Measurement and simulation of electromagnetic interference in low frequencies range

Jiří Otáhal, František Hruška, Stanislav Sehnálek

***Abstract*—**Low voltage electrical installation with frequencies 50 or 60 Hz and voltages of 110 or 240 V are almost omnipresent in domestic homes, office spaces and industrial environments. These electrical installations are adjoined to electrical devicees, other metallic cables, such as metallic data transmission cables and living organisms. Voltage and current in cables, which are commonly used for low voltage electrical installations, create an electromagnetic field around these cables. This intensity of electromagnetic field which electrical installation cables or especially single phase conductors create, depends on the magnitude of the current, magnitude of voltage, type of used cable and the distance between cable and the victim of influence of electromagnetic field. In this article, the electromagnetic field created by low voltage electrical installations is measured and simulated.

***Keywords*—** electromagnetic field, electromagnetic wave, interference, influence interference, electric smog.

I. Introduction

ELECTROMAGNETIC interference (EMI) is the process of the emission and immission of electromagnetic field or electromagnetic radiation. This emission from electric devices or electrical lines generates electromagnetic field or radiation into free space. The immission is a state of environment, where a field is created, and depending upon specific conditions, this field affects other electrical equipment. The quality of the electrical arrangement is given by electromagnetic compatibility (EMC) – namely, the generation of the electromagnetic field, i.e. the electromagnetic interference and by immunity of electrical devices to this field, i.e. their electromagnetic susceptibility. [7,8,10] This immunity could be improved by the physical construction of an electrical device, i.e. the electrical device´s shielding or the use of cables with shielding. Another method is to use electronic filters on inputs and outputs. [8]. Economical aspects play an essential role in this aspect. The optimum costs to ensure the EMC immunity of an electrical device could be 2-10% of the development and manufacturing price. [8] The determination of the optimum balance between the technical solution for the immunity of electrical devices and the costs of these technical solutions is necessary.

One of the couplings between the EMI elements is realized by a cable - for instance a galvanic structure or an environment, such as a capacitive or an inductive structure. A general view of EMI is shown in Fig.1.

The problem of EMI can be universally displayed as a negative way of influencing the correct functioning of an electrical arrangement and instruments, if is not resolved well.[1]

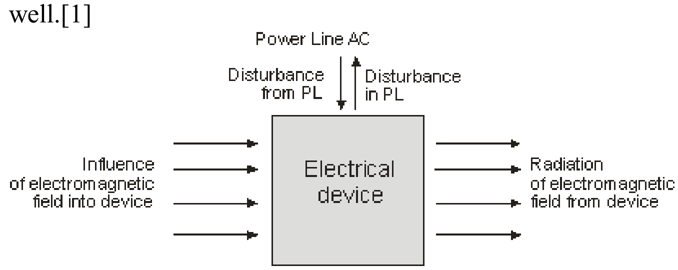

Fig. 1 Scheme of systems of intelligent buildings [1]

The primary focus of this paper is on the influence of electromagnetic field interference from two commonly used cables. The measured interfering electromagnetic fields around a 240V power line are described in this article. The magnitude of influence of electromagnetic field interference is dependent on the distance from cables and the type of cable, which is the source of interference.

II. Binding between electrical devices

Bindings between electrical devices cause EMI between the source and the receiver. Figure 2 shows the bindings.

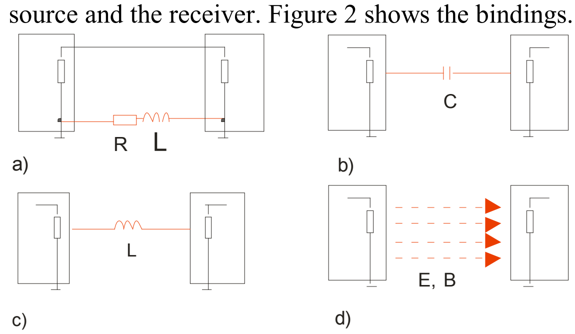

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Fig. 2 Kinds of bindings: a) galvanic, b) capacitive, c) inductance, d) electrical (E) and magnetic fields (B). [1]

Ac seen in figure 2, electromagnetic field binding is the most important kind of these bindings.

Inductive bindings are found in magnetic fields. A magnetic field can be increased by the motion of the charge or by alternation of the electric field or by increasing magnetic inductance in the current flow through the line.

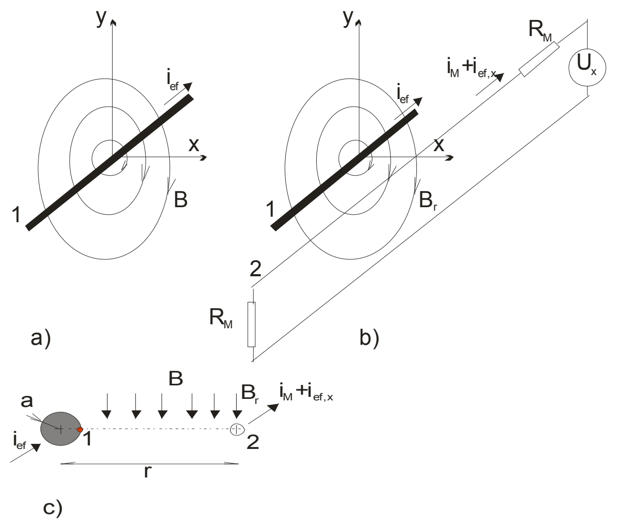


Fig. 3 Scheme of an inductive binding for evaluation of the calculation[1]

A magnetic field is defined by magnetic inductance B in accordance with the relationship for Distance x can be calculated for a conductor with current flow (with U_{rms} and with a 50 Hz frequency):

$$B_x = \frac{\mu . i_{ef}}{2\pi . x} \tag{1}$$

The quadratic equation below is valid for the description of Φ for an induction flux in a flat S, as follows:

$$\Phi = B.S.\cos\phi \tag{2}$$

Where Bef is the effective value of the alternate magnetic inductance induced by a sine-wave frequency, e.g. 50 cps (B.cosφ).

In close proximity of Conductor 1, there is a loop for measuring a circuit with Conductor 2. Changes in the magnetic field produce voltage U_2:

$$U_2 = -\frac{d\Phi}{d\tau} = B_{ef.r}.S_v \tag{3}$$

Where Sv is the area of line 2, and $B_{ef,r}$ is the magnetic induction.

This induced interferential voltage is added to the measuring voltage UM and represents changes U_x. [14]

III. Used Equipment for Measuring Electric and Magnetic Field

Two kinds of equipment were used for measuring electric and magnetic field:

A. *Low Frequency Analyzer ME3851A*

The low frequency analyzer ME3851A has switchable frequency range from 5 Hz to 100 kHz with accuracy: +/- 2 %, +/- 7 digits @ 50/60 Hz RMS. The measurement range for magnetic flux density is 0.1 - 1999 nT, and the measurement range for electric field strength is 0.1 - 1999 V/m. [3]

B. *Gaussmeter LakeShore 421*

The Hall effect devices used in gaussmeter probes produce a near linear response in the presence of a magnetic field. Gaussmeter LakeShore 421 has frequency range from 10 Hz to 100 kHz with accuracy: ±2% of reading (50 – 60 Hz.) RMS. AC Frequency Response is 0 to –3.5% of reading (10 – 400 Hz.) The measurement range for magnetic flux density is 30 G – 30kG. [4]

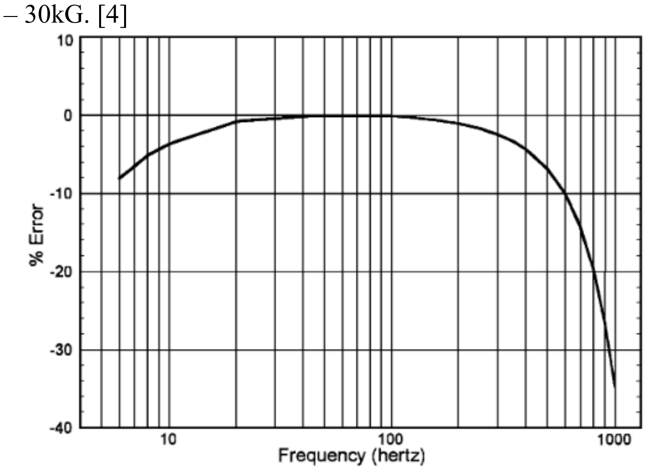


Fig. 4 The AC accuracy specs for sinusoidal input[5]

IV. The Experiment Environment

The experiment was conducted on a wooden plate on a wooden table in anechoic shielded chamber. The anechoic shielded chamber has a 3-line low voltage power input power filter. The active length of phase conductor was 433 cm. The conductor had a "U" shape with dimensions 158, 118, 158 cm. The experiment overview can be seen in figure bellow. The measurements were done in axis between parallel phase conductors. The influence of magnetic fields interference was measured each 2 cm in the 20cm surroundings around cables and after that every 5 cm.

V. Multiphysics Environment Software Comsol

Comsol is the multiphysical environmental software which is used for simulation. For comparison with experiment could be used finite element method (FEM). For this purpose was used COMSOL Multiphysics 3.5, where domain was setup to 2 dimensional. Comsol used anisotropic mesh which can be seen in fig. 6.

Fig. 5 Experiment overview

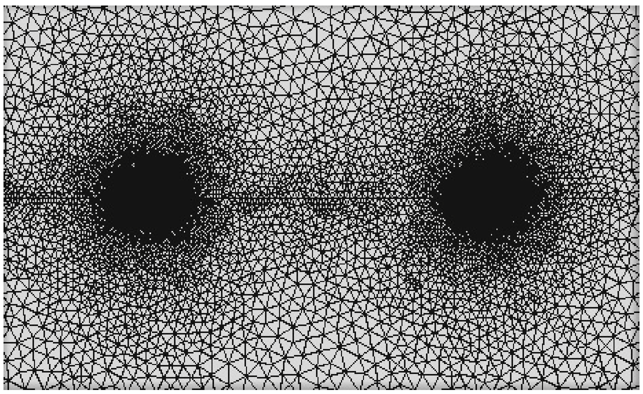


Fig. 6 The mesh for simulations

VI. Measuring and Simulation of Influence Interference Field

A. *Measuring and simulation of influence interference field around single phase conductor*

Interference influence magnetic field from single phase conductor was measured. As a source of the interference influence magnetic field was chosen conductor CYA 2,5mm^2.

The wire was a line with the voltage of 240V and frequency of 50Hz. The magnitude of current was 8.08 A. The electric field was measured by Low Frequency Analyzer ME3851A and the magnetic field was measured by Gaussmeter LakeShore 421. Simulation was done by software Comsol.

B. *Measuring of interference influence field around cable CYKY 3x2,5*

Interference influence magnetic field from cable 3G2,5 was measured. As a source of interference influence magnetic field, a 3 x 2,5mm^2 cable was chosen.

A typical connection of the cable was used. The first conductor in the cable was a line with the voltage of 240V and frequency 50Hz. The second was used like a neutral and the third was used like a ground. The magnitude of the current was 8.08 A. The electric and magnetic field was measured by Low Frequency Analyzer ME3851A.

VII. Measuring and Simulation of Influence of Interference Field Results

A. *Measuring and simulation of the influence of field interference around a single phase conductor*

The measurement was carried out and it was compared with data from simulation in software Comsol. As can be seen in fig. 7, simulation data strictly imitate measured values.

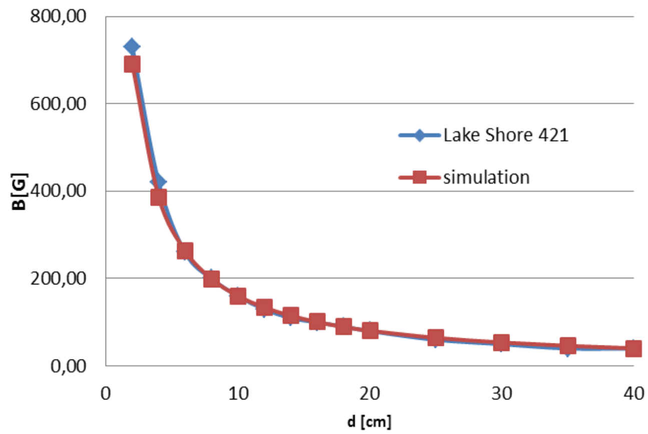


Fig. 7 Comparision between measurenment of magnetic field around cable CYA 2.5 and simulation in software Comsol, U=240V and I= 8.08 A

Fig. 8 displays the magnetic field simulation around CYA 2.5 cable in software Comsol, U=240V and I= 8.08 A. A very large area with strong magnetic field can be seen.

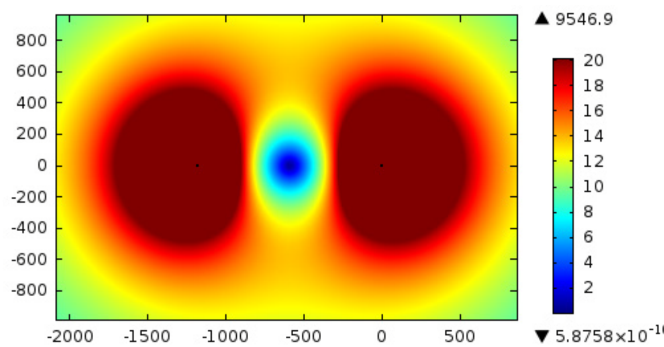


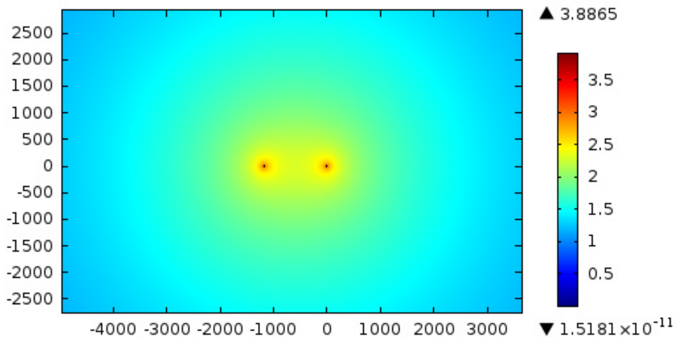
Fig. 8 Magnetic field simulation around CYA 2.5 cable in software Comsol, U=240V and I= 8.08 A

Fig. 9 displays the electric field simulation around CYA 2.5 cable in software Comsol, U=240V and I= 8.08 A. It should be noticed, the distance between cables is 118cm and the range of electric field is more than 2 m from the cable.

Measuring of interference influence field around cable CYKY 3G2,5

B. *Measuring the influence of field interference around a CYKY 3G2,5 cable*

The results from measurement of magnetic field can be seen in fig. 10 and fig.9 displays results from measurement of electric field.



VIII. Comparison of Fields Which Created Cables Used for Measurement

A. Comparison of electric field which the cables used for measurement created.

Intensity of electric fields around selected cable were compared. Fig. 9 shows magnitudes of electric field in same places. The electric field around the cable CYA 2.5 is 1.9 times higher than around cable CYKY 3x2.5.

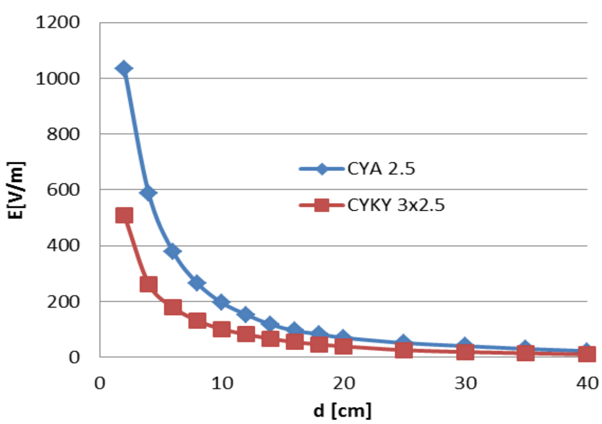


Fig. 9 Comparison of eletric fields around cables

B. A. Comparison of electric field which the cables used for measurement created

Intensity of magnetic fields around selected cable were compared. Fig. 10 shows magnitudes of magnetic field in same places. The magnetic field around the cable CYKY 2.5 is 85 times higher than around cable CYKY 3x2.5.

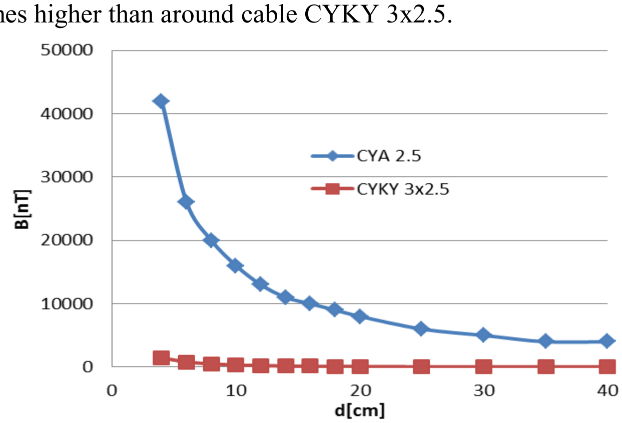


Fig. 10 Comparison of magnetic fields around cables

IX. Conclusion

Electric and magnetic fields were measured around cables CYA 2.5 mm^2 and CYKY 3x2.5 mm^2. Results of measurement of fields around cables were compared and cable CYA 2.5 mm^2 had 1.9 times stronger electric field and 85 times stronger magnetic field than CYKY 3x2.5 mm^2. Electric and magnetic fields were simulated in Comsol software and simulations strictly imitate measured values.

Another part of the work in the next period will be the measurement and the simulation impact of electric and magnetic fields to unified signals used for transmission of measured values.

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