production;
- 20.00%, environmental factors of own workplace;
- 8.57% load factors own workplace;
- 28.57% own worker factors.

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Legal aspects regarding tax evasion

Diana Gorun

Abstract— Tax fraud is a crime, distinguished by legal tax avoidance, which is defined as the skillful use of the opportunities provided by law. Tax evasion is illegal and it consists of the illicit procedures used by the taxpayer who violates a legal prescription in order not to pay the tax due.

Taxpayers usually respect the limit of their rights and the state cannot defend himself only through a well studied, clear, precise and scientific law. The only guilty of evasion by such means is the legislation.

Keywords—Fiscal obligations, tax evasion, fraud, state budget, VAT, income, illicit procedure

I. Introduction

Failure to pay or attempt to diminish the revenue owed to the state by operation of legislative imperfections or by using varied and ingenious methods is called tax evasion.

Tax evasion is a complex socio-economic phenomenon of the utmost importance that state entities face in ancient times, whose unintended consequences have limited its total eradication is impossible.

The effects of tax evasion have a direct impact on tax incomes, leading to distortions in the market mechanism and contributing to social inequities.

Tax evasion can be defined as all legal and illegal methods by which individuals or legal entities wholly or partly elude taxable matter and failure is willful tax obligations by the taxpayer. [1].

DEX defines the general evasion as escaping from tax obligations. [2].

The law on combating tax evasion in art. 1 defined tax evasion as: theft by any means, or the imposition of taxes, fees, contributions and other amounts owed to the state budget, local budgets, state social insurance budget and special funds by individuals and Romanian or foreign legal persons. [3].

1.1 . Licit and illicit procedures - tax fraud.

1.1.1. Legal or tolerated tax evasion is represented by the actions of the taxpayers to circumvent the law, using a combination unintended by the legislature and therefore permitted by dropping sight. This can be possible by exploiting inaccuracies or gaps due to the law and is rather common especially in eras when new types of businesses or new categories of taxes are initialized. Taxpayers use certain means of exploiting inadequacies of the law, circumventing what is "legal", thereby avoiding the payment of taxes in whole or in part, because of the shortfall of the legislation.

In doing so, taxpayers usually respect the limit of their rights and the state cannot defend himself only through a well studied, clear, precise and scientific law. The only guilty of evasion by such means is the legislation.

In practice based on the facts of tax evasion due to favorable interpretation of the law, they are very diversified, depending on the taxpayer's inventiveness and breadth of the law, but the most commonly used are:

- the practice of some companies to invest part of the profits into procurement of machinery for which the state provides income tax cuts, measure intended to stimulate the accumulation;
- the decrease of taxable income by including the costs of protocol, advertising and publicity;
- the practice of philanthropic donations and sponsorships that have occurred or not and that lowers the tax table thus leading to the theft of part of the income of the entity;
- the establishment of a sinking fund or reserve of an amount higher than economically justified, thus decreasing tax base;
- the taxpayer has the opportunity to exclude from taxable income the expenses related to labor, the training of personnel and also the amounts paid for the contracts of research, whose object priority might be some programs of national interest.

1.1.2. Tax evasion is represented by the legal taxpayer actions around the law by resorting to an unforeseen combination of the legislature, thus "tolerated" by dropping from sight. It is only possible through detection by gaps of the law , which occurs due to the particular case legally possible.

1.1.3. Tax fraud is a crime, distinguished by legal tax avoidance, which is defined as the skillful use of the opportunities provided by law. Tax evasion is illegal and it consists of the illicit procedures used by the taxpayer who violates a legal prescription in order not to pay the tax due. Tax evasion is fraudulent when taxpayer obliged to provide data in support of his declaration resort to concealing taxable object at understatement of taxable amount or using other ways of escaping from the payment of tax due. Fiscal fraud is encountered in practice in many forms, all of which related to the ingenuity of the taxpayer, the legislation at some point about the financial accounting and the opportunities of a tax system. Criminal groups of tax evasion, as in other areas, are established and operate on the principles of company law, following the latter and maximize profits in the shortest time

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possible by using illegal means, especially punished by the criminal law. [4].

II. Problem formulation

2.1. Legal framework is represented by

- Law no. 508/2004 on the establishment, organization and functioning within the Public Ministry of the Directorate for Investigating Organized Crime and Terrorism, published in the Official Gazette no. 1089 of November 23, 2004, with its amendments in force;
- Law no. 218/2002 on the organization and functioning of the Romanian Police, published in the Official Gazette no. 305 of May 9, 2002, with its amendments in force;
- Law no. 161/2003 on certain measures to ensure transparency in the exercise of public dignities, public functions and in business, prevent and punish corruption, published in the Official Gazette no. 279 of April 21, 2003, with its amendments in force;
- Law no. 12/1990 on the protection of the public against illegal commercial activities published in the Official Gazette no. 133 of June 20, 1991, with its amendments in force.

2.2. Types of tax and fiscal fraud

2.2.2. Tax fraud by avoiding the paying of income tax

This can occur through one or more of the following procedures:

- reduction of the tax base by including the cost of expenses without documentation and without legal basis (penalties, preliminary expenses, etc.);
- registration of oversized or above the permissible limit of spending bills (depreciation, social and cultural costs, travelling expenses, protocol, reserve funds, etc.);
- increase of interest expenses on loans for investment, economic situation encountered at state-owned or majority state-owned commercial agencies;
- deduction of personal expenses for the members and interest on loans granted by employers to their own society;
- not recording into accounting of the full revenues, either by primary evidence documents or by inclusion in documents delivery of some prices which are below those prevailing real;
- transfer taxable income to newly created companies in the same group, under the period of exemption from profit tax, along with record losses by the parent company;
- incorrect classification periods of relief, especially when simultaneously conducting several different periods of relief activities as well, and failure statutory operating condition, with the same activity, a period equal to that which has been granted exemption;
- the profit tax by applying inadequate legal provisions, especially with regard to the incorrect calculation of uncollected invoices and balance coefficient, as well as the reduction of tax on reinvested profit;
- failure to register accounting differences established by the audit or even tax obligations due.

2.2.3. Tax evasion on VAT

This can occur through one or more of the following procedures:

- incorrect application of the system of deductions. Such deviations were noted from economic units carrying out both transactions subject to VAT and exempt transactions, by observing the provisions in the calculation report in goods and services involved in the realization of taxable transactions and in this way influencing tax value added tax (VAT). There are cases where deductions are basically based on value added through illegal documents. The authorities have found cases of double deductions as a result of repeated entry of invoices journals and even shopping VAT deductions from documents belonging to other companies. There are also cases where the right to deduct is exercised in advance;
- tax fraud by using violation of intellectual property rights. Regarding to this aspect, in 2007 the European Parliament proposed a measure that would punish serious violations of regulations governing intellectual property rights, trademarks, industrial design, with up to four years' imprisonment and a fine of up to 300,000 euro. With this decision, the bloc aims to suppress production of counterfeit and pirated goods organized, especially in areas that can affect health, public order and national security.

We believe that issues of tax fraud in the field of intellectual property are among the most important violations of legislation, especially that last time it was found that huge amounts of money from infringement of intellectual property rights are used to feed terrorist groups.

The notion of "fictitious operations" may consist in expenses that did not actually existed or that are larger than actual or expenses for which no supporting evidence, but which are recorded in legal documents. A highlight fictitious operations is to record certain transactions that did not exist in legal documents, such as expenses that are not based on real transactions. Fictitious transactions can be done either by drawing up documents on a fictitious transaction, followed by its entry into legal documents or by registering legal right documents a fictitious operations for which there is no supporting document. [5].

2.2.4. Tax fraud by using "ghost" companies

The lack of legal regulations, combined with the lack of cooperation between institutions responsible with registration of new companies and with tax registration are speculated by various merchants who established many innovative companies, which although seemingly works legally cannot be identified at the premises declared. These companies do exist virtually, but they are not seen, practically they are nonexistent. Therefore, they are not in the real economy from the surface, the favorite place of action constituting one illicit economy. Such companies are major players in the field of tax evasion, fraud bankruptcy, other offenses considered as generating dirty money.

The establishment, registration and operation of phantom firms is not illegal in itself, but they are created with malicious purposes, to circumvent the law, mostly in the tax field. They are also often created especially for trading large illegal business, after some time they disappear from the business world. The shareholders also proceed in setting up other companies, used for the same purpose, which are later abandoned again and so on.

The existence of a high level of illicit economy is primarily the result of the operation of such companies.

2.2.5. Fiscal fraud by avoiding excise

The Tax and Fiscal Authorities must verify the followings:

- if the operator conducted operations (production, import or marketing) of excisable products, their legality;
- if the tax base was established according to the legal right for each particular job;
- if the used rates are legal and have been properly applied in the tax base;
- if the benefits have been established strictly in accordance with the provisions of law;
- if the products have been exported and their value returned from the outside country and if the operator has calculated and paid to the state budget according to established legal duty for products shipped;
- if the payment budget was done within the legal deadline, and for imports from the date of payment of customs duties;
- if the statement has been prepared in compliance with the law and submitted within the tax authorities etc. [6].

III. Problem Solution

The violation of these provisions constitutes a crime against the state and is punishable by criminal law, as follows:

3.1. The offense provided by article no. 9 paragraph 1b of Law no. 241/2005 consists in holding intentionally of amounts representing taxes or contributions withheld at source.

The act of the defendant to omit highlighting the company accounting documents of commercial operations performed and perpetuated over a period of one year, the act of the defendant to fail to fulfill its legal obligations repeatedly in order to escape the tax compliance, represents the offense called tax fraud which is provided by article no. 9 paragraph 1b of Law no. 241/2005, through repeated actions. [7].

In the new Romanian Criminal Code offense continued unity is governed by article no. 35 paragraph 1: " The offense is continued when a person commits at different times, but by having the same thing in mind and by using similar methods and against the same passive subject, actions or inactions that each one represents as itself the content the same offense" .

In one case, the defendant G.G. was sentenced to 1 year and 6 months imprisonment for the offense of tax evasion under the provisions of article no. 9 paragraph 1b of Law no. 241/2005, and by using the provisions of article no. 41 paragraph 2 of Criminal Code. He was also sentenced to 10 months imprisonment for the offense of intentionally restraint amounts representing taxes, provided by article no. 6 of Law no. 241/2005. Therefore, the defendant G. G. was obliged to execute the sentence of 1 year and 6 months imprisonment. In order to cover the damage caused to the Romanian state, the defendant G. G. was ordered to pay the sum of 9,259 lei, with legal delay increases until full payment. [8].

To decide this way, the court observed that, according to the documents, the defendant did not record incomes in 2010 and 2011 as the authorized person, thereby avoiding the payment of income tax amounting to 2.095 lei; the defendant also detained and did not pay to the state budget the amount corresponding to his income. This represents the offense of tax evasion under the provisions of article no. 9 paragraph 1b of Law no. 241/2005, with the applying of the provisions of article no. 41 paragraph 2 of Criminal Code.

In terms of the objective side, the act was committed by omission, exactly by the failure to highlight in the company accounting documents of commercial operations performed and real incomes, conduct which took place over a period of one year, the defendant by his own choice failing in achieving same criminal judgments, to fulfill his legal obligations, in order to escape the tax obligations.

In sentencing the defendant, the court considered the concrete social threat of committed acts, determined by the severity of the damage to social values protected by law, which are patrimonial values, the actual amounts that were not paid to the state budget, and subjective elements, the fact that the defendant acted continuously, being able to appreciate on its criminal behavior.

In another case, the defendant O.M.I. was convicted, under the provisions of article no. 9 paragraph 1c and paragraph 2 of Law no. 241/2005, applying article no. 41 paragraph 2 Criminal Code, to a penalty of six years in prison and three years additional punishment provided by article no. 64 paragraph 1a, b and c of the Criminal Code.

Moreover, the defendant was ordered to pay to the civil party ANAF (which is the Fiscal Authority, representing the state), the amount of 1.373.352 lei with interest and penalties related to payment of the flow, as civil damages.

To decide like this, the court took into account that the defendant O.M.I. acted as the administrator of SC L. Ltd., between February 2008 and March 2009, buying from several individuals many animals at low prices without VAT registered and bookkeeping entries at lower prices and with VAT. This way, the defendant illegally deducted and collected VAT from beneficiaries. The accused O.M.I. defrauded the consolidated budget of state by reducing the tax base in

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accounting and by making inputs at higher prices than those really paid.

By auditing report carried out during the trial - following the verification documentation outlined in the company accounts administered by the defendant - it was established that, by registering false operations, the damage caused to the state budget for the period was 1,373,352 lei. For the period February 2008 - March 2009, the tax inspection authority established a VAT rate of 546,630 lei, without giving the right to deduct from invoices issued by a freight company that delivered by SC L. SRL. Also, the expert report established a value of 319.314 lei, being accepted right to deduct VAT invoices for closed societies. [9].

The trial court held that the injury determined by the expert report is correct, as these fictitious operations were recorded in the period, without being able to exist any right to deduct VAT on any of operations.

The act of the defendant was placed under the provisions of article no. 9 paragraph 1c and paragraph 2 of Law no. 241/2005, applying article no. 41 paragraph 2 of Criminal Code.

Another case is about tax evasion through repeated actions. Incomes derived from a commercial contract for services, not included in the accounting documents constitutes the offense of tax evasion under the provisions of article no. 9 paragraph 1b of Law no. 241/2005, applying article no. 41 paragraph 2 of Criminal Code.

The act of the defendant to omit the evidence in company accounting documents of all benefits obtained from a commercial contract for services, while prolonged omission of the same criminal result, represents the constitutive elements of the offense of repeated tax evasion.

The defendant argued that in this case it is a contract for entrepreneurs, but did not prove its existence. It is therefore unjustified claim that unreported income were obtained from a civil contract for entrepreneurs, while not proved neither its existence nor any payments made for this contract. [10].

Based on article no. 334 of Criminal Procedure Code, in another case the Court has changed the legal classification of the offense against the defendant D.I., eliminating the application of article no. 13 of Criminal Code. Consequently, the defendant was sentenced to 1 year imprisonment for committing repeated tax evasion acts, provided by article 9 paragrah 1b of Law no. 241/2005, applying aricle no. 41 paragraph 2 of Criminal Code.

According to article no. 998, 999 of the former Romanian Civil Code, it was admitted the civil action of the civil party Romanian State, represented by the Ministry of Public Finance - ANAF. So, the defendant was ordered to pay the amount of 53,675.88 lei civil, plus interest until the effective date of payment. [11].

To decide so, the trial court found that the act of the defendant D.I., which, as manager of SC IC Ltd., under the same criminal intention, in 2005-2007, failed highlighting a part of the incomes obtained under the services agreement, in order to avoid payment of tax obligations, thus causing damage to the state budget in the amount of 53,675.88 lei, has the constitutive elements of the offense of tax evasion through repeated acts. This was committed by the omission of declaring the income in whole or in part, in the accounting or other legal documents, business operations in order to escape from the payment of tax obligations, provided and punished by article no. 9 paragraph 1b of Law no. 241/2005, applying article no. 41 paragraph 2 of Criminal Code.

On the civil side of the case, it was admitted the civil action of the civil party Romanian State, through the Ministry of Public Finance - ANAF, and the defendant was ordered to pay the sum of 53,675.88 lei civil, plus interest until the effective date of settlement of the amount due.

The offense provided by article no. 6 of Law no. 241/2005 consists in the action of retention of amounts representing fiscal contributions. Therefore, the act of retaining and not to spill the state budget amounts of taxes has the constitutive elements of the offense provided by article no. 6.

On the other hand, the offense of tax evasion prescribed by article no. 9 paragraph 1b of Law no. 241/2005 consists in the failure to register the amounts in the accounts, with the condition of existence of a real patrimonial damage. In the absence of the damage caused to the state budget, there is no crime, so the legal consequence is the acquittal for the defendant.

According to the provisions of article no. 9 paragraph 1b of Law no. 241/2005, the defendant cannot be sentenced for tax evasion because it lacks one of the constitutive elements of the offense. According to the text of the law, the defendant's act should make a damage for state budget so that we are in the presence of this crime. [12].

Pronouncing the criminal sentence no. 46/2012, The County Court convicted the defendant RVC to the payment of an amount of 500 lei as for the criminal offense of tax evasion provided and punished by article no. 6 of Law no. 241/2005, applying the provisions of article 320^{1} of Criminal Procedure Code. In the mean time, based on article no. 11 paragraph 2a in relation to article no. 10 paragraph 1d of Criminal Procedure Code, the defendant R.V.C. was acquitted for tax evasion offense provided by article no. 9 paragraph 1b of Law no. 241/2005. He was obliged to pay 9.358 euro to the civil party ANAF.

To deliver this solution, the court first held that the prosecutor's indictment of the Prosecutor's Office was set in motion early in criminal proceedings and to put the prosecution of the defendant R.V.C. for committing tax evasion according to article no. 9 paragraph 1b and article no. 6 of Law no. 241/2005.

The defendant, as the administrator at SC RCC Ltd., during December 2008 - August 2010, ordered the use of amounts withheld and consolidated for state budget for other purposes (bill payment, payment machines) and not recorded in the accounts the amount of 5.400 lei.

Analyzing the documents and papers in the case file, the court stated the following facts:

The defendant, as manager of SC RCC Ltd, has retained the employees and not transferred to the state budget in the period individual contribution to social insurance, the individual contribution of employees' unemployment insurance, health insurance contributions and income tax wages.

The defendant admitted committing the offense, he asked the court to apply the provisions of art. 320 [1] of Criminal Procedure Code and tried to recover some of the damage. [13]. The court, using the legal criteria for a penalty, referring to the defendant and his procedural position of recognition, his manifested disposal to recover the damage caused by his acts, established that the purpose of the punishment, as required by article no. 52 of Romanian Criminal Code, can be reached by applying a criminal fine in the amount of 500 lei.

Regarding the tax evasion offense provided by article no. 9 paragraph 1b of Law no. 241/2005, the court found that it lacks one of the elements of the offense. According to the legal text of the law criminalizing the act committed, the offense is an offense only if a real patrimonial damage occurred, or by not recording in the accounts of the amount of 5,400 lei, the state budget was not harmed, so that we are not in the presence of a crime.

The provisions of article no. 9 paragraph 1b of Law no. 241/2005 are also related to payment of withholding tax and avoiding double taxation.

According to Law no. 85/1999, which ratified the Convention between Romania and the Kingdom of the Netherlands for the avoidance of double taxation and prevention of fiscal evasion with respect to taxes on income and on capital and the Protocol attached, the profits of an enterprise of a Contracting State shall be taxable only in that State, unless the enterprise carries on a business in the other Contracting State through a permanent establishment situated therein.

In one case, the defendant tried to justify not fulfilling the obligation of payment fiscal taxes by using a document from the Netherlands with payment of the tax, but which indicated that the company would have paid tax obligations for the period during January, 1 2002 - December, 31 2003. This cannot be considered as payments for the company in Romania because here it took place between January, 1 2003 - November, 29 2004. Therefore, the defendant did no evidence of payment of the tax either in Romania or in the Netherlands. [14].

In another case, the court convicted the defendant V.R.H. to a penalty of 1 year imprisonment for the offense of bad faith use of the goods of society, offense under the provisions of article no. 272 paragraph 1 of Law no. 31/1990. [15].

The defendant committed the crimes - fraud, tax evasion and bad faith use of the property or loan company interest.

However, the incorrect determination by the defendant of VAT (value added tax) - calculated only on the margin, not on the sale price of some goods - which are recorded in the accounting documents of the society, isn't a tax fraud. The national tax authorities must establish the correct amount of the sums due in respect of VAT.

The correct determining of VAT is a fiscal matter, without being the offense of tax evasion according to article no. 9 paragraph 1b of Law no. 241/2005. [16].

Tax evasion through repeated acts. Precautionary measures

Under the provisions of article no. 11 of Law no. 241/2005 , if there was committed an offense of fiscal nature, it is necessary to take precautionary measures. According to article no. 163 of Criminal Procedure Code, for precautionary measures it is necessary to risk personal assets that could ensure recovery of damages to be disposed of or hidden, in order to avoid civil liability. It also required the establishment of a seizure, identifying the assets belonging to the person against whom was instituted a protective measure and achieving the purpose of an inventory report. [17].

The new Criminal Procedure Code (article no. 249), regulation of precautionary measures is similar to the previous code (article no. 163): "(1) The prosecutor, during prosecution, preliminary chamber judge or court, ex officio or at the request of the prosecutor, the preliminary chamber procedure or during trial, may take precautionary measures by ordinance or, where appropriate, reasoned ruling to prevent concealment, destruction, alienation or circumvent the tracking of goods that can be under special confiscation or extended confiscation or which may serve to enforcement of the fine or legal costs or to repair the damage caused by the offense. (2) Precautionary measures consist of unavailability of movable and immovable property … (3) Precautionary measures for the enforcement of the fine can be taken only on goods belonging to the suspect or defendant. (4) Special precautionary measures in order to seize or extended confiscation can take over the assets of the suspect or defendant or other persons to whom the property or possession of the goods are to be confiscated. (5) Precautionary measures to repair the damage caused by the offense and the enforcement of the legal costs may be taken over the assets of the suspect or the accused and the person civilly responsible, up to their probable value. (6) Precautionary measures in paragraph 5 may take over the prosecution, the preliminary chamber procedure and judgment, and at the request of the civil party. Precautionary measures taken ex officio by the judiciary in paragraph 1 may use the civil party. (7) Precautionary measures taken under paragraph 1 are required if the injured person is a person without legal capacity or with limited legal capacity. (8) There cannot be seized goods belonging to authority or another public or public persons or property exempted by law".

In connection with tax evasion, people organized into criminal groups commit acts such as fraud or cheating, punished by the provisions of article no. 215 of the previous Criminal Code and of article no. 244 of new Romanian Criminal Code.

In analyzing the existence or nonexistence of this crime, the court first found that should be considered unanimous order respected by the parties that are already in a criminal group.

In the case, the defendants did not intend to deceive each other as parts of those contracts, but together, by using apparently a legal way to deceive third parties, the creditors.

According to the first instance court, the defendants were formed in a group gathered by the idea of committing offenses of the same or different kind. From this point of view, it should not be given a limited interpretation of the offense of fraud or cheating, meaning that should not be pursued if either party was really deceived or not. What it must be considered is the intention to fraud or to cheat the creditors, either they are individuals or the authorities of state.

In fact, the very definition of the crime provided by article no. 8 of Law no. 39/2003 requires the initiation or constitution or joining or supporting any form of a group in order "to commit crimes," the purpose of the present case representing cheating.

Either the prosecution or the court have claimed that the defendants, by using the sale-purchase contract itself of some companies recorded the state budget have committed a crime, as long as there is incriminated by criminal law, but interests the purpose of deceiving of third parties, the creditors, to no longer pay the debts, even if the creditor is the State, represented by the General Institution of Public Finance or Labour Inspectorate, banks or even individuals. [18].

IV. Conclusion

The analysis of the above cases make clear that tax evasions are generally committed repeatedly, the persons committing this type of offenses trying constantly to avoid tax payment.

This situation is possible due to legislative gaps, which as soon as possible should be corrected, according to the European legislation.

Combating fraud and tax evasion is an objective of the National Defense Strategy of Romania in the context of global crisis.

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[9] Galati Court of Justice, Penal Division, decision no. 269/07.05.2012.

[10] Highest Court of Justice, Penal Division, decision no. 943/27.03.2012

[11] Mures Court of Justice, Penal Division, decision no. 95/23.06.2011

[12] Highest Court of Justice, Penal Division, decision no. 117/16.01.2013

[13] Article no. 320 [1] of Criminal Procedure Code, provides Judgment if pleading guilty. Until the start of the judicial inquiry, the defendant may declare personal or authentic document that acknowledges committing the facts found in the document instituting the proceedings and to make judgment calls based on the evidence in the prosecution stage. The judgment can take place only on the evidence given during the criminal prosecution only if the defendant declares that fully acknowledges the facts established in the document instituting the proceedings and does not require the taking of evidence, except the documents mitigating circumstances that may be given to this hearing.

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Aspects regarding the conception of an air quality control system of the vehicles with the recovery of the energy from the ventilation air

D. Constantin

Abstract—This paper aims at proposing a ventilation system in motor vehicles on the one hand to ensure a minimum intake of fresh air in order to keep some air quality parameters (carbon dioxide), and on the other hand offer the possibility of recovering a parts of the energy consumed for heating / cooling the cabin air.

Keywords— Energy recover ventilation system, carbon dioxide, energy, ventilation.

I. Introduction

The concern for maintaining a healthy and comfortable indoor/ inside air is no longer the attribute of Estate builders but it also begins to be object of interest for car manufacturers. The breathing air inside the passenger compartment of a vehicle can affect alertness and the ability of make a decision of the drivers and sometimes can jeopardize the children's health, the elderly passengers or the suffering people from vehicles.

Maintaining a clean, fresh air is closely related to the vehicle's fuel consumption, the costs involved in such consumption and in the case of electric vehicles to the distance it can travel as a result of energetic availability of the vehicle.

Electric vehicles are a challenge for the car manufacturers which on the one hand are seeking technical solutions to increase their energy independence and, on the other hand try to provide comfort parameters and air quality in the cabin

From the desire to save energy, in order to increase the number of kilometers traveled, electric vehicles drivers tend to use more often recirculation of the air inside the vehicle compared to drivers of conventional heat engines equipped cars. Their option is fully motivated by reducing energy consumption, used for cooling (in summer) or heating the air in winter. But if the air inside a car is recirculated, it is not sufficiently ventilated with fresh air, and the presence of people in vehicles (their breath) leads to degradation of air quality in such a way as to affect the concentration and reactions necessary for safe driving.

Existing studies highlight a link between carbon dioxide concentration and its effects on both health and performances and also on the perception of the state of comfort. These effects on health are highlighted by studies of Erdmann and Apte about sick building syndrome in relation with CO_2 [1], by studies of Chao about respiratory symptoms [2] and by studies of Simon, about asthma in relation with CO_2 [3]. Regarding the effects of carbon dioxide on performances the studies highlight the significant correlations between increasing carbon dioxide levels and decrease performance (% of identified errors) in a reading test [4] and a computer test [5]. Norback, Smedje and Wargocki obtained significant results between CO2 reduction and the perceptions of air quality, specifically in connection with the freshness of the air [6]-[8].

Studies conducted on buildings highlight the role of mechanical ventilation in maintaining air quality. The comfort ventilation with heat recuperation seduced by its contribution to the comfort and the quality of indoor air but by the savings in heating it causes (up 30%).

Heat exchangers are essential in energy management policy given their increasingly higher importance in the energy conservation field, recovery conversion and use of new energy sources. Appreciation of the heat exchangers comes from the direction of environmental concerns, thermal pollution attenuation concerns, air pollution, water pollution and waste disposal.

Through the ventilation or treatment air system are carried large amounts of air, air that has a high caloric/ thermal level. When arriving at comfort level, for reasons of ensuring air quality, the air is rejected outdoor for the introduction of new air. But this rejected air has a higher energy level than the outside air which is introduced inside.

A heat exchanger allows the extracted air to yield its heat to the new air, which is preheated without mixing the the two air streams. Heat recovery through the use of double flow controlled mechanical ventilation leads to considerable savings for heating (or cooling) the air, while contributing to the comfort and air quality of an indoors/ closed environment.

The main criteria to be taken into account in the conception of a ventilation system (CETIAT, 2001) are related to: occupants' needs (air quality), maintaining comfortable environmental conditions (hydrothermal comfort, acoustic

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D. Constantin is with the Politehnica Unibersity of Timisoara Romania (corresponding author e-mail: doru.constantin@ upt.ro).

comfort), and economic regardings (investment and operating costs).

II. METHOD

Starting from the above mentioned issues we present the objectives of this study:

- The concept of an air quality control system based on the level of carbon dioxide produced by the occupants of an electric vehicle
- Proposing a ventilation system of an electric vehicle that uses the recovery of energy from the air removed
- Determination of the energy recovered when using a double flow heat exchanger air-to-air exhaust ventilation (80% efficiency) on a Renault ZOE electric car.

A. *Conduct of the study*

In order to establish the life/ duration of the forced ventilation usage we carried out to measure the carbon dioxide levels form the respiration accumulated from the occupants of an electric vehicle

Measurements of carbon dioxide levels were carried out in Renault ZOE cars, once with and the vehicle stationary and once with recirculation and ventilation on .

To determine the recovered energy, air flow measurements had also been madeyou submit your final version, after your paper has been accepted, prepare it in two-column format.

B. *Study population*

Measuring the carbon dioxide accumulated from the occupants breathing of an electric vehicle has required the measurement with one, two, three or four occupants of the vehicle, in two recording situations, namely in stationary position with air recirculation on or off. The Participants in this study was [(1 + 2 + 3 + 4) x2]. All participants signed an Informed Consent before participated in research where they were informed about the purpose of the study, the procedure to be undergone, and the potential risks and benefits of participation.

C. *Vehicle instrumentation*

Carbon dioxide measurements were made with a machine Trotec Data logger Air Quality CO2 BZ30 with this technical data: CO2 sensor- NDIR (non-dispersive infrared); carbon dioxide measuring range: 0 to 9999 ppm CO2; resolution (precision) CO2: 1 ppm (± 75 ppm or ± 5% of measured value); measuring range: 2 seconds; readings memory: 50000 measured values. A zero calibration was applied prior to every use.

Measurements were made with wind anemometer TA300. Anemometer TA300 straight probe - is a hot wire professional anemometer for accurate measuring of air speed, air temperature and air flow volume and has the following technical data: fan speed (m / s): Measuring range: 0.1 - 25.0; Accuracy: ± 5% of measuring value + 1 unit; Resolution: 0.01; The principle of measurement: hot wire; The volume of airflow (m^3 / min | ft^3 / min): Measuring range: 0.001 to 999,000

III. RESULTS

The ventilation system of a vehicle must be designed in such a way that on the one hand to ensure a minimum intake of fresh air in order to keep a number of air quality parameters, and on the other hand to offer the possibility of recovering a part of the energy consumed for heating / air cooling of the cabin.

A. *Adjusting the air quality inside the vehicle depending on CO2 levels and on the number of occupants of the vehicle of the study*

The interest and concerns of the car manufacturers are oriented more towards capturing some phenomena outside the cabin. For example, many vehicle models have rain and light sensors so in poor visibility or rain, the headlights and wipers start automatically.

Determination of the time in which CO2 level reaches the limit that may affect driver alertness is an important element in the conception of air quality control and adjustment. Therefore our attention was turned towards to the capture and evaluation of parameters in the cockpit. Thus, we determined the level of CO2 and its evolution by time and the number of passengers

	Stationary vehicle without recycling					Stationary vehicle with recycling			
Level CO_2	Time (in seconds) Renault ZOE				Level CO_2	Time (in seconds) Renault ZOE			
(ppm)	1 pers	2 pers	3 pers	4 pers	(ppm)	1 pers	2 pers	3 pers	4 pers
1.000	230	210	180	80	1.000	270	180	200	100
2.000	635	520	370	220	2.000	725	540	420	250
3.000	1295	960	670	400	3.000	1405	1060	740	450
4.000	2140	1480	970	600	4.000	2280	1600	1120	670
5.000	3120	2170	1310	810	5.000	3290	2360	1590	890

Table 1 - The time in which air of cockpit reaches certain values of CO2 (stationary vehicle without and with recycling)

At a global and European level there are regulations regarding the ventilation of inhabited environments: a level of 1000 -1500 ppm of CO2 under normal occupancy of non-residential buildings. A minimum value of 5000 ppm (9000 mg.m3) was regulated for occupational exposure. The same limit is established in other 19 European countries, also establishing short-term exposures between 10000 and 30000 ppm (Gestis, 2013).

For instance, we will make the following example on Renaul ZOE electric vehicle, we will take as a benchmark the level of 2,000 ppm, a higher level than indicated in the rules of CO2 in residential buildings because for this level, recent research revealed significant changes in attention and capacity of decision (Satish, 2012).

Thus, in a Renaul ZOE when activating the recirculation button, the carbon dioxide reaches a value of 2,000 ppm after about 220-250 seconds (4 minutes) if there are 4 people in the vehicle or after about 700 sec (12 min) if the vehicle is only one person. Values of the CO2 gathered through respiration may vary depending on the number of persons inside the car, their chest capacity and the work they perform etc.

The values presented may be useful indicators in the design of a control and regulating air quality system in which the fresh air forced ventilation must intervene when the carbon dioxide concentration exceeds certain limits that have a potential traffic safety risk.

Taking into consideration the significant volumes of ventilated air (200-600 m3 / h) in extreme conditions (very hot or very cold) forced fresh air ventilation can drastically affect the autonomy of an electric vehicle. Therefore, it requires finding a solution for energy recovery.

B. Energy ventilation system recovery from the air removed

Our solution for recovering energy in an electric vehicle refers to controlled double flow mechanical ventilation that works in terms of compliance parameters of comfort and air quality.

The system components are: outer air intake, air filters for air conditioning loop heating, ventilation and / or air conditioning, air quality detectors, air-to-air heat exchanger, automation and control elements.

We present below a scheme of a heating, ventilation and / or air conditioning system of a vehicle in which has been integrated an air to air heat exchanger. This scheme is a concept scheme in which can be integrated in principle and other equipment depending on the chosen technical solutions.

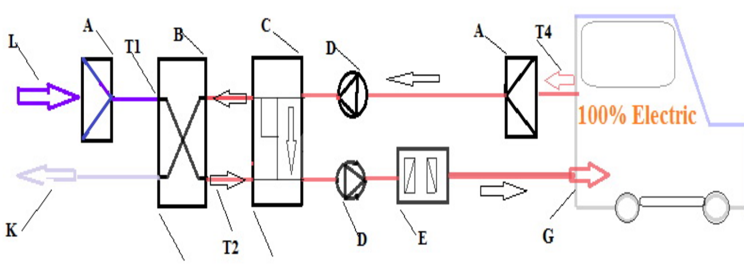

Figure1 - Scheme of a heating, ventilation and / or air conditioning of a vehicle that has been equipped with air to air heat exchanger

L – Outdoor air
A – Air cleaner location
B – Energy recover ventilation system
C – Alternate paths for recirculated air
D – Ventilators
E – Air conditioning unit
G – Supply air for cockit
K – Exhaust air

T1 – temperature outdoor air
T2 – temperature after energy recover ventilation system
T4 – temperature return air from cockpit

C. Determination of recovered energy when using a double flow heat exchanger air-to-air and exhaust ventilation (80% efficiency) at a Renault ZOE electric car mentation

For reasons of rational use of energy present in the following calculations and arguments that support the use of mechanical ventilation double flow of air energy recovery of an electric vehicle rejected.

In 2014, the top countries in selling electric cars in Europe were: first Norway with 18,000 electric vehicles registered, followed by France with 15,000 and Germany with 9,000.

(LeFigaro, 01.30.2015). In the same year in China has registered about 24,000 (Ducamp, 2014).

In the calculations in Table 2, we have chosen to exemplify outside temperatures in winter averages of 4 cities belonging to these top 4 countries with sales of electric cars in the field, namely: Paris (50), Berlin (-20), Oslo (- 9.50), and Harbin, China (-240)

	T1	T4	T2	T4-T1	η	Q	Volumic heat	Debit (m3/h)	ΔTrec= T2-T1	Recoveri Energy (W)
Paris	5	22	18,6	17	0,8	5,78	0,34	275	13,6	1271,6
Berlin	-2	22	17,2	24	0,8	8,16	0,34	275	19,2	1795,2
Oslo	-9,5	22	15,7	31,5	0,8	10,71	0,34	275	25,2	2356,2
Harbin	-24	22	12,8	46	0,8	15,64	0,34	275	36,8	3440,8

Table nr.2 – Energy recovered during one hour, in case of an electric car with the flow of 675m^3/h equipped with a double flow heat exchanger (η=80%)

T1 – temperature outdoor air
T2 – temperature after energy recover ventilation system
T4 – temperature return air from cockpit

To calculate the heat recovery potential of the rejected air to the newly introduced air we have calculated the energy contained in a m3 rejected air outside.

The amount of heat in each m3 of air is equal to the product between the heat volume (0,34Wh / m3.K) and the difference in temperature in degrees:

$Q = 1m^3 \times 0{,}34 Wh/m^3.K \times (T4-T1)$;

Thermic efficiency = T2 – T1 / T4 – T1

Returned energy = Air flow (m3) x 0.34w/m3/k x (T2-T1)

IV. CONCLUSIONS AND DISCUSSION

The autonomy of electric vehicles is a major handicap in selling electric cars. The user needs to know the distance they can travel, where can charge the car and how long each charge. Ensuring air conditioned and warming consume much electricity and drastically reduce the autonomy of electric vehicles and so is limited (approx. 100-150km cars on the market in 2014. In each winter conditions increase with every km of autonomy is of great interest.

The proposed solution can generate a surplus of autonomy in winter conditions of 10-15%, using the warming permanently. This increase is significant and can be a viable solution to ensure passenger comfort without affecting significant distance traveled.

V. ACKNOWLEDGMENT

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Recurrence Plots for understanding vibration of Soils

Silvia García

***Abstract*—**In this paper an alternative vision, based on the Chaos Theory, for the analysis of soils systems oscillating under seismic forces is described. The topological tool, Recurrence Plots RPs, enables recognition and treatment of accelerations recorded in seismological stations located on soil deposits. The chaotic attributes obtained from RPs are interpreted for determining the natural period of vibration. This dynamic non-linear characterization could help in the evolution or reinterpretation of some partially understood aspects of seismic phenomena.

***Keywords*—** Chaos, Earthquakes, Ground motions, Natural Period, Recurrence Plots, Soft soils, Time series analysis.

I. Introduction

The most astounding damages during earthquakes are caused by amplification due to site conditions. Present seismic design practices, which incorporate information from strong motion accelerograms, very seldom reconcile the differences between accelerographic measurements and theoretical predictions. One factor involved, which is recognized as being very influential, is the effect of local conditions.

Scholars studying earthquake damage have observed the modification of earthquake motion by local soil for a long time [1]. The earliest researchers to quantify the problem were the Japanese, the most prominent ones being Sezawa [2],[3] and Kanai [4], [5]. These researchers obtained algebraic expressions in the frequency domain for the surface motion to incident wave ratio from the assumption of stationary, vertically propagating, plane SH waves. Their work is limited to one and two horizontal layers of constant velocity for which they included the visco-elastic behavior and predict important amplification at the natural mode periods of the soil given by

$$T_n = \frac{4H}{V_s(2n-1)} \quad (1)$$

where n is the mode number, H the soil depth and VS is the soil shear wave velocity. Therefore, when Fourier spectra from earthquake accelerograms show important peaks at the natural frequencies of the soil, they are normally considered to be a consequence of the soil amplification of stationary, incoming shear waves.

However, the unexpected collapse of structures due to soil amplification effects, designed according to modern seismic codes during the Mexico 1985, Chile 2010 or Tohoku 2011 earthquakes, for mentioning a few, has taken to review soil amplification theories by deploying high-density accelerograph arrays to have a better understanding of the phenomenon. A key aspect to be elucidated in this topic is the natural periods of soils deposits. In this investigation, an alternative process to estimate the natural period of the vibration from accelerograms is presented: Recurrence Plots RPs [6].

The RPs, a topological technique from the Chaos Theory, enable the treatment of the measured accelerations for efficient interpretation of the movements. In an RPs the dynamics of soils systems vibrating under seismic forces, is reconstructed. Through the projection of the one-dimensional time series to the topological space of much higher dimensions, behaviors and trends, discovered in the reconstructed dimension, are studied. This theoretical approach captures the *true* oscillations (deterministic, chaotic or both) and permits to categorize vibrations by the fundamental period, directly from the accelerations registered. An important contribution of this study is the possibility, by means of RPs, of identifying i) materials highly sensitive to initial conditions, e.g. small differences in directivity, fault mechanism or distance, yield widely diverging outcomes (accelerations) and ii) deterministic or "predictable" stratigraphies, it means, soils systems whose behaviors can be acceptably predicted. Even more interesting is the conclusion about the changes in the conditions of soils masses that could drive the system from determinism to chaos.

II. Analyzing Complex Systems

"*The real voyage of discovery consists not in seeking new lands, but in seeing with new eyes*", M Proust (1871-1922). The strategy in any earthquake&geotechnical conception is designing based on solid criteria, intuitive imagination and emergent learning. Transformation and perpetuation, interaction and coexistence, order and conflict are words that must be integrated in the engineering knowledge because the specialist in this area have to find solutions to the problems faced by the most challenging environment: the nature.

What is needed is an alternative and reliable recording-based approach to explore, to characterize and to quantify earthquake-induced effects. Analysis from a nonlinear

S.R. García is with the Instituto de Ingeniería UNAM, Ciudad Universitaria, Coyoacán, México DF, 04510, MEXICO (corresponding author 5255 56233600; e-mail: sgab@pumas.iingen.unam.mx).

dynamics perspective may yield more fruitful results; still, this is not a straightforward task. Calculation of empirical global nonlinear quantities, such as Lyapunov exponents and fractal dimension, from time series data is known to often yield erroneous results [7],[8]. The literature is replete with examples of poor or erroneous calculations and it has been shown that some popular methods may produce circumspect results [9],[10]. Limited data set size, noise, nonstationarity and intricate dynamics are presented as additional complications. The concerns about the data are compounded by concerns about analysis. It is expected that the following consistent synthesis of the RP-analysis will enable researchers to perform studies more efficiently and more confidently. Thus it is encouraged that first at all, the user familiarizes him with the background and the methodology before attempting any analysis. To make the paper self-contained, some key concepts of Chaos Theory and Recurrence Plots are presented in the following paragraphs.

A. *Recurrence Plots*

Having established that a system contains a chaotic attractor, the process can be modeled by reconstructing the state space. Two methods are available: the method of delays and principal component analysis. We will not give a detailed description of principal component analysis because in this investigation the method of delays is used. Thus, we refer the reader interested on the former method to Broomhead and King [11].

Mutual Information. Frasier and Swinney [12] proposed *mutual information* method to obtain an estimate for delay time, τ [13]. Mutual information provides a general measure for the dependence of two variables, thus, the value of τ for which the mutual information goes to zero is preferred. Additional arguments for choosing the first zero can be found in [14].

Mutual information is a measure found in the field of Information Theory. Let S be a communication system with $s_1, s_2, \ldots, s_n$ a set of possible messages with associated probabilities $P_s(s_1), P_s(s_2), \ldots, P_s(s_n)$.

The entropy H of the system is the average amount of information gained from measuring s and it is defined as

$$H(S) = -\sum_i P_s(s_i) \log P_s(s_i) \quad (2)$$

For a logarithmic base of two, H is measured in bits. Mutual information measures the dependency of $x(t+T)$. Let $[s,q] = [x(t), x(t+T)]$, and consider a coupled system (S,Q). Then, for sent message s and corresponding measurement s_i,

$$H(Q|s_i) = -\sum_i P_{q|s}(q_j|s_j) \log [P_{q|s}(q_j|s_j)] \quad (3)$$
$$= \sum_j \frac{P_{sq}(s_i,q_j)}{P_s(s_i)} \log \frac{P_{sq}(s_i,q_j)}{P_s(s_i)}$$

where $P_{q|s}(q_j|s_i)$ is the probability that a measurement of q will result in q_j, subject to the condition that the measured value of s is s_i. Next we take the average uncertainty of $H(Q|s_i)$ over s_i,

$$H(Q|S) = \sum_i P_s(s_i) H(Q|s_i) \quad (4)$$
$$= -\sum_{ij} P_{sq}(s_i,q_i) \log \frac{P_{sq}(s_i,q_j)}{P_s(s_i)}$$
$$= H(S,Q) - H(s)$$

with

$$H(S,Q) = -\sum_{i,j} P_{sq}(s_i,q_j) \log P_{sq}(s_i,q_j) \quad (5)$$

The reduction of the uncertainty of q by measuring s is called the mutual information $I(S,Q)$ which can be expressed as

$$I(Q,S) = H(Q) - H(Q|S) \quad (6)$$

$$= H(Q) + H(S) - H(S,Q) = I(S,Q) \quad (7)$$

where $H(Q)$ is the uncertainty of q in isolation. If both S and Q are continuous, then

$$I(S,Q) = \int P_{sq}(s,q) \log \frac{P_{sq}(s,q)}{P_s(s) P_q(q)} \, ds \, dq \quad (8)$$

If s and q are different only as a result of noise, then $I(S,Q)$ gives the relative accuracy of the measurements. Thus, it specifies how much information the measurement of x_i provides about x_{i+1} . The mean and variance of the mutual information estimation can be calculated [15]. Although mutual information guarantees decorrelation between x_k and x_{k+t}, and between x_{k+t} and x_{k+2t}, it does not necessary follow that x_k and x_{k+2t} are also uncorrelated [16].

False Nearest Neighborhoods. Mutual information gives an estimate for τ_s, but does not determine the embedding dimension d. The Takens' Theorem [15] states that an m-dimensional attractor will be completely unfolded with no self-crossings if the embedding dimension is chosen larger than $2m$. In this work, the method of false nearest neighbors is used for finding a good value for d [17].

The method is based on the idea that two points close to each other (called neighbors) in dimension d, may in fact not be close at all in dimension $d+1$. This can happen when the lower dimensional system is simply a projection of a higher dimensional system, and it is unable to completely describe the system. Thus, the algorithm searches for "false nearest neighbors" by identifying candidate neighbors, increasing the dimension, and then inspecting the candidate neighbors for false ones. When no false neighbors can be identified, it is assumed that the attractor is completely unfolded and d, at this point, taken as the embedding dimension.

B. *Recurrence Analysis*

The set of nonlinear dynamic techniques, called Nonlinear Time Series Analysis [18], can be classified into metric, dynamical, and topological tools. The metric approach depends on the computation of distances on the system's attractor. The dynamical approach deals with computing the way nearby orbits diverge by means of estimating Lyapunov

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exponents. Topological methods are characterized by the study of the organization of the strange attractor, and they include close returns plots and Recurrence Plots RPs [6].

RPs are intricate and visually appealing. They are also useful for finding hidden correlations in highly complicated data. In this work the RP-analysis is extended, formalized, and systematized in a meaningful way that is based both in theory and experiments and that targets both quantitative and qualitative properties for its geotechnical and seismological application.

In this section, we briefly outline some of the basic features of RPs and describe how an RP of an experimental data set can be generated. The standard first step in this procedure is to reconstruct the dynamics by embedding the one-dimensional time series in a d_E −dimensional reconstruction space using the method of delay coordinates. Given a system whose topological dimension is d, the sampling of a single state variable is equivalent to projecting the d-dimensional phase-space dynamics down onto one axis. Loosely speaking, embedding is akin to “unfolding” those dynamics, albeit on different axes (Packard et al, 1980; [15]). Given a trajectory in the embedded space, finally, one constructs an RP by computing the distance between every pair of points (y_i, y_j) using an appropriate norm and then shading each pixel (i, j) according to that distance. The process of constructing a correct embedding is the subject of a large body of literature and numerous heuristic algorithms and arguments. Abarbanel [20] gives a good summary of this extremely active field.

Delay Coordinate Embedding. To reconstruct the dynamics, we begin with experimental data consisting of a time series:

$$\{x_1, x_2, \dots, x_N\} \tag{9}$$

Delay-coordinate reconstruction of the unobserved and possibly multi-dimensional phase space dynamics from this single observable x is governed by two parameters, embedding dimension d_E and time delay τ. The resultant trajectory in R^{d_E} is:

$$\{y_1, y_2, \dots, y_m\} \tag{10}$$

where $m = N - (d_E - 1)\tau$ and

$$y_k = (x_k, x_{k+\tau}, x_{k+2\tau}, \dots, x_{k+(d_E-1)\tau}) \tag{11}$$

for $k = 1,2, \dots, m$. Note that using d_E=1 merely returns the original time series; one dimensional embedding is equivalent to not embedding at all. Proper choice of d_E and τ is critical to this type of phase-space reconstruction and must therefore be done wisely; only “correct” values of these two parameters yield embeddings that are guaranteed by the Takens Theorem [15] to be topologically equivalent to the original (unobserved) phase-space dynamics.

Assuming that the delay-coordinate embedding has been correctly carried out, it is natural to assume that the RP of a reconstructed trajectory bears great similarity to an RP of the true dynamics. Furthermore, we expect any properties of the reconstructed trajectory inferred from this RP to be true of the underlying system as well. This is, in fact, the rationale behind the standard procedure of embedding the data before constructing a RP.

Constructing the Recurrence Plot. RPs are based upon the mutual distances between points on a trajectory, so the first step in their construction is to choose a norm D. In this work the maximum norm is used, although in one dimension the maximum norm is, of course, equivalent to the Euclidean p-norm. We chose the maximum norm for two reasons: for ease of implementation and because the maximum distance arising in the recurrence calculations (the difference between the largest and smallest measurements in the time series) is independent of embedding dimension d_E for this particular norm. This means that we can make direct comparisons between RPs generated using different values of d_E without first having to re-scale the plots. Next, we define the recurrence matrix A as follows:

$$A(i, j) = D(y_i, y_j), 1 \leq i, j \leq m \tag{12}$$

$$D(y_i, y_j) = \max_{1 \leq k \leq d_E} \left| x_{i+(k-1)\tau} - x_{j+(k-1)\tau} \right| \tag{13}$$

The time series spans both ordinate and abscissa and each point (i, j) on the plane is shaded according to the distance between the two corresponding trajectory points y_i and y_j (Figure 1). The pixel lying at (i, j) is color-coded according to the distance. For instance, if the 117th point on the trajectory is 14 distance units away from the 9435th point, the pixel lying at (117, 9435) on the RP will be shaded with the color that corresponds to a spacing of 14.

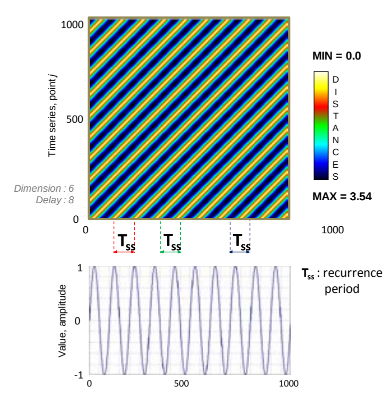

Fig. 1 RP graphique description

Structures in RPs. As already mentioned, the initial purpose of RPs was to visualize trajectories in phase space, which is especially advantageous in the case of high dimensional systems. RPs yield important insights into the time evolution of these trajectories, because typical patterns in RPs are linked to a specific behavior of the system. Following the phase space characteristics, the path in the correlation dimension curve and the large scale patterns in RPs, designated as typology, the RPs structures can be classified as *homogeneous, periodic, drift* and *disrupted* ones [21]:

- Homogeneous RPs are typical of systems in which the relaxation times are short in comparison with the time spanned by the RP. An example of such an RP is that of a stationary random time series.
- Periodic and quasi-periodic systems have RPs with diagonal oriented, periodic or quasi-periodic recurrent structures (diagonal lines, checkerboard structures). Irrational frequency ratios cause more complex quasi-periodic recurrent structures (see the ECG, Lorenz, Rössler and sun spots examples); however, even for oscillating systems whose oscillations are not easily recognizable, RPs can be very useful.
- A drift is caused by systems with slowly varying parameters, i.e. non-stationary systems. The RP pales away from the line of identity, LOI (the main diagonal line in a RP, $\mathrm{R}_{\mathrm{i,j}} = 1$).
- Abrupt changes in the dynamics as well as extreme events cause white areas or bands in the RP, for example the Brownian motion. RPs allow finding and assessing extreme and rare events easily by using the frequency of their recurrences.

A closer inspection of the RPs reveals also the texture or small-scale structures [6], which can be typically classified in single dots, diagonal lines as well as vertical and horizontal lines (the combination of vertical and horizontal lines obviously forms rectangular clusters of recurrence points); in addition, even bowed lines may occur [21,6]:

- Single, isolated recurrence points can occur if states are rare, if they persist only for a very short time, or fluctuate strongly.
- A diagonal line $\mathrm{R}_{\mathrm{i+k,j+k}} \equiv 1|_{\mathrm{k=0}}^{\mathrm{l-1}}$ (where l is the length of the diagonal line) occurs when a segment of the trajectory runs almost in parallel to another segment for l time units:

$$\overrightarrow{x_i} \approx \overrightarrow{x_j}, \overrightarrow{x_{i+1}} \approx \overrightarrow{x_{j+1}}, \dots, \overrightarrow{x_{i+l-1}} \approx \overrightarrow{x_{j+\mathrm{l}-1}}$$

A *vertical* (*horizontal*) line $R_{i,j+k} \equiv 1|_{k=0}^{v-1}$ (with v the length of the vertical line) marks a time interval in which a state does not change or changes very slowly:

$$\overrightarrow{x_i} \approx \overrightarrow{x_j}, \overrightarrow{x_i} \approx \overrightarrow{x_{j+1}}, \dots, \overrightarrow{x_i} \approx \overrightarrow{x_{j+v-1}}$$

The state is trapped for some time. This is a typical behavior of laminar states (intermittency) [21].

- *Bowed lines* are lines with a non-constant slope. The shape of a bowed line depends on the local time relationship between the corresponding close trajectory segments.

RPs of paradigmatic systems provide an instructive introduction into characteristic typology and texture but the visual interpretation of RPs requires some experience. A deeper explanation about typology and texture is presented in [22].

III. Recurrence in accelerograms

A set of acceleration time series recorded in the soft soils of the Mexican metropolis are used to study its chaotic nature. The soil systems and the recorded responses studied here are on the surface of 16 soft soils (clays) and 4 stiff deposits within the urban area of Mexico City. The soft soils are located on the lacustrine basin where soils were deposited by air or water transportation (very soft clay formations with large amounts of microorganisms interbedded by thin seams of silty sand), some others are product of volcanic effusions that took place within the last one million years (fly ash and volcanic glass) and there are stations on a third type of soils that are considered firm or materials rock-like. The elastic natural periods T_n (key parameter in ground motions categorization) of the sites included in the database vary from $T_n = 2\ s$ to $T_n = 4.2\ s$. Fifteen earthquakes were selected having at least 100 s and high signal-to-noise ratios. These events are representative of the tectonic regions (different source mechanism) that affects the valley. The set is denser in events from the subduction of the Cocos Plate into the Continental Plate because they are associated to the most damaging shocks.

Information accumulated over the last four decades has firmly established that the seismic movements within the Basin of Mexico can differ considerably from one site to the other [22]. The statutory regulations have tried to take into account these facts but still there are dangerous doubts about the outcome patterns. The purpose of the following analysis is to illustrate an alternative way in which the oscillations can be described and to provide a qualitative understanding of the complex system responses.

A. RPs- large scale

Examples of RPs obtained from accelerograms recorded during the earthquakes are shown in Figure 2. One intriguing and puzzling characteristic of the RPs is the structural similitude that they exhibit with different seismic and site conditions. Evaluating RPs constructed from accelerograms recorded during the same event on different site conditions, one question is obligated: do soft soils and rocks, when are excited by the same seismic force, move similarly? On the other hand, keeping constant the soil properties (dividing the database in a separated sets: soft-soils/rock -stiff- masses) and varying the seismic inputs (earthquakes), the RPs structures are exceptionally comparable and the doubt is evident: do earthquake mechanism, distance (from epicenter to the site) and directivity have a tangible, real impact on materials vibrations? The answers, based on large scale, do not correspond with engineering criteria and experience: soils and rocks do move differently and seismic inputs do have a deep effect on the response recorded.

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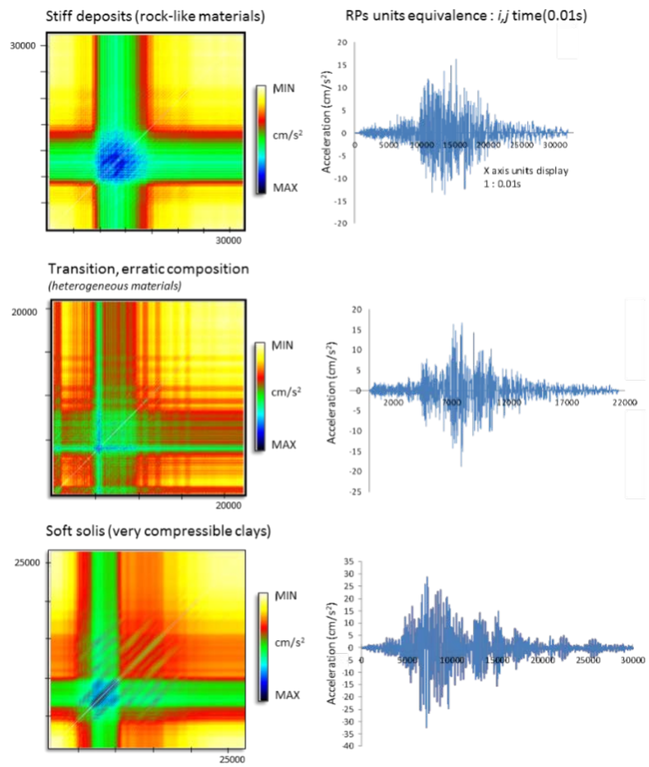

Fig. 2 Recurrence Plots from soft and stiff deposits, different input seismic loads.

Through a deep inspection of the RPs and using nonlinear concepts we found that the ground structures (soft and stiff, homogeneous and heterogeneous deposits) when are affected by seismic forces, in a macro scale, evolve in a similar way. The time evolution of the ground accelerations exposes well defined white areas and cold bands (green/blue strips), hallmark in nonstationary systems. The combination of vertical and horizontal strips forms rectangular clusters where the maximum accelerations are located. Because of the abrupt changes between the beginning, the intense and the final part of the movements, a ground motion can be defined as an event that contain *extreme* sub-events (maximum accelerations) where the ground conditions are anomalous for some seconds to then vanish until the movement finishes. The number of clusters that appears in the RPs is the recurrence of the sub-events. The study of vertical RP structures makes the identification of *trapping time* (seconds that soil and rocks are being truly perturbed) possible. The ground response is very far from the deterministic behavior of the very well-known pendulum's oscillation (under damped vibration - low drive frequencies or if the drive frequency is raised and the attractor undergoes a series of bifurcations). None of the RPs of accelerograms can be related with the patterns of the pendulum's attractors. The underlying process in seismic ground motions seems much more complex, large-scale observed, and it cannot be directly labeled as "deterministic", "chaotic" or "random".

As a conclusion we can say that soils and rocks are nonlinear devices because they become activated when their reaction potential crosses a certain threshold. The activity of large formations of geological materials (soils and rocks) is macroscopically measurable in the accelerogram which results from a spatial integration of many reaction potentials (the environment interacting). The RPs-vertical structures displayed by the layered natural materials should be related with *intermittence* (alteration of phases of seemingly periodic systems). The apparent periodic phases of the ground behavior are not quite, but only nearly periodic. Thus, rather than a truly-periodic series of values, the data are apparently periodic but where the chaotic nature of the system becomes apparent after certain ground acceleration is reached. It is very important to point out that *intermittence* is more patent during large earthquakes, and a probably reason, which looks a paradox, is that the energy released from the source is not permanently continuous on time, there are relax intervals in between without important seismic wave arrivals from the source. The *intermittence* in accelerograms could be related with the intense part of the earthquake.

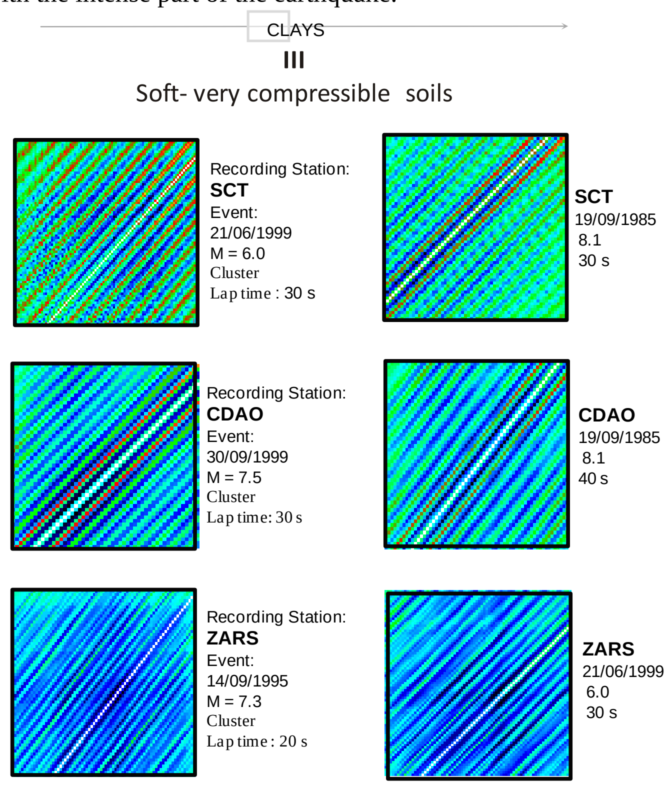

Fig. 3 Diagonal structures in soft soils.

A. RPs- small scale

Delay-coordinate embedding produces clean, easily analyzable pictures of the ground dynamics and the results suggest that the dynamical behavior of the soils/rocks is very high-dimensional. This implies that the system is probably influenced by variables that can be hardly identified or that are beyond the limits of our current understanding [23]. However, a proper definition of initial conditions permits characterizing the system evolutions and extracting meaningful (for engineering purposes) conclusions about the behavior of this complex natural structure. Zooming into the RPs, above the intense part of the response (blue/green clusters) the soil response can be studied from the clear and suggestive

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signatures in the sub-plots. The width of the vertical band indicates the time in which the *intense* state does not change or changes very slowly. The strong ground accelerations are trapped for some seconds (the cluster base) and because this extreme situation is not an isolated point (rare) the possibility that this alteration had been produced by noise is eliminated. In this *intense* time, periodic, chaotic or random patterns can be recognized and the parameters range over which the system is stable and where the trajectories are divergent could be identified.

Harmonics in soft soils oscillations. Observe Figure 3 . These clusters were obtained from accelerograms recorded in soft soils deposits. These examples show diagonal oriented recurrent structures that can be related with the vibration of one degree of freedom 1D oscillator. Due to space restrictions only some examples are showed, but they are representative of the structures displayed for the whole soft-soils set.

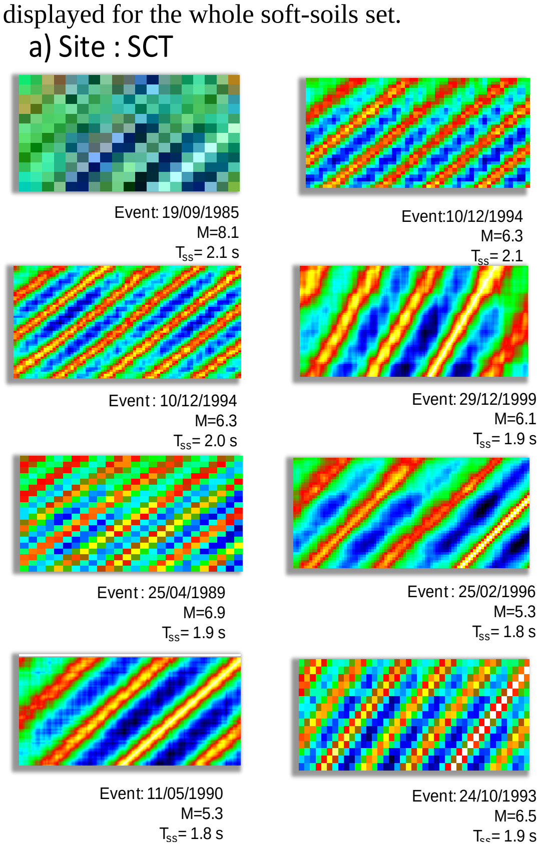

Fig. 4. Recurrence period for soft soils.

Assuming that during *intermittence* soft soils behave as a 1D oscillator, the period of soil vibration during the semi-sinusoidal oscillation (in this investigation called T_{ss}) can be obtained from the distance between diagonals, as shown for sine signal in Figure 1. For a same site, no important degradation is observed in T_{ss}, even when the records came from different intensity, frequency and duration input conditions. Beyond the scope of this work is the discussion about the impact of the differences between T_{ss} and T_n in the aseismic design, but no doubt exists that the T_{ss} values are more authentic than those obtained from spectral analyses and many important conclusions about nonlinearity and site effects must be re-evaluated using these findings. In Figure 4 and 5 some sub-plots are presented to make clear this assumption. The sites are SCT and CDAO, two emblematic deposits because of their astounding amplification behavior. During the catastrophic earthquake suffered in Mexico City (Sept 19th 1985 Michoacán event) these two stations recorded more than 10 times the accelerations measured in stiff deposits (rock like materials) and resonance phenomena is added to the scientific explanations about the enormous movements in this zone. In Mexican construction codes the recommended fundamental period for SCT is $T_n = 2.1\ s$ and for CDAO $T_n = 3.5\ s$.

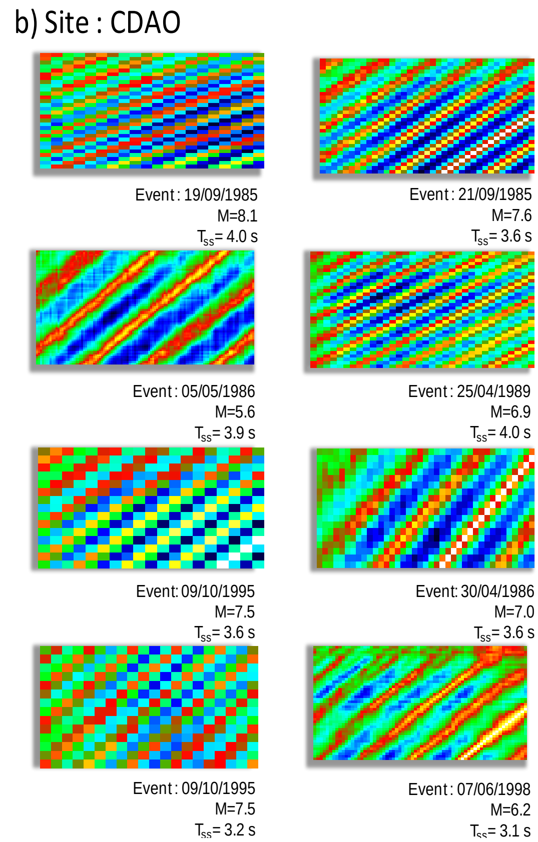

Fig. 5 Recurrence period for soft soils.

Chaotic vibrations in stiff soils structures. The clusters in Figure 6 are far more complicated. The checkboard structures and the upward diagonal lines result from strings of vector patterns repeating themselves multiple times down the dynamics. This type of recurrent structure indicates that the dynamics is visiting the same region of an attractor at different times; therefore, the presence of diagonal lines indicates that deterministic rules are present in the dynamics. The set of lines parallel to the main diagonal is the signature of determinism, however, it is not so clear as in soft-soils (e.g., the size of the lines being relatively short among a field of scattered recurrent points), i.e., the RPs contain subtle patterns not easily ascertained by visual inspection.

Although the blocklike structures resembling to what might be expected from a periodic signal, the rock-like materials exhibit a complex recurrent behavior with irregular cyclicities that qualifies them as dynamical systems and their behavior as typical for nonlinear or chaotic systems. This means that the deposits in Hill zone are highly sensitive to initial conditions, e.g. small differences in directivity, fault mechanism or distance, yield widely diverging outcomes.

As in many natural systems, the geological materials constitute systems that can be called deterministic, meaning that their future behavior is fully determined by their initial conditions, with no random elements involved. The deterministic nature of rock (stiff materials) systems does not make them predictable. The rock-like deposits behavior can be described as deterministic chaos, or simply chaos.

IV. Conclusions

Based on the findings of this study, recorded accelerograms on soils and rocks should be considered as a sequence of episodes of seismic wave arrivals alternated with free soil vibrations episodes, behavior related with intermittence.

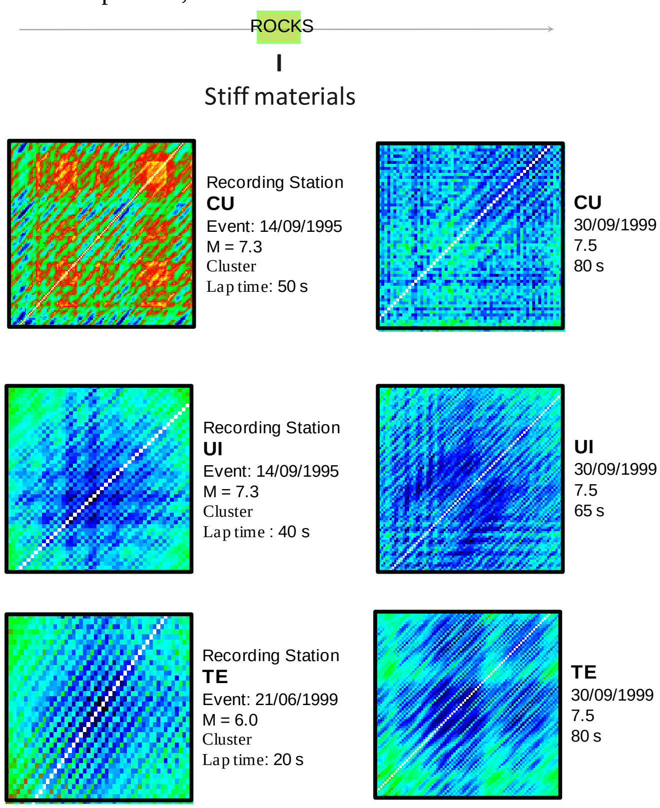

Fig. 6 Quasi-periodic structures in stiff deposits.

It has been noticed, from the analyzed cases (different fault mechanisms, epicentral distances and magnitudes), that there are no significant differences between soil and rock time evolutions (macro-scale). The study of the alteration of phases in RPs drives to the conclusion that soils and rocks deposits responses can be characterized only in the intense part of the time series (clusters blue/green bands, maximum accelerations zone).

RPs of stiff materials, in general, display more complicated structures but they resemble chaotic movements for the universe of initial conditions analyzed. Despite being chaotic, the trajectories are actually quite organized, but a vibration period cannot be determined.

Soft soils deposits progress from quasi-periodic to periodic oscillations as the amplitude of the seismic responses exceeds certain acceleration thresholds. The deposits studied can be linked to certain determinism, the diagonal bars in the intense part of the response are directly related with the natural period of each stratigraphy.

The inconsistency between soil amplification theories and accelerographic measurements for large earthquakes could be re-interpreted through Chaos theory: Geological materials are systems that evolve in a similar way, in the macro-scale, but is in the micro-scale that the materials display particular trajectories.

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Ground motions due to seismic forces under Hilbert-Huang transformation

Silvia R. García

***Abstract*—**The recent catastrophic experiences have shown that seismic forces and the ground responses are still a challenging concern and more efforts are needed to improve the engineering art and the praxis. This study explores the use of the Hilbert-Huang Transform HHT for analyzing earthquake recordings and the associated responses of soft-soils deposits in Mexico City where, in a single earthquake, the motions at one site can easily be 10 times stronger than at a neighboring position, even when their distance from the ruptured fault is the same. Based on the numerical findings, geotechnical-earthquake engineers, insurance companies, and emergency-management officials could use this tool to elucidate about complex/anomalous shaking-amplification patterns. The use of emerging techniques will not only help to save lives and protect property in future Mexican quakes but will also help to improve understanding of seismic hazards in many earthquake-prone regions of the world.

***Keywords*—**Earthquake response, Hilbert-Huang Transform, Mexico City clays, Response spectra analysis, Site effects, Soft soils, Time series analysis.

I. Introduction

Soil effects are a very important contributor to human suffering and damage during earthquakes. There are mainly two types of problematical ground response when the ground starts to shake: i) the soil fails, cracks and moves laterally/horizontally and, ii) the soil changes the character of the ground shaking by amplifying it and making it more destructive.

In a single earthquake the shaking at one site can easily be 10 times stronger than at another site, even when their distance from the ruptured fault is the same. Scientists have assumed that local geologic conditions (the softness of the rock/soil near the surface and the thickness of the sediments above hard bedrock) are the cause of this difference in shaking intensity, but they have not been certain of the particular conditions that are most responsible, and the degree to which they affect the different consequences levels.

The consideration of surface soil amplification is based on motions recordings and their interpretation drives theories and conclusions about the phenomena. This research explores the spectra-based methods for studying rock/soil accelerations and illustrates how this tactic could lead to a distorted picture of nonlinear site amplification/response [8], [21].

As an alternative to the *traditional* spectrum-based approach, in this study the Hilbert-Huang Transform HHT [9]. A method for nonstationary data processing, is used to describe soil response from earthquake recordings. The HHT is an empirically-based data-analysis method. Its basis of expansion is adaptive, so that it can produce physically meaningful representations of data from nonlinear and non-stationary processes. The proposed scheme of HHT analysis for discerning soil nonlinearity permits to infer aspects related to duration, frequency and intensity of shakings where significant nonlinear behaviors can develop. Different intensity motions recorded in clayey soft deposits in Mexico City are examined to demonstrate the validity and effectiveness of the HHT system in estimating site effects.

S. R. Garcia is with the Instituto de Ingeniería, Universidad Nacional Autónoma de México, Ciudad Universitaria, Coyoacán México DF 04510 MEXICO, 52-55-56233600; e-mail: sgab@pumas.iingen.unam.mx

II. Complex soils, complex shaking

Useful study of the site effects requires comprehensive computer simulations of potential earthquakes on a case-by-case basis and deep analyses of soils-conditions→monitored-responses to validate simulations and models. In general, evaluating the amplification levels requires i) determining the response spectrum on the bedrock, (generally, materials with shear wave velocity V_s greater than about 500m/s) ii) characterizing/organizing the response spectrum on the soils deposits/sediments and iii) a framework examination for developing numerical relations that model the ground motions. Then, under a simplistic position, an earthquake ground motion on the ground surface can be estimated efficiently by multiplying the rigid-base (bedrock) spectra by a response spectrum ratio that describes amplification factors (frequency dependent) including specific characteristics of the soil layer(s).

If an attenuation formula (for estimating the acceleration response spectrum on the bedrock from the earthquake source –epicenter) and the transfer function are applied, in theory, it is possible to compute the response on the ground surface for any seismic input. Following this analysis scheme, the relations between the acceleration response spectrum of the bedrock and the response spectrum ratio of the ground surface are completely described. The relation between the acceleration response spectra of the bedrock and those of the ground surface is

$$S_{As}(T,h,G_c,E_c,A_c) = S_{Ab}(T,h)\cdot R(T,h,G_c,E_c,A_c) \qquad (1)$$

where $S_{As}(T,h,G_c,E_c,A_c)$ is a linear/nonlinear acceleration response spectrum of the ground surface, $S_{Ab}(T,h)$ is the acceleration response spectrum of the bedrock, $R(T,h,G_c,E_c,A_c)$ is the acceleration response spectrum ratio with a linear/nonlinear response characteristics of surface soil,

T is the period, h is the damping ratio, G_c is topographical classifications, E_c is the earthquake type, and A_c is the earthquake ground motion intensity described by peak acceleration. By using topographical classification, earthquake type and earthquake ground motion intensity, a simple estimate for the acceleration response spectrum ratio of surface soil with a nonlinear characteristics is

$$R(T,h,G_c,E_c,A_c) = \widehat{H}_L(T) \cdot \alpha(T,h,G_c,E_c,A_c) \quad (2)$$

where $\widehat{H}_L(T)$ is the smoothed transfer function that represents a weighted average of the (usually) linear response transfer functions, and $\alpha(T,h,G_c,E_c,A_c)$ are coefficients deduced from topographical classifications, earthquake types, and earthquake ground motion intensities. The described spectrum ratio procedure seems to be able for reproducing acceleration response spectrum at any point contained in the soils system.

Through the analysis on particular cases, where the predicted and experienced responses differ dangerously, it has been concluded the simplistic method is not competent to reproduce acceleration response spectrum of complex soils deposits and multifaceted shaking generation. In this investigation it is argued that the postulate about amplification ratios is very useful but the interpretation environment (frequency/period dominion) is possibly distorting the implicit information in accelerations time series and originating mistaken numerical/linguistic conclusions.

III. THE HILBERT-HUANG TRANSFORM

The Hilbert-Huang Transform HHT was proposed by [9] and consists of two parts: i) Empirical Mode Decomposition EMD, and ii) Hilbert Spectral Analysis HS or Hilbert transformation. With EMD any data set can be decomposed into a finite number of intrinsic mode functions IMFs. An IMF is described as a function satisfying the following conditions: i) the number of *extrema* and the number of zero-crossings must either equal or differ at most by one; and ii) at any point, the mean value of the envelope defined by the local maxima and the envelope defined by the local minima is zero. An IMF admits well-behaved Hilbert transforms [7].

For an arbitrary function x(t) in linear programming-class [19], its Hilbert transform y(t), is defined as,

$$Y(t) = \frac{1}{\pi} P \int_{-\infty}^{\infty} \frac{X(t')}{t-t'} dt' \quad (3)$$

where P indicates the Cauchy principal value. Consequently an analytical signal *Z (t),* can be produced by,

$$Z(t) = X(t) + iY(t) = a(t)e^{i\theta(t)} \quad (4)$$

Where

$$a(t) = [X^2(t) + Y^2(t)]^{\frac{1}{2}}$$

$$\theta(t) = arctan \frac{Y(t)}{X(t)} \quad (5)$$

Are the instantaneous amplitude and phase of X (t), respectively. Since Hilbert transform Y(t) is defined as the convolution of X(t) and 1/t by Eq. 3, it emphasizes the local properties of X(t) even though the transform is global. In Eq. 4, the polar coordinate expression further clarifies the local nature of this representation. Using Eq. 4, the instantaneous frequency of X(t) is defined as,

$$\omega(t) = \frac{d\theta(t)}{dt} \quad (6)$$

However, there is still considerable controversy on this definition. A detailed discussion and justification can be found in [9]. EMD is a necessary pre-processing of the data before the Hilbert transform is applied. It reduces the data into a collection of IMFs and each IMF, which represents a simple oscillatory mode, is a counterpart to a simple harmonic function, but is much more general. We will not describe EMD algorithm here due to the limitation of the length of the paper. The readers are referred to [9] for details.

By EMD, any signal *X(t)* can be decomposed into finite IMFs $imf_j\ (t)\ (j = 1, \dots n)$, and a residue, *r (t)* where *n* is nonnegative integer depending on *X (t)*, i.e.,

$$X(t) = \sum_{j=1}^{n} imf_j(t) + r(t) \quad (7)$$

For each imf_j, let $X_j\ (t) = imf_j\ (t)$, its corresponding instantaneous amplitude, a_j (t), and instantaneous frequency, $w_j(t)$, can be computed with Eqs. 5 and 6. By Eqs. 4 and 6, imf_j can be expressed as the real part RP in the following form,

$$imf_j(t) = RP\left[a_j(t)\exp\left(i \int \omega_j(t)dt\right)\right] \quad (8)$$

Therefore, by Eqs. 7 and 8, *X (t)* can be expressed as the IMF expansion as follows,

$$X(t) = RP \sum a_j(t) \exp\left(i\omega_j(t)dt\right) + r(t) \quad (9)$$

which generalize the following Fourier expansion

$$X(t) = \sum_{j=1}^{\infty} a_j e^{i\omega jt} \quad (10)$$

by admitting variable amplitudes and frequencies. Consequently, its main advantage over Fourier expansion is that it accommodates nonlinear and non-stationary data perfectly. Eq. 9 enables us to represent the amplitude and the instantaneous frequency as functions of time in a three-dimensional plot, in which the amplitude is contoured on the time-frequency plane. The time-frequency distribution of amplitude is designated as the HS or simply Hilbert spectrum, denoted by $H(\omega, t)$. For a comprehensive illustration of the HHT-seismic approach, Reference [6] is suggested.

IV. HHT ON ACCELEROGRAMS

As an example of the Huang transformation and the Hilbert spectra applied to earthquake recordings, the accelerogram of the September 14th 1995 earthquake recorded in CDAO site, soft-soils deposit in México City, is studied. From this signal, see its HS and its corresponding Fourier spectrum in Figure 2. Fourier spectrum indicates that the frequency content of the waves is spread out with the maximum spectral amplitudes at 0.3 and 0.9 Hz, with a well-defined peak amplitude value of ~170 cm/s at 0.3 Hz, the dominant frequency.

On the other hand, the Hilbert spectra HS (bottom of Figure 2) shows quantitatively the temporal-frequency distribution of vibration characteristics in the ground-motion recording.

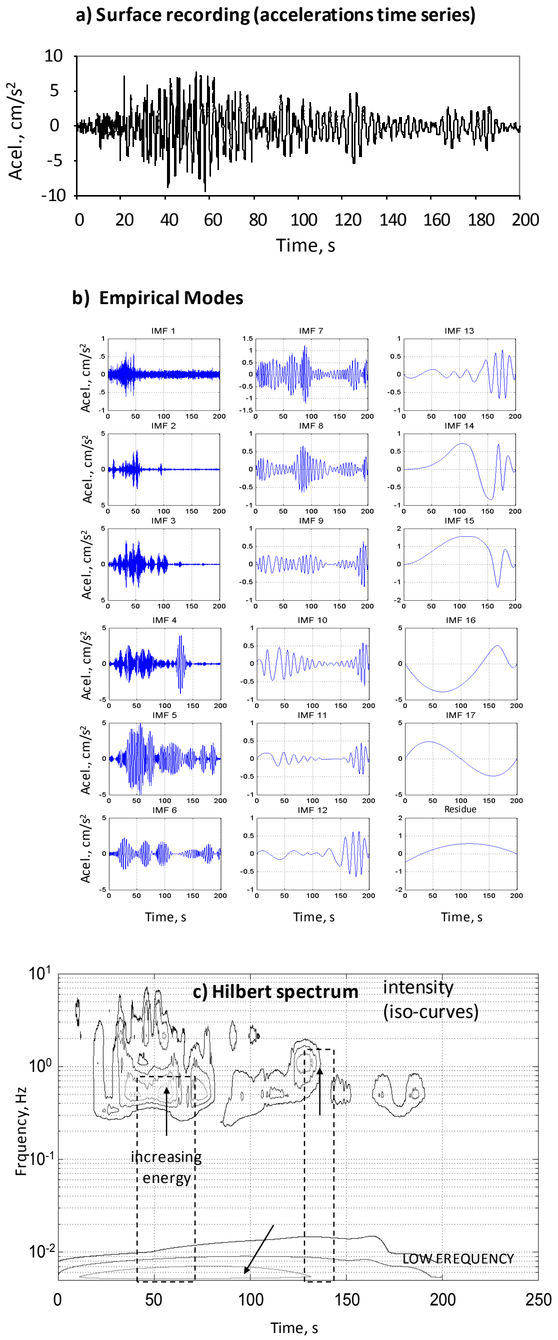

Fig. 1 Example of the Empirical Modes and Hilbert Spectrum

obtained from an accelerogram

A detailed description of the motion can be identified from the 2D display: i) two sets of ground motion in the time intervals 70–75 and 135–150s consisting of low-frequency signals between 0.25 to 0.80 Hz with intensities around 28 and 14 cm/s2, respectively, ii) the highest intensity Imax (~28 cm/s2) at 0.4 Hz is surrounded by an important concentration zone (iso-acceleration curves ~ 20 cm/s2) on a wider frequency band (from 0.2 to 0.5 Hz) and iii) the second motion arrival, with accelerations on the middle of the intensity-scale registered, covers frequencies around 1.0 Hz.

Since these amplitudes and frequencies are quite often used as an index to characterize and define the seismic inputs, the distinction between values based on the two different methods can be critical to the seismic design, retrofit guidelines and codes. It is worth further analyses to see which value (Fourier or HHT-based) is more appropriate for structural design, but the differences between frequency-energy content can be critical when site effects are being analyzed. The full understanding of these characteristics is a subject of continuing study, for now, the potential exists for a useful quantitative measure of a motion's input energy to structural and geotechnical systems.

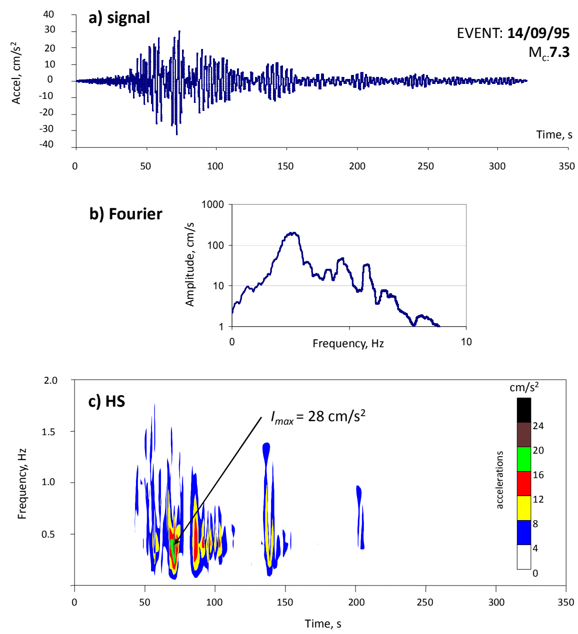

Fig. 2 Acceleations time series, Fourier amplitude spectra and Hilbert spectra

A. *Interpreting site effects*

The numerical procedures, all of them based on the wave equation, have been proposed to take into account of several of the various aspects of amplification due to soils characteristics. However, the experimental methods are the most recommended for singular materials and/or erratic stratigraphies because the records of earthquakes enclose specific information to model more rationally site effects and the response of structures. The experimental techniques use the spectral ratios of motions records (weak and strong) to

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conclude about behaviors (earthquake ratios, peaks ground accelerations ratios, resonance frequency). Amplification of ground motion due to geological and soil conditions could be extrapolated by means of linear methods. However, recent analyses [13], [20], Have demonstrated important presence of nonlinear behaviors. There is a bulk of technical information showing that both linear and nonlinear approaches are capable of explaining this behavior and, with a certain degree of accuracy, computing the response of soil deposits under earthquake loading. This sole fact does not elucidate the rather generalized controversy about the significance of nonlinear soil effects [1], [5], [22]. In the authors' opinion the direct way to clarify this question is to look into hard seismological evidence showing the influence of such phenomenon. Thus, it boils down to decode the encrypted information that records of ground motions possess.

For the Mexican heterogeneous soils deposits where analytical solutions for determining site effects do not seem valid, it is desirable to use the *in situ* information. Mexico City has already suffered a destructive earthquake (Michoacán event Sept 19th 1985) thus detailed macroseismic observations are available. More than 50 years of monitoring makes possible estimate the site-specific transfer functions experimentally through minor, intermediate and strong earthquake records [2], [10], [16].

Being the HHT ideal for studying nonlinear /nonstationary processes, in the following the recordings from two Lake Zone sites of Mexico City are transformed into their HS to illustrate i) the possible misinterpretations originated by traditional spectra approach and ii) the advantages of examining accelerograms in the I-F-T (intensity-frequency-time) space (Hilbert spectra HS).

CDAO and SCT stations are the soils deposits studied (Figure 3). For the UBC (Uniform Building Code) and EC8 (Eurocode 8) standards, based on the Vs30 values, [3], [17], [14] SCT and CDAO are classified into the same soil class SF (UBC) / S1 (EC8): "deposits consisting- or containing a layer <100 at least 10 m thick- of soft clays/silts with high plasticity index (> 40) and high water content".

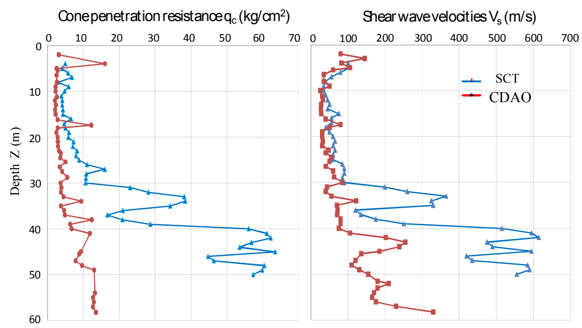

Fig. 3 Soil properties of SCT and CDAO (very soft, high water content, very compressible clays)

In comparison with data analysis in a transformed domain, major characteristics of the data can be simply and directly obtained from the analyses in the time domain. A typical example to illustrate this point is the Michoacán, Mexico earthquake of 19 September 1985. While many factors contributed to the enormous damage in the city, such as design and period of buildings, year of construction, site characteristics, and population density, it nevertheless indicates that a comprehensive description of ground motion for engineering use likely needs more information, such as frequency content associated with the peak motion. The original data from the two lake-zone sites, SCT and CDAO, and a rock-like site (CU station), after decomposing by EMD (12 IMFs plus a residue) generate the corresponding HS depicted in Figure 4.

It can be assumed, based on these Hilbert spectra, that significant energy in SCT and CU is related with frequencies from 0.3 to 2 Hz while the energy resides along horizontal belts below 1 Hz for CDAO. These findings are not clearly shown in other representations as Fourier spectra (top of the Figure 5). HHT can efficiently reveal frequency-energy distribution of the seismic intensity during the more than 100s registered. Higher amplitudes (zones from red to black) can be recognized for SCT site between 0.2 and 2.0 Hz, pulses-like waves are not detected. For CDAO, the energy is released from the source permanently in time, there are a few relax intervals but it is clear that CDAO registered the important seismic arrival at t= 40s with amplitude and frequency content almost constant the next 50s. Nevertheless CU and SCT are clear examples of transient processes.

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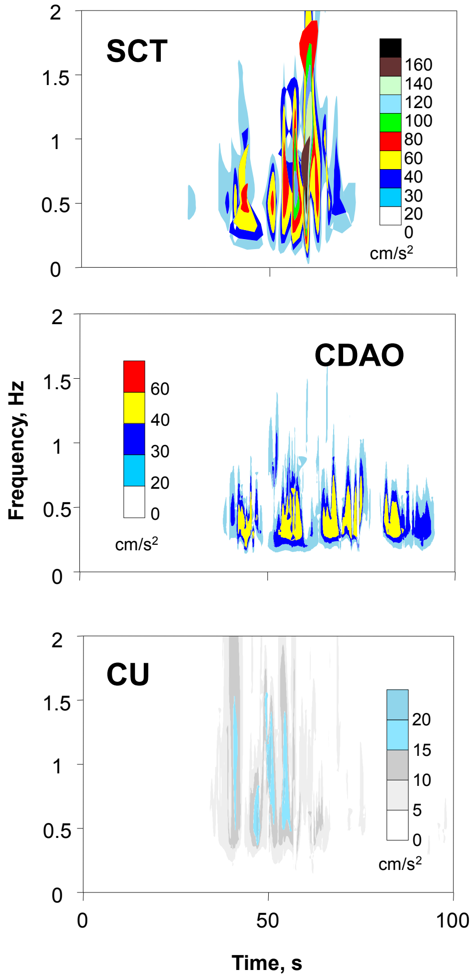

Fig. 4 HS of two soft-soils deposits (SCT and CDAO) and a rock-like site (CU) for the Michoacán earthquake (Sept. 19th 1985, Mw8.1)

Their HS show the arrivals of the energy-containing packets with increasing frequencies, within a brief span of time. In SCT and CU a low-frequency pulse-like packet is registered around 60 s, where the maximum amplitudes and the broader frequencies are activated. It is obvious that there are different accelerations readings in the soft-soil (SCT) and rock (CU) sites but their energy-time-frequency distributions are much related.

From a seismological perspective, these observations imply two major subevents in the rupture process. From the viewpoint of structural engineering, the first set of waves will cause much larger dynamic responses of long period structures than will the second, but it is important to point out that the major amplitudes are registered in the second packet. The key parameter to characterize the responses would be the duration of the shaking packets, so a proper argument about the nature of ground motions and their dependence on soil and seismic conditions should contain the triplet I-F-T (intensity-frequency-time).

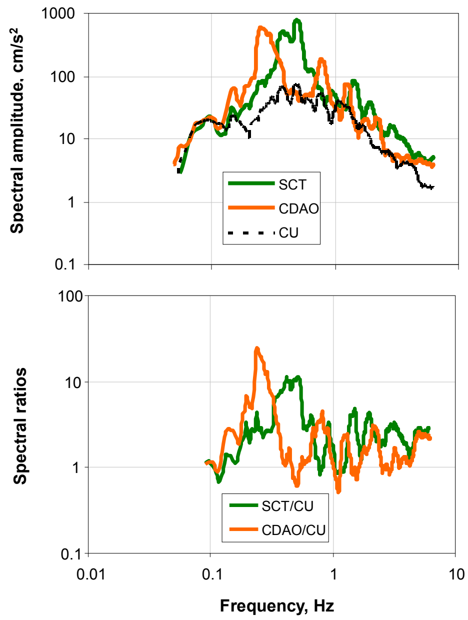

Fig. 5 Fourier amplitude spectra and spectral ratios: strong shaking, 19/09/1985, Mw8.1

The amplitude spectra of SCT and CDAO for the 1985 event (strong motion) have been extensively used for some authors (e.g. [11], [12], [15], and [18]) For quantifying the amplification of motions in the lakebed of Mexico City. They reported that in the lakebed (SCT/CDAO) as compared to the hill zones (CU), the motions were amplified by 8 to 20 times. Spectral ratios were calculated using a simple amplification function relationship and they substantiate the dominant low frequencies of the motions in Mexico City. Via this Fourier approach SCT and CDAO could be characterized as exhibiting dominant frequencies between 0.3-0.8 Hz with amplification ratios around 10 units.

The findings obtained from weak motions exhibit several distinctive characteristics, being one of the most relevant that they amplification levels are significantly larger than those from strong motions.

In Figure 6 the HS for the SCT, CDAO, and CU stations after decomposing the recordings (event 7Oct. 24th 1993, Mc6.5) are shown. It can be assumed, based on these Hilbert spectra, that significant energy in SCT is related with frequencies from 0.3 to 4 Hz, CDAO with 0.3 to 1.5 and CU with 0.2 to 0.8 Hz. The energy resides along horizontal belts below 1 Hz for CDAO and CU but for SCT important energy concentrations are around a broad range of frequencies during a short period of time (spike-like). These important differences cannot be observed in the Fourier spectrum (top of Figure 7). HHT can efficiently reveal frequency-energy distribution of the low seismic intensity during the ~100s registered. Again, higher amplitudes (zones from red to black) are recognized for SCT site but they covered from 0.2 to 4.0 Hz, while CDAO behavior is very similar to that observed during the strong event: the energy is released from the source permanently in time.

Because of the amplitude accelerations, for CU cannot be

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recognized a particular behavior. Its HS show the arrival of a low-energy-containing packet with frequencies under 1Hz within a brief span of time. In SCT a pulse-like packet is registered around 50 s, and for CDAO a similar conduct cannot be concluded. It is obvious that there are considerable differences between the two soft-soil (SCT/CDAO) energy-time-frequency distributions. It is important to point out that studying the responses for strong and weak events, the obtained amplification patterns (~spectral ratio) are not related.

Observe the energy peaks and the frequency content for "weak" and "strong" events (see Figures 4 and 6). Rock-site distribution of energy changes substantially going from a localized predominant frequency at 0.4 Hz for "weak" events to a frequency-zone (0.5 to 1.5) activated during the "strong" event.

The mixed frequency content of the recordings, containing low and high frequencies, is truthfully reflected in the HS. CDAO shows a response of ~8 cm/s2 at 0.2 Hz for the "weak" shaking and of ~80 cm/s2 at 0.4 Hz for "strong" input. SCT, with a broader band of frequencies, depicts an intensity of 180 cm/s2 at 0.85 Hz for the strong event and 18 cm/s2 at 1.0 Hz for the weak motion. The SCT abnormal peaks, for example at 55 s for the Oct 24th 1993 event and at 60 s for the Sept 19th 1985 event, (cusped waveforms and high-frequency spikes) are symptomatic of a nonlinear response at some soil sites [4].

Contrary to the Fourier results (Figure 8), HHT demonstrates that the responses to the strong movement contain lower frequency levels compared with those generated during the weaker earthquake.

Even in Mexico City, an ideal case where the most common assumptions for soil amplification are fulfilled, the most accepted theories are partially verified. The theories based on Fourier schemes can reproduce the natural soil response period but fail in reproducing the amplification intensity and duration. Using HS we can avoid the misinterpretation of soil amplification patterns.

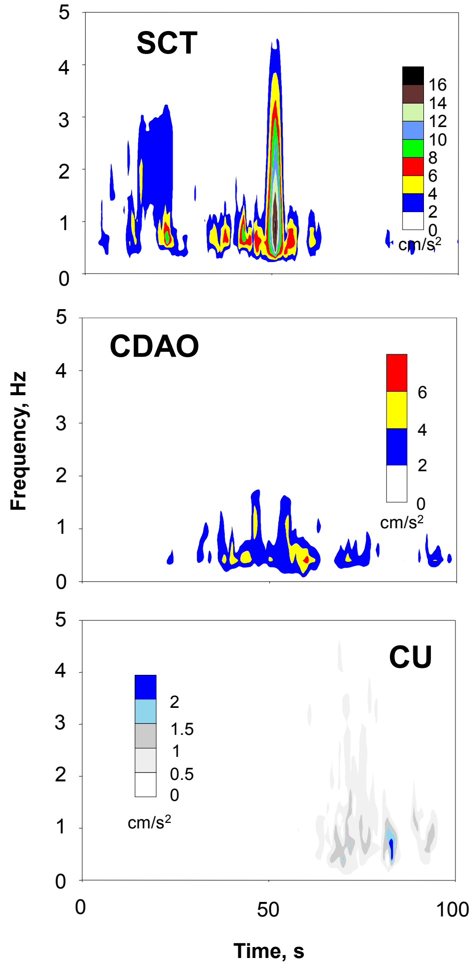

Fig. 6 HS of two soft-soils deposits (SCT and CDAO) and a rock-like site (CU), Oct. 24th 1993, Mc6.5

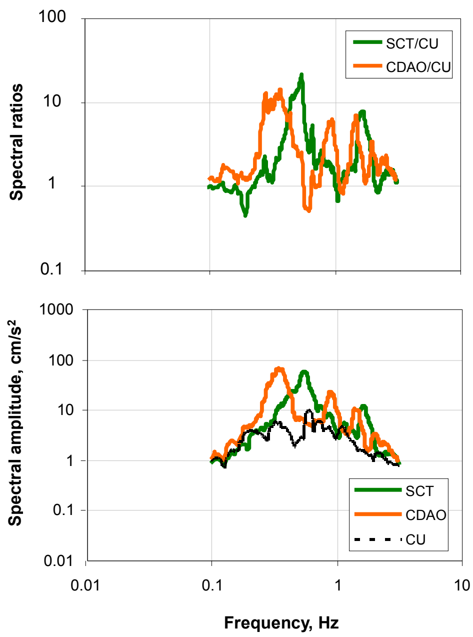

Fig. 7 Fourier spectra and spectral ratios for soft-soils deposits/rock-like site Oct. 24th 1993, Mc6.5 (weak shaking)

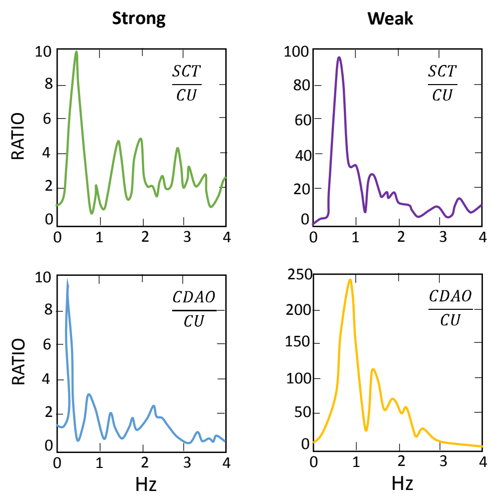

Fig. 8 Spectra ratios obtained from studying the Fourier amplitude spectrum from weak and strong events

Fourier spectra ratios of the weak motions are slightly larger than strong motion ratios over the frequency range of 0.1 to 1.0 Hz (Figure 8) but this evidence cannot be interpreted as a clear indication of nonlinear response. The ground motion at SCT is amplified at its natural frequency (fn = 0.5 Hz) about 10 times for the strong motion and around 20 times for the weak motion, while CDAO responses show an amplification of approximately 23 times for strong and about 12 times for the weak event, this ambiguous indication of nonlinear clay-behavior could be driven by the analysis tool rather than the actual encrypted in the recorded motions.

The mixed frequency content of the recordings, containing low and high frequencies, is truthfully reflected in the HAS. The CDAO-HAS show a maximum intensity response (~8 cm/s2) at 0.2 Hz for weak input (CU) and at 0.4 Hz for strong input (~80 cm/s2). SCT-HAS, with a broader band of frequencies, depict an intensity of 180 cm/s2 at 0.85 Hz for the strong event and 18 cm/s2 at 1.0 Hz for the weak motion. The SCT abnormal peaks, for example at 55 s for the Oct 24th 1993 event and at 60 s for Sept 19th 1985 event, (cusped waveforms and high-frequency spikes) are symptomatic of a nonlinear response at some soil sites [4]. Contrary to the Fourier results, HHT demonstrates that the responses to the strong movement contain lower frequency levels compared with those generated during the weaker earthquake.

Time is a key factor when site effect is being studied. Duration is one of the main parameters characterizing ground motions and the cumulative damage endured by the structures. In this sense, the advantage of using HS is that it reveals directly the duration of the event (where significant amplitudes and frequencies are activated) and showing the nonstationary characteristics of the seismic phenomena.

Vertical accelerographic array allows detecting and studying this effect. As an example see the CDAO Fourier spectra shown in Figure 10.

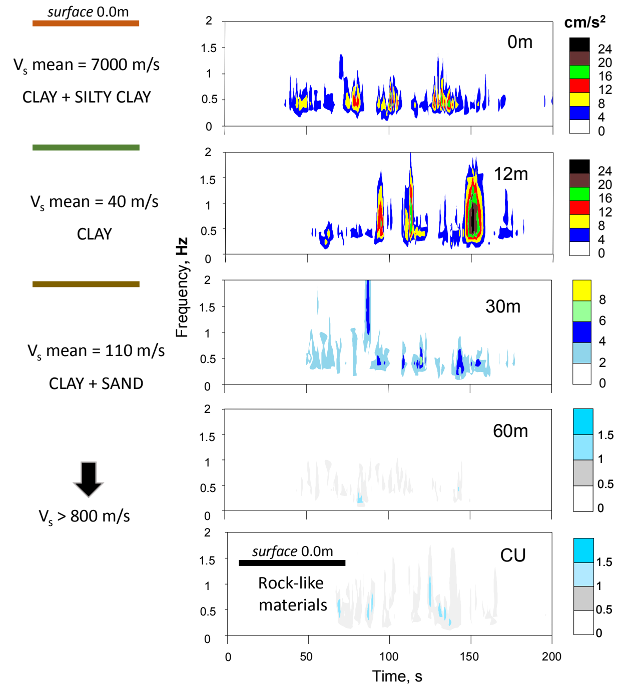

Fig. 9 Vertical accelerographic array in CDAO: HHT interpretation (Event Nov. 9th 1995, Mc: 7.5)

Noticeable differences in amplification are detected in 60 m and 30 m responses, while the spectrum at 12 m is equivalent to the surface spectrum implying that this upper layer does not amplify the motions (this is more evident under strong than weak shakings). On the other hand, the Hilbert spectra showed in the same Figure permit to outline the differences between these superficial responses and to mark the effects of the input characteristics on the amplification ratios. Variations between the HS of the record at 60 m deep and the motion at CU (outcropping) in intensities and frequency content alert about the potential impact of the input on the amplification ratios and soil-nonlinearity conclusions that have been drown in past studies that make use of Fourier analyses.

Furthermore, HHT results reveal deamplification from 12 to 0 m and because of the modification of the frequency content this superior layer can be considered as if it were a low-pass filter. In the frequency range containing most of the radiated energy (around CDAO natural frequency), the attenuation of the strong motion by hysteretic damping be larger than for weak motions.

The above arguments indicate that the HHT allows a more precise characterization of the layers behaviour as linear or nonlinear and demonstrates that Fourier analysis is not able to account some aspects of the response characteristics related with nonstationary time histories. More analyses about nonlinearity, fundamental period and soil degradation are needed but there is no doubt that the HHT is more versatile when explaining the seismic phenomena because makes use of an adequate space: [intensity, frequency, time].

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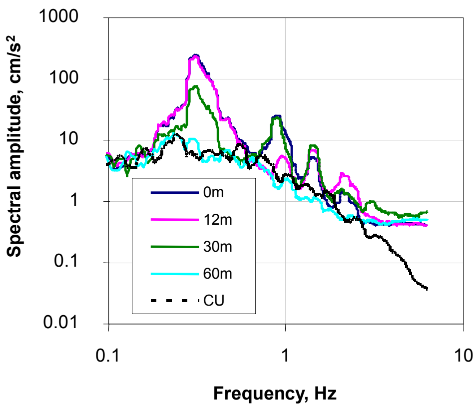

Fig. 10 Fourier amplitude spectrum for the vertical accelerographic array in CDAO (Event Nov. 9th 1995, Mc: 7.5)

V. Conclusions

This study introduces the method of HHT for earthquake data analysis and investigates its rationale for studies of earthquake engineering and seismology. The results presented here reveal the HHT capabilities for analyzing nonstationary dynamic and earthquake motion recordings. The decomposed components, namely, the IMF components, may contain observable, physical information inherent to the original data and also capture the features of the response spectrum of the original data. The Hilbert spectra show the temporal-frequency energy distribution for dynamic and earthquake motion recordings precisely and clearly. For natural systems (i.e. soil deposits) where only exist measured responses, the question as to whether linear or nonlinear characteristics (of the systems) can be identified from the data cannot be answered from the traditional duality cause-effect. For seismic processes the Fourier-based spectral analyses are not adequate because they are based on linear and stationary assumptions. In this short paper we have addressed the possibility of characterizing natural systems (soil deposits) by the time-frequency variations of system signals (accelerograms represent the systems dynamics). The objective of describing data from engineering perspectives (timefrequency-intensity domain) for finding specific and indicative behavior patterns reducing the error mechanisms is addressed applying the HHT to the seismic information. Our analysis is of a preliminary nature and many issues have to be investigated rigorously but the HHT seems to have much potential for this approach.

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