Abstract— In this paper a methodology has been developed for optimum planning of hybrid PV, Wind and diesel generator system with some battery backup in Kirkuk Technical College in Iraq. The local solar radiation, wind data and components database from different manufactures are analyzed and simulated in HOMER model to assess the technical and economic viability of the integrated system. Performance of each component was evaluated and sensitivity analysis was performed to optimize the system at different conditions. Optimal hybrid model has been selected on the basis of cost associated with the system and reliability using HOMER. The optimal cost of energy from the proposed hybrid system is (0.154 $/kWh.). Comparison was also made with the cost per kilowatt hour from the National grid.

Keywords— stand-alone, hybrid energy system, homer.

1. INTRODUCTION

Renewable energy is defined as the energy generated from natural resources such as sunlight, wind, and geothermal heat, which are renewable. The application of renewable energy system has become an important alternative when the conventional sources are depleted and the price of oil reaching its highest level [1-2]. Hybrid power systems usually integrate renewable energy sources with fossil fuel based generators to provide electrical power. Hybrid systems offer better performance, flexibility of planning and environmental benefits compared to the diesel generator based stand-alone system. Hybrid systems also give the opportunity for expanding the generating capacity in order to cope with the increasing demand in the future [3-6].

2. HYBRID POWER SYSTEMS

Hybrid energy system usually consists of two or more renewable energy resources used together to provide increased system efficiency as well as greater balance in energy supply [7-8]. Hybrid power systems usually integrate renewable energy sources with fossil fuel, (diesel/petrol) based generators to provide electrical power and traditional diesel system acting as back-up in case of lack of the primary source [9].

3. MODELING OF HYBRID SYSTEMS

In order to design a mini-grid hybrid power system, one has to be provided with information for the selected location. Typical information’s required are; the load profile that should be met by the system, solar radiation for PV generation, wind speed for the wind power generation, initial cost for each component, cost of diesel fuel, annual interest rate, project lifetime, etc. Then using these data one can perform the simulation to obtain the best hybrid power system configuration. One of the available tools for this purpose is the HOMER software from USA National Renewable Energy Laboratory (NREL) [10]

4. RESEARCH METHOD

The proposed hybrid renewable consists of wind turbine and solar photovoltaic (PV) panels with battery; generator and inverter are added as part of back-up and storage system. Proposed system is shown in Figure 1 and the project building load demands are shown in Figure 2.

Figure 1: The proposed hybrid system.
In this paper, Hybrid optimization model of renewable energy (HOMER) has been used to optimize the best energy efficient system for the dean office in Kirkuk Technical College (KTC), see Figure 3, considering different load and wind photovoltaic (PV) combinations. The study site location Latitude is 35° 5' north and 44° 4' east. Daily solar radiations in the study site and wind speed were got from NASA web site. [11].

Figure 3: The building of the dean of Kirkuk Technical College

4.1 SOLAR PV PANELS

The proposed solar power system is 40kW. The supposed cost is 7000 $/kW and the lifetime of the panels will consider to be 25 years. Figure 4 shows the solar resource profile considered over a span of one year. The monthly averages of daily global solar insolation data are normally available for several locations in a region. The data should be such that it covers a larger range of latitudes. These data are then reduced to the monthly average daily clearness index (KT) by taking the ratio of measured global solar insolation to the calculated extra-terrestrial horizontal insolation. The annual average solar radiation was scaled to be 5.27kWh/m2/day and the average clearness index was found to be 0.634. The graph plot in the Figure 4 shows that solar radiation is available throughout the year; therefore a considerable amount of PV power output can be obtained.

Figure 4: The daily solar ratio and clearness index
4.2 WIND TURBINE

Wind turbine type PGE 20/25 was chosen among many manufactured turbines, has a capacity of 20 kW. Its initial cost is $20000 and its replacement cost is $16000. Annual operation and maintenance cost is $1000 per year. Its hub and anemometer is proposed to be located at 10 m height. Lifetime is assumed for 15 years. The chosen wind turbine specifications, capital and replacement costs were shown in Figure 5 [12], and the wind speed for our case study location is 5.758m/s as shown in Figure 6. Also it shows that there are 16 hours of peak wind speed. The wind speed variation over a day (diurnal pattern strength) is 0.14 and the randomness in wind speed (autocorrelation factor) is 0.93.

4.3 DIESEL GENERATOR

STAMFORD AC generator from NEWAGE INTERNATIONAL LIMTED ENGLAND which was already installed in the college, has a capacity of 170 kW. Its initial and replacement costs are 30000$ and 28000$ respectively. The operation and maintenance is 5$ per hour. Its lifetime is estimated to be 5000 operating hours. Other details of generator were shown in Figure 7.

4.4 CONVERTERS:

A converter is a device that converts electric power from dc to ac in a process called inversion, and/or from ac to dc in a process called rectification. HOMER can model all types of converters.

The converter size, which is a decision variable, refers to the inverter capacity, meaning the maximum amount of ac power that the device can produce by inverting dc power. The user specifies the rectifier capacity, which is the maximum amount of dc power that the device can produce by rectifying ac power, as a percentage of the inverter capacity. The rectifier capacity is therefore not a separate decision variable.

HOMER assumes that the inverter and rectifier capacities are not surge capacities that the device can withstand for only short periods of time, but rather, continuous capacities that the device can withstand for as long as necessary. The economic properties of the converter are its capital and replacement cost in dollars, its annual operation and maintenance (O&M) cost in dollars per year, and its expected lifetime in years.

5. DESIGNE RESULTS

The overall optimization results table by HOMER will show system configurations sorted by total net present cost which contain a few of the key simulation results: namely, the total capital cost of the system, the total net present cost, the levelized cost of energy (cost per kilowatt hour), the annual fuel consumption, and the number of hours the generator operates per year. HOMER can also show a subset of these overall optimization results by displaying only the least-cost configuration within each system category or type as shown in Table 1 for the five least cost.
6. THE FIRST LEAST-COST RESULT (as shown in the first row of Table 1): wind turbine, diesel generator, converter and batteries.

The schematic diagram is shown in Figure 8. There are two busbars DC and AC. The load, turbine generator PGE 20/25 and diesel generator are connected to AC busbar. Batteries are connected to DC busbar, while converter is connected to both DC and AC busbars.

![Figure 8: The first schematic design.](image)

6.1 COST CALCULATIONS:

Renewable and nonrenewable energy sources typically have dramatically different cost characteristics. Renewable sources tend to have high initial capital costs and low operating costs, whereas conventional nonrenewable sources tend to have low capital and high operating costs. In its optimization process, HOMER must often compare the economics of a wide range of system configurations comprising varying amounts of renewable and nonrenewable energy sources. To be equitable, such comparisons must account for both capital and operating costs. Life-cycle cost analysis does so by including all costs that occur within the life span of the system. Figure 9, shows the first design cost summary: Wind turbine= 34,940$, Diesel generator= 12,358$, Batteries= 13,361$, Converter= 9,283$ and the system total cost is 69,941$.

![Figure 9: The first design cost summary (by components).](image)

6.2 MONTHLY AVERAGE ELECTRIC PRODUCTION

The percentage of electric production from wind generator and diesel generator are 94%, and 6% respectively. The details of the monthly electric production are show in Figure 10.

![Figure 10: The details of the monthly electric production.](image)

6.3 WIND TURBINE:

Wind generator (PGE20/25) rated capacity, mean and maximum output are 25, 9 and 26.3kW respectively. Total production is 78,464 kWh/yr. Details of simulation results are shown in Figure 11.

![Figure 11: wind generator PGE20/25 simulation results details.](image)
6.4 DIESEL GENERATOR:

Diesel generator in the 1st design works 582 hr/yr. and produce 16,546kW/yr. The specific fuel consumption is 0.132L/kWh and diesel generator consumes 618 L/yr.

6.5 BATTERIES:

The dc bus voltage in the system is 12V. Among battery types and specifications we chose the battery type (Surette 4KS25P) of 4V terminal voltage for its good specifications. The string size is 3 to get 12V dc. We use 16 strings in parallel and the overall will be equal to 16*3=48 batteries total. Figure 12 shows battery simulation results in details.

6.6 CONVERTER

The inverter and rectifier capacity are 20kW and 50kW respectively. Figure 13 shows capacity, maximum output, minimum output, capacity factor, energy in, energy out and losses for both inverter and rectifier.

HOMER calculates its fixed and marginal cost of energy for comparison with other dispatchable sources. Unlike the generator, there is no cost associated with “operating” the battery bank so that it is ready to produce energy; hence its fixed cost of energy is zero. For its marginal cost of energy, HOMER uses the sum of the battery wear cost (the cost per kilowatt-hour of cycling energy through the battery bank) and the battery energy cost (the average cost of the energy stored in the battery bank).

6.7 Grid Extension Cost vs Stand-alone Hybrid System

It is important to compare the hybrid system with the National grid. In Homer model, the National grid inputs as shown in Figure 14 are: capital cost= 8000$/km, operating and maintenance cost= 600$/yr./km and grid power price as 0.4$/kWh.[10]
Homer will use these inputs to calculate the breakeven grid extension distance, which is the grid minimum distance that makes cost of energy COE in a stand-alone system cheaper than COE in extending the grid.

In the 1st design the breakeven grid extension distance is (-8.54) km. The negative distance value means that COE in hybrid system is cheaper always than COE in National grid.

6.8 GAS EMISSIONS:
Most of the pollutants result from the production of electricity by the generator(s), the production of thermal energy by the boilers and the consumption of grid electricity. The amount of pollutants for the 1st design category are shown in the table2

Table2: The amount of pollutants for the 1st design category.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Emissions (kg/yr)</th>
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<tbody>
<tr>
<td>Carbon dioxide</td>
<td>1,627</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>4.02</td>
</tr>
<tr>
<td>Unburned hydrocarbons</td>
<td>0.445</td>
</tr>
<tr>
<td>Particulate matter</td>
<td>0.303</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>3.27</td>
</tr>
<tr>
<td>Nitrogen oxides</td>
<td>35.8</td>
</tr>
</tbody>
</table>

6.9 THE OTHER LEAST-COST RESULTS:
6.9.1 THE SECOND LEAST-COST RESULT: wind turbine + solar panels + diesel generator + converter + batteries. Cash flow summary is shown in Figure 15. The schematic diagram is shown in Table 3a.

In the 2nd design, the breakeven grid extension distance is (-3.54) km. The negative distance value means that COE in hybrid system is cheaper always than COE in National grid.

6.9.2 THE THIRD LEAST-COST RESULT: wind turbine + solar panels + converter + batteries. The schematic diagram is shown in Table 3b. In the 3rd design, the breakeven grid extension distance is (-2.12) km. The negative distance value means that COE in hybrid system is cheaper always than COE in National grid.

6.9.3 THE FORTH LEAST-COST RESULT: wind turbine + solar panels + converter + batteries. The schematic diagram is shown in Table 3c. In the 4th design, the breakeven grid extension distance is (-0.830) km. The negative distance value means that COE in hybrid system is cheaper always than COE in National grid.

6.9.4 THE FIFTH LEAST-COST RESULT: wind turbine + diesel generator. The schematic diagram is shown in Table 3d. In the 5th design, the breakeven grid extension distance is (3.43) km. This means that COE in hybrid system is cheaper than COE in National grid for distances greater than 3.43 km as shown in Figure 16.

6.10 COMPARISON BETWEEN OPTIMAL and OTHER CATOGERIS.
Comparison between the hybrid systems in total cost, levelized COE, operating cost, fuel consumption, grid distance and CO2 is shown in Table 4.
Table 3: The system schematic designs (a, b, c and d).

Table 4: Comparison between Optimal and Other Categories.

<table>
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<tr>
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<tbody>
<tr>
<td>1st</td>
<td>69,441</td>
<td>0.154</td>
<td>3,214</td>
<td>618</td>
<td>-8.54</td>
<td>1,627</td>
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<tr>
<td>2nd</td>
<td>136,695</td>
<td>0.302</td>
<td>3,374</td>
<td>615</td>
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<tr>
<td>3rd</td>
<td>155,565</td>
<td>0.345</td>
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<tr>
<td>4th</td>
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<td>0.376</td>
<td>13,655</td>
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<tr>
<td>5th</td>
<td>229,708</td>
<td>0.5</td>
<td>12,239</td>
<td>4,286</td>
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<td>11,287</td>
</tr>
</tbody>
</table>

6.11 CONCLUSIONS:

The systems based on PV alone, wind alone, solar-battery, solar-Diesel Generator (DG), wind-battery, wind-DG, wind solar- battery, and wind-solar-DG and other possible configuration for the utilization of distributed generating systems were investigated. For a given location, optimization is carried out on the basis of the cost and reliability of the system. As shown in Table 4, it is found that the hybrid system based on wind turbine, diesel generator, battery storage and converter is the best hybrid generating system for the given location in Kirkuk city.
REFERENCES


