Investigate the optimal power system by using hybrid optimization of multiple energy resources software

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ABSTRACT

Increasing the effects of global pollution and the availability of renewable energy sources has push many countries to use reasonable energy sources such as wind and solar energy. This paper presents a case study of evaluating a hybrid renewable energy system by using a hybrid optimization of multiple energy resources (HOMER) software program based on the entered data available from the net for the considered location. The hybrid system consisting of a wind turbine, a photovoltaic system, a battery and a diesel generator. The simulation results are presented in a graphical curves n HOMER software. The obtained results indicate that by using the HOMER simulation program, the optimal design of the hybrid electrical power system for the considered location can be achieved which can help the designer to decide the types and number of the competent required for conducting the intending hybrid electrical power system which results in optimum output power in addition to reducing the overall operating costs.

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1. INTRODUCTION

Renewable energy is energy that is exploited at the same rate at which it is naturally renewed. Most countries around the world will face an energy shortage in the near future due to an increase in consumption [1]. The natural and technical potential of renewable energy sources is sufficient to meet the overall energy requirements of the world's population, because their natural daily potential is 20,000 times higher than the daily consumption of nuclear and fossil fuels [2], [3]. The biggest problem in the use of renewable energy sources is the oscillating nature of such energy sources or the inability to guarantee the installed power [4]. The solution of the mentioned problem is the installation of an auxiliary energy source or connection to the hybrid composition [5]. An auxiliary energy source is usually a diesel generator [6].

Wind turbine and photovoltaic energy system directly converts wind or solar energy into electrical power [7]. It is not necessary to use them together, but it is recommended because of their complementarity [8]. During the winter months, solar radiation is less and the wind is more intense, so the wind farm produces more electrical power compared to the summer months [9].

The optimization and sensitivity analysis algorithm in hybrid optimization of multiple energy resources (HOMER) make it easy to estimate a number of system configuration options [10]. HOMER makes it possible to define models with input data, which describe technological choices, component prices, and resource availability [11], [12]. HOMER software program uses the data entered to simulate system configurations for a combination of components, and generates results that can be seen as a list of achievable configurations [13]. The results of simulations in different tables and graphs help to compare configurations and evaluate them according to their economic and technical values [14].

Recently, a lot of research has been done on the optimal design and operation of a hybrid renewable electrical power system. For example, the authors extend their work to consider the optimal operation of the hybrid electrical power system by further exploring how different demand schedules affect operating costs and peak loads [15], [16]. Since the growing trend towards peak loads is a major challenge for power systems [17]. Chotia and Chowdhury in [18], the authors discuss the optimization of power consumption and analyzes under different scenarios show that distributed power sources can influence the load curve.

Rudolf [19], for example, both researchers provide communication-based controls for intelligent component management, while [20] provide multidimensional drop control for control of micro wind turbine and the economics of real micro slot systems. For example, the study of [21] analyzes the discrete micro-grid installed on the island of Kythnos, Greece, and in particular the technical and economic aspects of the replacement of diesel generators by fuel cells, electrolyte and traditional hydrogen storage. Udoakah *et al.* [22] also analyzes two implemented micro-grids, independent and interconnected, both located by the sea side Athens, Greece [23]. Most of the articles above estimate the energy needs of hybrid/photovoltaic system by calculating the electrical power quantities needs for each household appliance by numerical calculating the optimum output power of the system [24].

2. METHODOLOGY

HOMER program performs three basic tasks: simulation, optimization, and sensitivity analysis. In the simulation process, HOMER models the appearance of a particular micro power system configuration every hour of the year to determine its technical feasibility and life cycle cost. In the optimization process, HOMER simulates many different system configurations in search for one that meets the technical requirements at the lowest life cycle cost. In the sensitivity analysis process, HOMER performs numerous optimizations in the area of input assumptions to assess the consequences of uncertainty or changes in input data [25].

2.1. Basic load data

The proposed systems consist of a small wind turbine, photovoltaic system, battery bank and diesel generator. Based on the entered data and with the set operating conditions of the system, HOMER will find the optimal solution. Figure 1 shows the scheme of the proposed system with 21.2 kWh/d, and the peak load 5.9 KW in HOMER software. Figure 2 shows the hourly, daily and seasonally load profile.

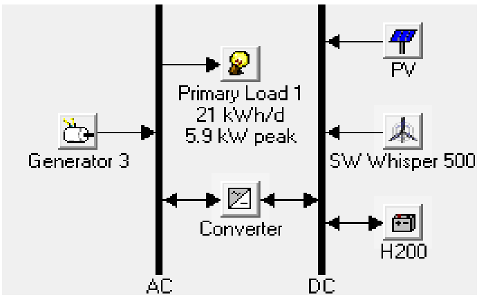

Figure 1. Scheme of the proposed system in HOMER software

2.2. Selection of system components

2.2.1. Selection of wind

The basic wind data used during the simulation are shown in Figure 3. These data are: altitude (m) and above sea level, Anemometer height (m), diurnal pattern strength, autocorrelation factor, Weibull k constant, daily wind regularity, and hour of peak wind speed. The most common values are between 14 and 16 hours. Here, when modeling the proposed system, it was chosen that the maximum wind speed clock is 15 hours. By choosing the monthly average option and entering all the required data, the calculation results of the annually average of the wind speed (m/s) and the wind speed values of every month are shown in Figure 3. By analyzing the wind speed annually average and loads, a 3 kW SW Whisper 500 wind turbine from the American manufacturer Wind energy was selected. The price of the selected turbine is around 1500$. Figure 4 shows a window in HOMER, in which we selected a specific wind turbine, as well as the characteristics and costs associated with that turbine.

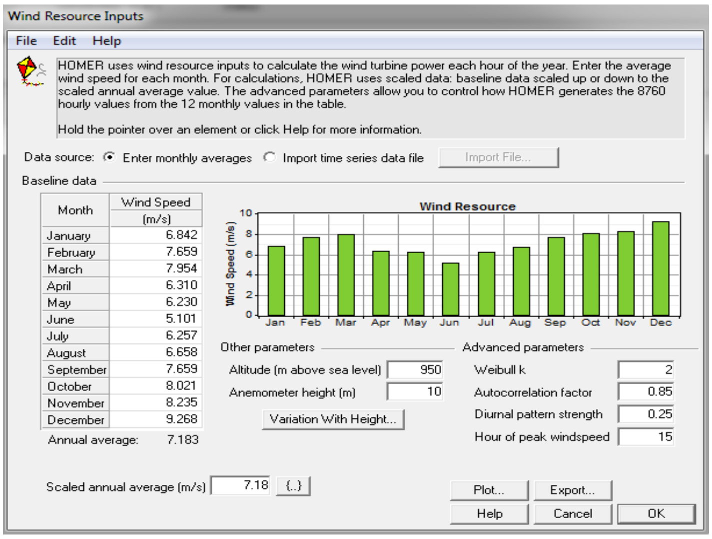

Figure 2. Hourly, daily and seasonally load profile

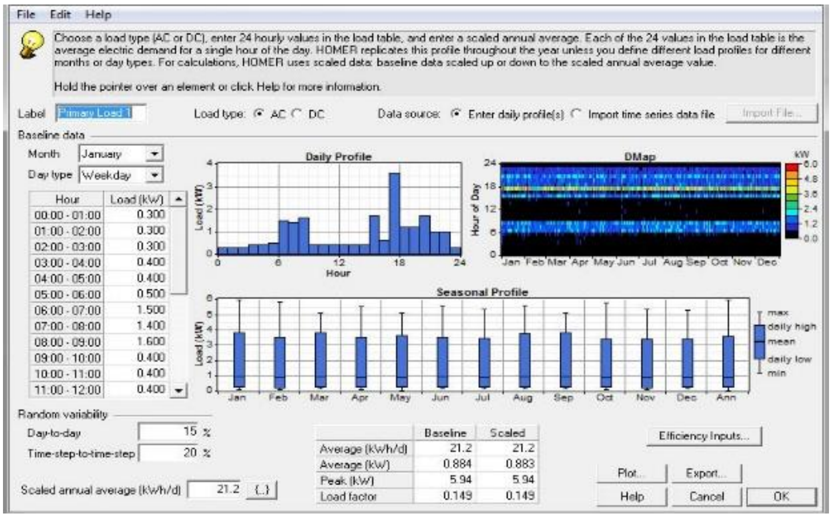

Figure 3. Wind speed through year months

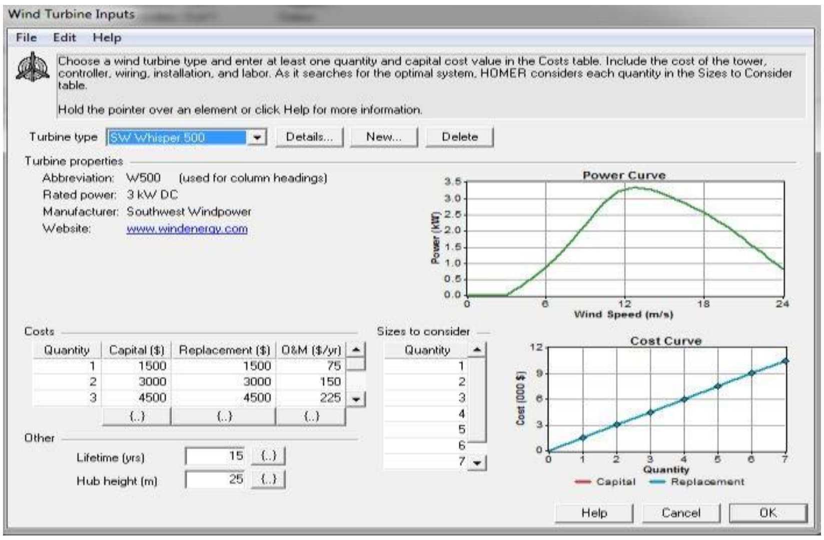

Figure 4. Wind turbine selection window

2.2.2. Solar panel selection

The basic sun data used during the simulation can be entered in two ways. The first way is for HOMER to the required data automatically via the internet from NASA's Surface Meteorology and Solar Energy database, by entering only the longitude and latitude of the desired location, as well as the time zone of the location illustrated in Figure 5. Another way is to manually enter global solar radiation data on a horizontal surface. For the proposed system, we used the first method, in which data on global solar radiation are automatically interred in the HOMER software through the internet from NASA's surface meteorology and solar energy database on a horizontal surface, will obtained directly from HOMER.

Since HOMER program does not have specified types of photovoltaic (PV) modules, but HOMER is primarily an optimization tool that seeks the most cost-effective combination of system components based on the data entered. For the proposed module, the following data have been entered: the module size (1.140 KW), lifetime of the PV module (20 year), debating factor (80%), tracking system, angle of inclination of the PV module (44.1°), azimuth (0), ground reflectance (20%). The effect of temperature has not been entered. The resulted calculating cure of the capital and replacement costs in ($) of the model are shown in Figure 6.

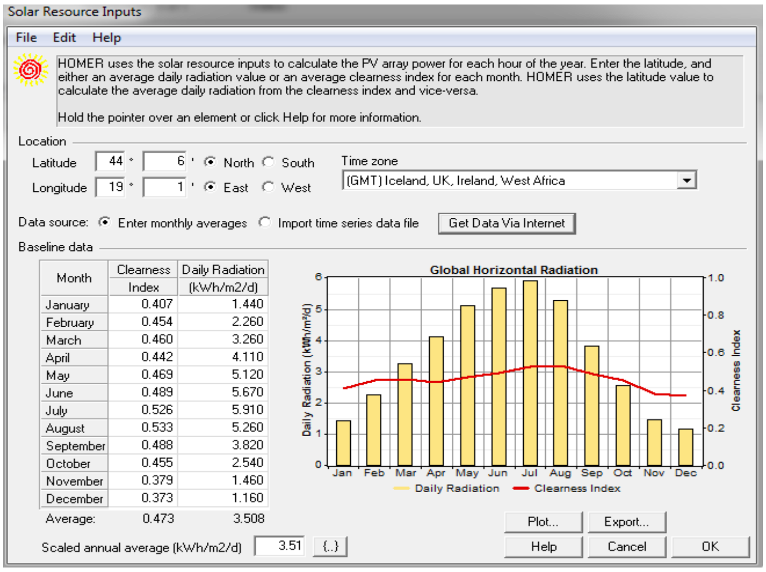

Figure 5. Global horizontal radiation resulted for the proposed location

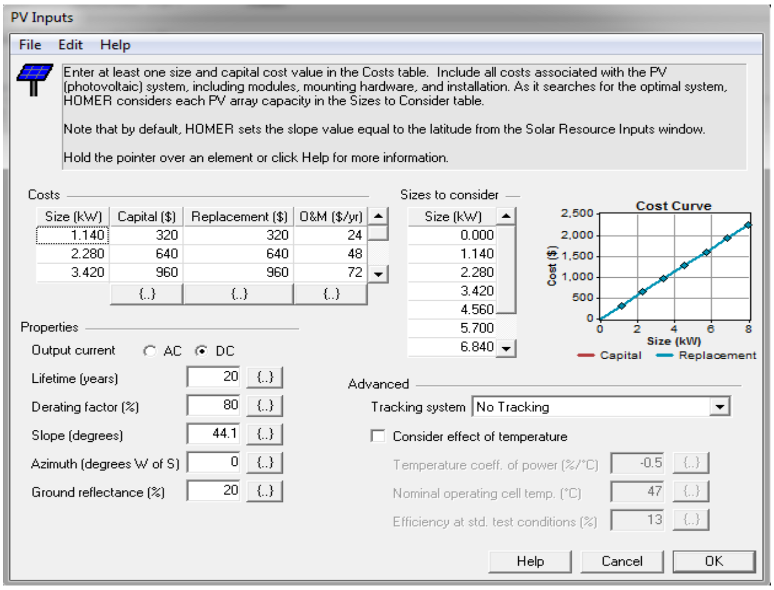

Figure 6. Photovoltaic module selection window

2.2.3. Inverter selection

In the solar system, it is possible to use special consumers adapted for operation on battery voltage, but in practice, in some more serious applications, most users want to use consumers for a standard mains voltage of 220 V/50 Hz. That is why a converter in a solar installation is needed. The converter is a device used to convert a standard battery voltage of 12 or 24 V into a standard mains voltage of 220 V, 50 Hz. A TY-3000-S-24V converter was selected for the design. Figure 7 shows a window in HOMER in which these parameters are entered for the selected inverter. The investment costs of the selected converter is about 400$.

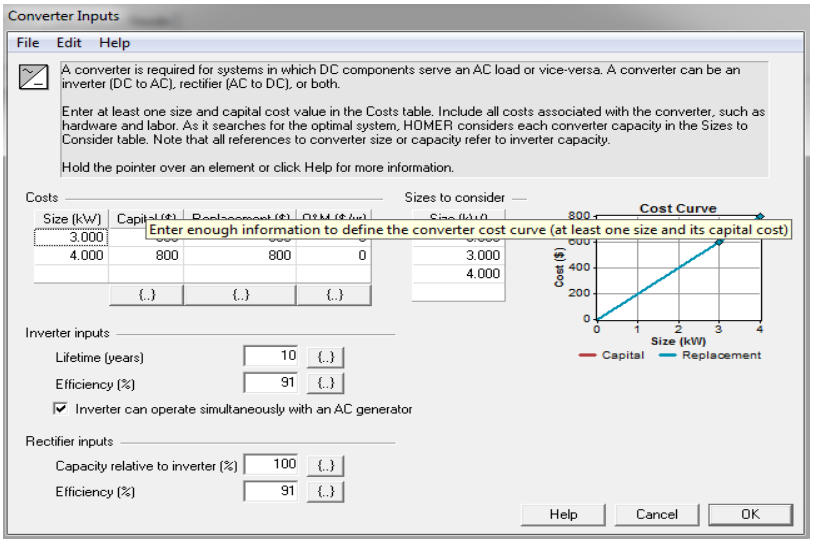

Figure 7. Inverter selection window

2.2.4. Selection of diesel generator

The GF5500 CX diesel engine type was chosen as independent sources. The chosen option for the considered generator is the (fuel) option with a size of (4500 KW), a live time or expected operating hours of (15000 h) and the minimum load ratio has been chosen to be (30%). The resulted calculating cure of the capital and replacement costs in ($) of the model are shown Figure 8. From Figure 8, we can see that the capital cost is (1500$), while the replacement cost is (3000$).

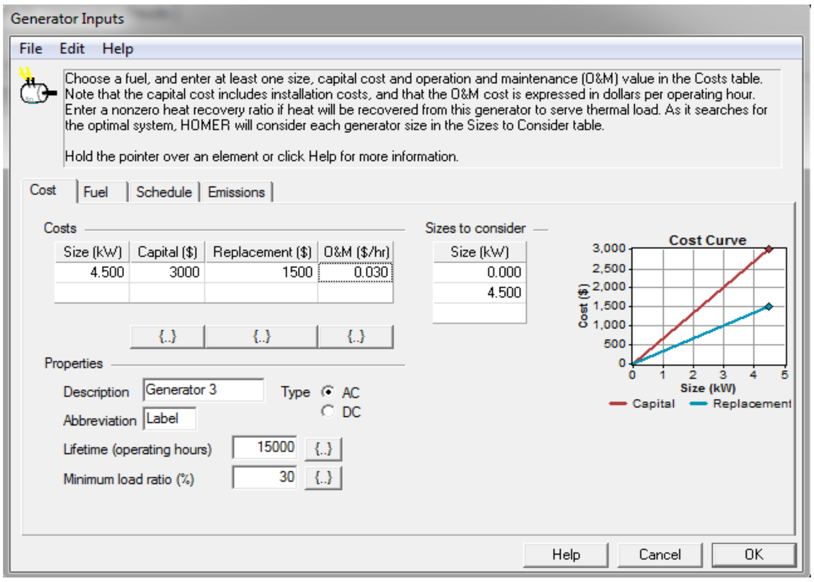

Figure 8. Diesel generator selection window

2.2.5. Battery selection

Hoppecke 4 OpzS 200 batteries, manufactured by the American company Us battery, were used in the proposed system. The chosen type has a nominal average of (2 V), lifetime throughput (680 KW/h) and Wirth a minimum life of (4) years. The resulted calculating cure of the capital and replacement costs in ($) of the model are shown Figure 9. From Figure 9, we can see that the capital and replacement costs are identical and equal (220$) for one battery unit.

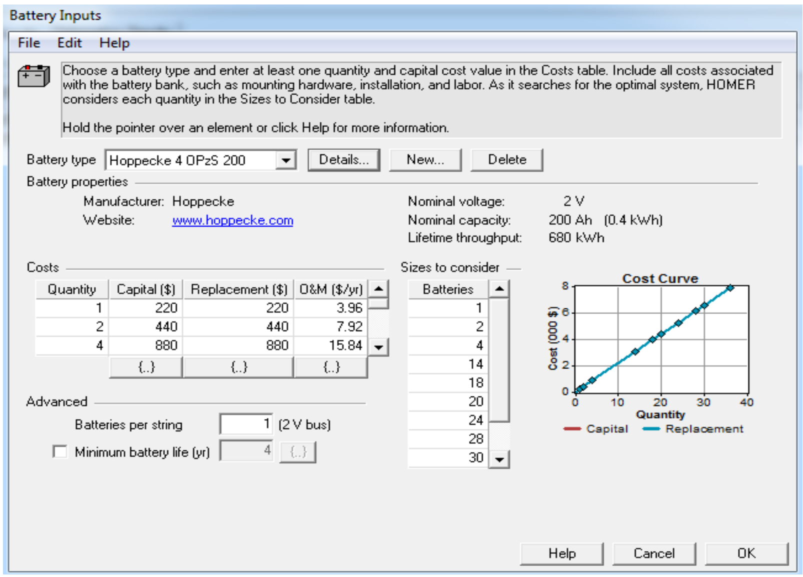

Figure 9. Battery selection window

3. RESULTS AND DISCUSSION

In preparing this paper, the investment costs of all system components are approximately correct. Upon completion of data entry, HOMER starts simulating and searching for the optimal system. After the task is completed, a display of systems sorted by cost-effectiveness appears, from most cost-effective to less cost-effective. Figure 10 shows the simulation results by choosing the resnet present costs option and the by choosing the competent costs option.

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	640	200	614	0	-112	1,341
SW Whisper 500	3,000	1,252	1,918	0	-233	5,936
Generator 3	3,000	0	208	4,716	-33	7,891
Hoppecke 4 OPzS 200	3,080	2,469	709	0	-528	5,730
Converter	800	696	0	0	-93	1,403
System	10,520	4,617	3,448	4,716	-999	22,302

Figure 10. Costs of the optimal system

Figure 11 shows the total monthly on electrical power production. Figures 11 shows that the maximum output power of the PV module gives 2.669 kWh/year winch equals to 9% of the total module production, Figure 12 represent the maximum output power of the wind turbine (25.513 kWh/year) winch equals to 87% of the total module production. Figure 13 represent the maximum output power of the diesel generator module (2.669 kWh/year) winch equals to 9% of the total module production. Figure 14 represent the annually battery bank charging state (1.063 kWh/year) winch equals to 4% of the total module production, the calculated total power output of the proposed module is 29.245 kWh/year.

Figure 14 indicates that in the months when the wind is more intense, the production of electrical power is higher. Problems in the operation of such a system are appeared during the summer months when the utilization of wind energy is low. The wind turbine capacity factor is 48.5%, which means that it is not large, and one of the reasons could be the variability of wind intensity during the year.

Figure 11. Monthly total output power of the proposed module

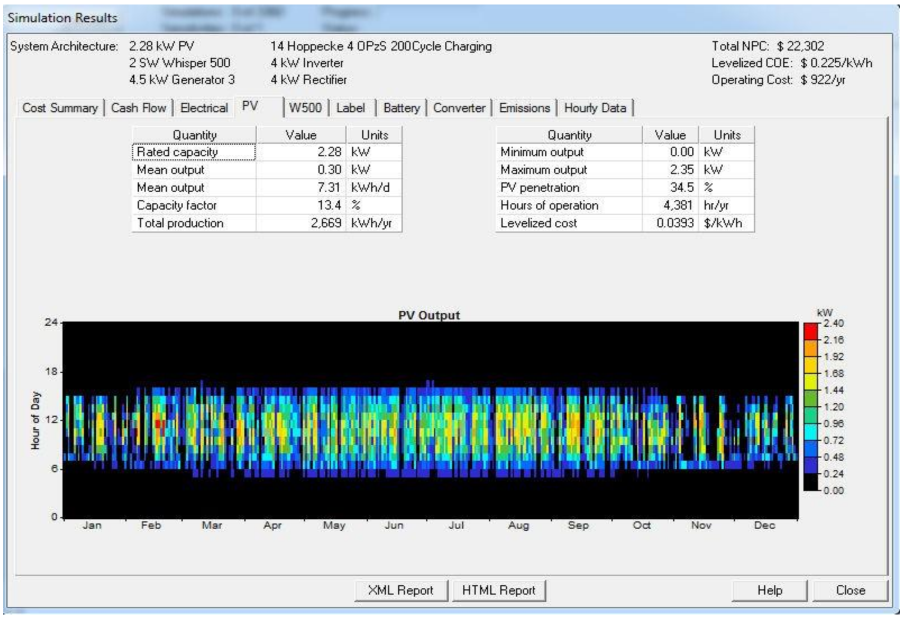

Figure 12. Annually total output power of the PV module in the proposed module

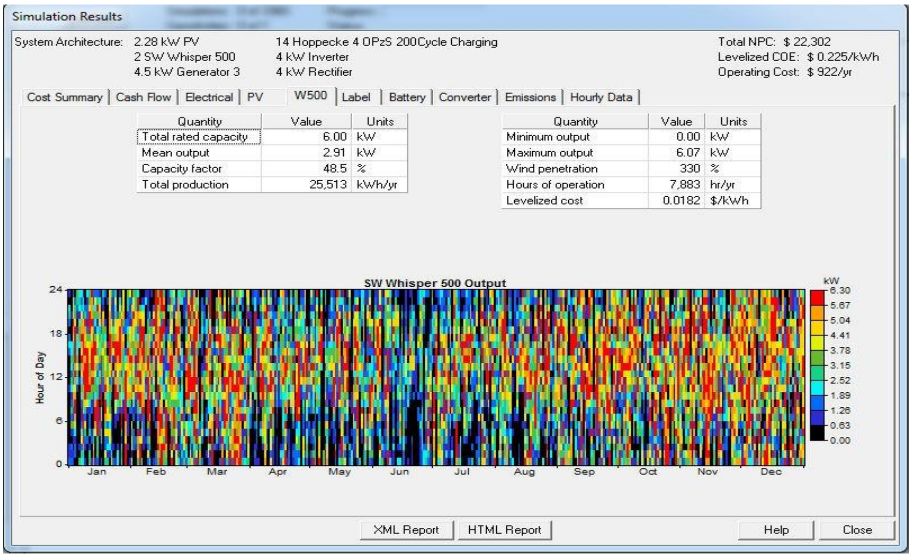

Figure 13. Daily operation diagram and data on wind farm operation

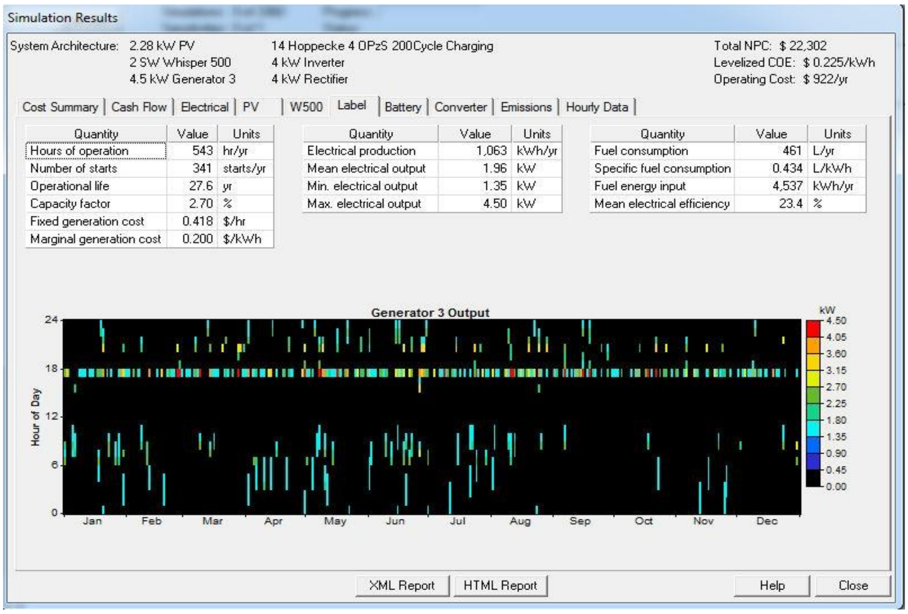

Figure 14. Daily operation diagram and data on the operation of diesel generators

From Figure 14, we can see that the generator set is more engaged in the evening when the load increases, and the solar panels cannot produce energy. During the year, the generator unit works for 543 hours, and its capacity factor is 2.6%. The service life of the generator unit is 27.6 years. The average annual output power is 1.96 kW, gasoline consumption is 461 l, and the average efficiency is 23%. During the modeling of the proposed system, fossil fuels were used, so there is an emission of harmful gases. The value of emissions of individual gases are shown in Table 1. The battery bank is shown in Figure 15.

Table 1. Emissions of harmful gases

No.	Pollutent	Emissions [kg/year]
1.	Carbon dioxide	1214.00
2.	Carbon monoxide	3.00
3.	Unburdened hydrocarbons	0.331
4.	Particulate matter	0.221
5.	Sulfate di	2.43
6.	Nitrogen oxides	26.6

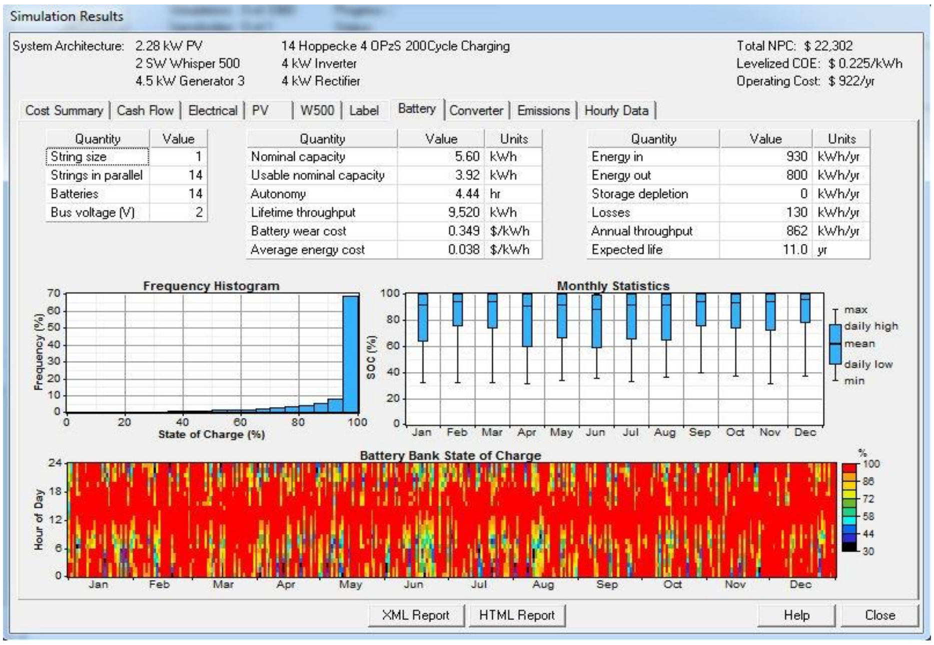

Figure 15. Annually battery bank charging state

Figure 15 shows that the battery system consists of 14 solar batteries connected in parallel, whose autonomy is 4.4 h. The nominal capacity is 5.6 kWh and the usable nominal capacity is 3.92 kWh. The batteries are full 68% of the time a year. The annually inverter and rectifier outputs are shown in Figure 16.

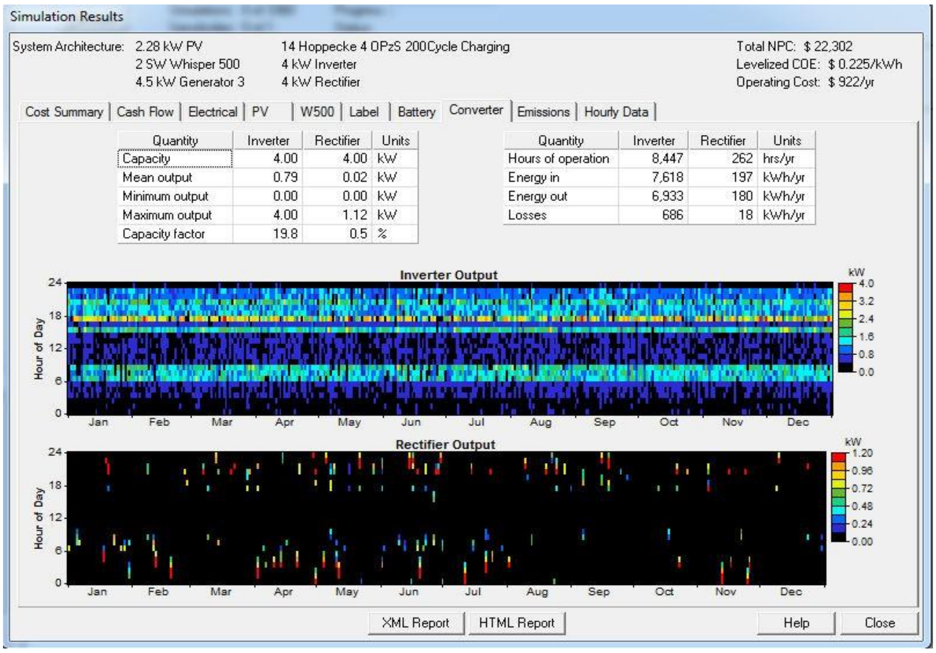

Figure 16. Annually inverter and rectifier output

From Figure 16, we can see that the converter works most of the time as an inverter, 8447 hours versus 262 hours when it works as a rectifier. The maximum output power of the inverter is 4 kW, and the rectifier 1.12 kW. Most of the time the converter works at night when the consumption is minimal, so the energy produced accumulates inside the batteries.

4. CONCLUSION

For remote facilities such as remote communication control room, caravans and other facilities that do not have the ability to connect to a low-voltage distribution network, the use of the renewable sources is a very good choice. The biggest problem in the use of renewable energy sources is the oscillating nature of such energy sources, or inability to guarantee the installed power. New systems are being developed which represents a computer program that simulate the operation of the system itself and enable a better understanding of the problem. So, in this paper a simulation optimizing proposed module has been conducted by using HOMER simulation program to investigate the optimum design including the cost effectiveness as well as the optimum output power. The proposed module consists of PV, wind turbine, diesel generator and battery bank.

The use of wind energy is economically very profitable. The wind turbine industry is developing rapidly and the installed capacity of wind turbines is increasing from year to year. The obtained results indicate that the use of the HOMER simulation program can give the optimum possible renewable electrical power system and cost-effectiveness. So, for designing any renewable hybrid electrical power system, it is preferred to make a simulation hybrid electrical power system by using the HOMER simulation program to determine the optimum output power and the overall system components costs.

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