Design of Renewable Energy System for a Mobile Hospital in Libya

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***Abstract*—Renewable Energy Systems are becoming a common choice for small communities around the world. Recently the United Nation efforts to provide field hospitals have decreased in areas that face a high risk in transportation, lack of power and lack of security for field officers. In this paper, a *PV* hybrid system is being considered for supplying an electric load of a mobile hospital in an area where there is no grid. An optimal configuration has been determined by taking the total cost as the objective. In a world where civil wars are increasing, lack of aids and health resources have a major effect on people lives. A hybrid system is a cost effective solution to power a mobile hospital. Furthermore, it is expected that the proposed system will help communities to provide uninterrupted power for their sites to accommodate a doctor and two nursing staff in remote areas.**

***Index Terms*—Renewable energy, solar energy, feasibility study, hybrid power systems, photovoltaic, diesel generator, structural designs, and HOMMERPRO software.**

I. Introduction

As stated by the UN everyone has the right to a standard health care [1] "The Universal Declaration of Human Rights, the world will need to exploit energy resources in increasing amounts if we are to have any hope of bringing people in the developing world up to a reasonable standard of living". Renewable energy is considered by many a good resource to exploit. For example, the Earth Day Network claims that: Renewable sources of energy are virtually inexhaustible and are naturally and quickly replenished [2]. Switching to clean, renewable energy will bring us cleaner air and water, while improving human health and increasing energy security. Renewable energy resources like wind and solar power generate electricity with little or no pollution and global warming emissions—and could reliably and affordably provide up to 40 percent of U.S. electricity by 2030, and 80 percent by 2050 [3]. " The Union of Concerned Scientists". A small solar electric or photovoltaic (*PV*) system can be a reliable and pollution-free producer of electricity for homes and offices [4]. *PV* technology uses both direct and scattered sunlight to generate electricity [5]. The solar resource across Libya is ample for home solar electric systems [6]. *PV* power systems can be designed to meet any electrical requirement, no matter how large or how small, because their modularity can connect them to an electric distribution system (grid-connected), or standalone (off-grid). Many developing communities forced to use these systems, as they are too far from electrical distribution. As a result, numerous software models been developed to simulate hybrid renewable energy systems. Several authors have keyed in on a potential solution to the logistical challenge of transporting fuel to Mobile hospitals in remote areas. The objective of this paper is to determine the best configuration of a hybrid renewable system for a mobile hospital to help in solving a major crisis. Few remote areas right now are in great need for small field hospital unit with a doctor in charge and two nurses, two containers can be put together equipped with solar panel system is what this paper aims to design. Referring to the optimal sizing and operational strategy of diesel generator and solar energy that can offer the lowest amount of Total Net Present Cost (TNPC), hybrid optimization model for electric renewable software (HOMER) has been used to perform selection and operational strategy of generating system in order to obtain the finest solution of hybrid renewable energy with lowest TNPC [7].

II. Structural Design of Mobile Hospital

Mobile hospitals are designed to be portable while providing maximum comfort, sizes, full medical aids center with 3 beds area, main waiting room and an office that include a kitchen, bathroom, and a double bed for staff. AutoCAD drawing shows a steel frame constructed with steel beams, steel cross channels, rubber baseboard floor framing provides convenient, 2 mm sheet single floor styling without compromise [8]. For exterior, walls have to be light weight, resistant to bugs in remote areas, and can be used in all climates. To increase longevity, finishing up with clear sealer. Windows will provide warm sunshine, light, and will have a higher protestation against climate change such as a sand storm. Regarding insulation, R-21, and 3/8" painted plywood on each side of the floor, guarantee most efficient insulation. Steel doors with U-2.0 W/(m^2ċ) that can take up various temperatures. For interior measures, walls painted with two coats of antique latex paint eggshell, ceiling painted with 2 coats of antique latex as well with batten strips on joints, R-21 batt Insulation due to the hard weather, sealing the interior with a polyurethane varnish for easier surface cleaning and protection from damage. Staining the interior is an excellent idea because traveling can cause paint to crack and peel. Lighting in an area, where there is lots of sunlight availability should not be an issue, but for long periods of the day it's still dazzle and to illuminate the space with high-quality fixtures.

Fig. 1 shows the structure drawing.

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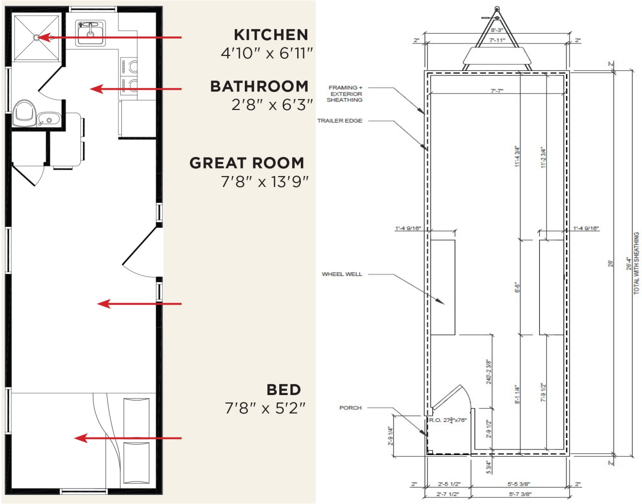

Fig. 1. Structure design and interior.

Energy 3D is also used to generate the load data [9]. And to simulate the heat analysis for the building which includes energy usage, season change and track of temperature. Two trailers are connected by platform made of wood, with an entrance and a waiting area lounge that connect both the main office/bedroom/bathroom trailer with the medical aid trailer, Fig. 2 shows the design on a shape of the letter H for the word hospital when both the trailers are connected. Mobile Hospital structure is simulated in Energy 3D and through the use of hour-by-hour data for energy, with annual energy consumption of 65,00 kWh/year. This model produces a minimum cost design at $65,416 material cost. A typical Mobile Hospital provided at the field has 100-amp Electrical Panel (38 circuit), electric heat, florescent light fixtures, electrical mast and meter box, and emergency lighting/exit signage.

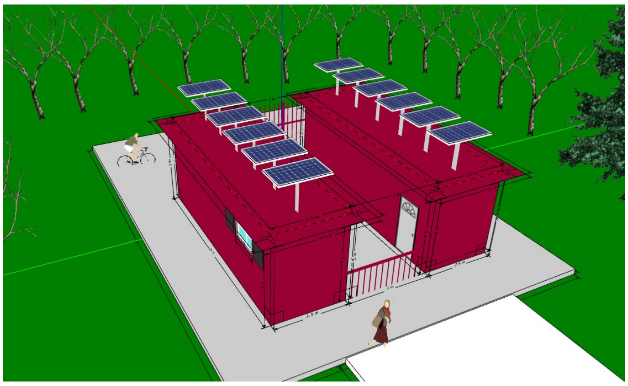
Fig. 2. Energy 3D design.

III. Generation of Load Data

Mobile Hospital details such as size, insulation average Walls, Roof, Windows-double pane, and Doors all this data were put under consideration in Energy3D. Afterwards, running the thermal simulation indicates the annual energy analysis for the building 17.8kWh/day. From these results, a monthly annual consumption has been acquired as shown below in Fig. 3, and for the analysis in HOMERPRO an hourly load consumption was collected in a txt file format, 8760 data points are generated in a txt file for the use of Homer.

Month	Windows	Solar Panels	Heater	AC	Net
1	4.40124181...	7.25215707...	14.4617939...	11.3572237...	18.5668606...
2	5.17476546...	9.73199210...	14.6687497...	12.8480539...	17.7848115...
3	5.44771393...	12.4715351...	11.8954530...	16.8688094...	16.2927273...
4	4.36011685...	14.1527823...	8.62709303...	18.6933320...	13.1676427...
5	4.37125054...	17.5921797...	0.0	27.2157365...	9.62355676...
6	5.17884078...	20.4832778...	0.0	33.2758777...	12.7925998...
7	5.10657026...	20.1306143...	0.0	37.4776164...	17.3470021...
8	4.72261247...	19.1064454...	0.0	37.3805862...	18.2741408...
9	4.26737623...	16.4180339...	0.0	40.8095230...	24.3914890...
10	5.18219294...	13.3431270...	0.0	37.5009754...	24.1578483...
11	4.64989645...	9.94892842...	4.44844824...	26.0014999...	20.5010197...
12	4.09722353...	6.85268609...	10.8507943...	15.4489740...	19.4470823...

Fig. 3. Monthly energy consumption (kWh/day).

IV. Mobile Hospital Electrical Load

Importing the hourly data to generate the load, which indicates the approximate power consumption of the Mobile Hospital, is 17.8kWh/day, with 1kW peak and the system run on a 48V DC bus-voltage. Companies are committed to provide uninterruptable service and therefore these sites require continuous power throughout the year. Therefore, the hourly load is almost a constant, as the power consumption remains the same. Fig. 4 shows load profile of the mobile office.

Fig. 4. Load profile.

V. Renewable Energy Resources

The most important factor in developing a hybrid energy system is the geographical location, where the available solar radiation and solar data vary significantly. Some resources are available in specific places for most of the time such as hydro, and some resources are available seasonally such as wind and photovoltaic. Our study suggests that the location at Sabha, Libya has sufficient solar energy for generating sufficient power for this application. Collecting weather data is one of the main tasks for this pre-feasibility study for a renewable energy system [10].

VI. Solar Energy Resources

One of the major renewable sources implemented in the system is solar. Solar data for this site is collected from NASA surface meteorology, which is used to get the approximate solar radiation at different sites. Fig. 5 shows the latitude and longitude of the location and can be easily downloaded once the exact location is entered in the Homer software. The hourly solar radiation data has been collected for a year from NASA, the average solar irradiation is only 5.7kwh/m²-d and sensitivity analysis is included with three different values. Clearness index and the average daily radiation for a year are added with three values of sensitivity analysis for solar radiation are chosen and added in HOMERPRO [11].

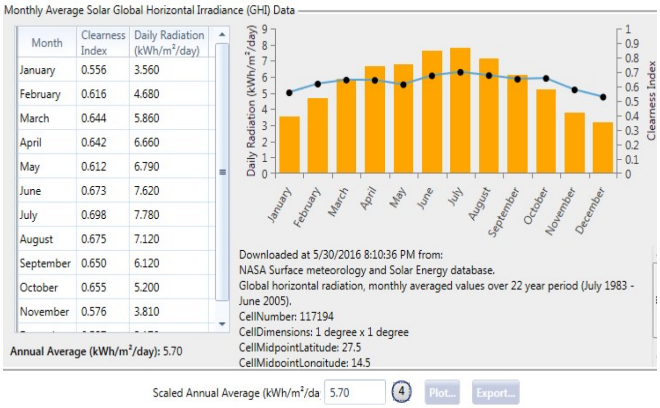

Fig. 5. Monthly solar radiation and average daily irradiation.

VII. System Optimization

The proposed hybrid renewable energy system shown in Fig. 6 which consists of 12 *PV* solar panels and a 500W Generator. The proposed system is going to reduce fuel consumption and associate operation and maintenance cost. In this system the PV will be the primary power source and a diesel generator will be used as a backup and batteries for short-term storage system.

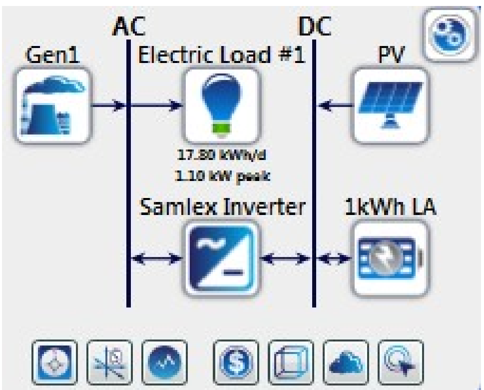

Fig. 6. System optimization.

VIII. Solar Panels

It is important to have a proper understanding of *PV* module performance under different operating conditions for appropriate application of *PV* modules in a stand-alone system. Various parameters that influence the performance of a crystalline silicon *PV* module are temperature of module, *PV* module material and the solar radiance on the *PV* module surface [12]. Generic Flat Plates, solar modules are used in this system and each solar array provides 1000W at 48V. Therefore, in this system six Modules are connected in series. The initial cost of each panels connected in series is $3000, replacement cost is $3000, and operational and maintenance cost is $10. More details are shown in Fig. 7 [13].

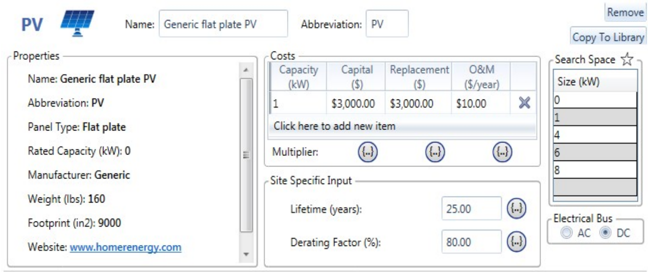

Fig. 7. Generic flat plate *PV*.

IX. Generator

During winter times, there is a drop in renewable resources, and huge need for an heat bump to warm up the place during cold nights, and the opposite during hot summer days, for that reason having an electric DG2500E small portable 500W Diesel generator with 500W at 1200rpm with engine rebuild every 12,000 hours, will generate 15% of electricity in-time of need during the hours of operation. The initial capital cost is $500, replacement cost is $500, and operational and maintenance cost $0.03/hr. As shown in Fig. 8.

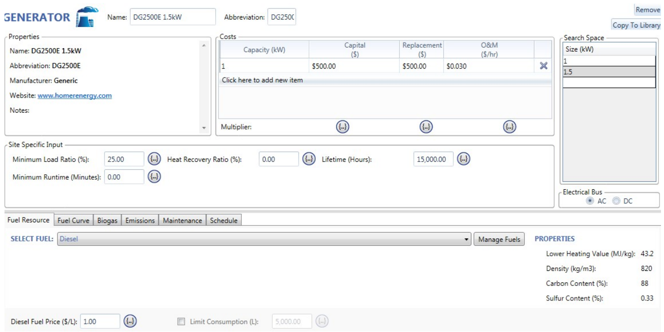

Fig. 8. 500W generator.

X. Battery

The type of battery used for the system is Lead Acid 1kWh, 84AH Battery, with the rating of 48V Bus-voltage, 83.333Ah. The cost for one battery is $300 with a replacement cost of $300. Fig. 9 shows some details.

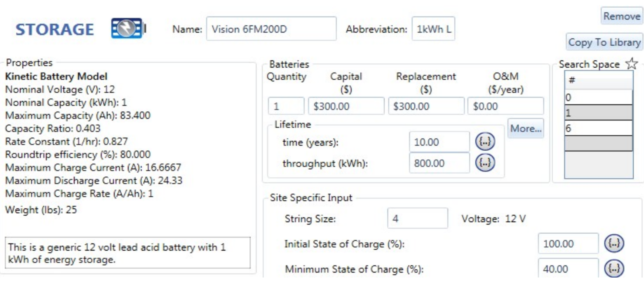

Fig. 9. Lead acid battery.

XI. Power Convertor

A power electronic converter used to maintain the flow of energy between ac and dc components [14], [15]. The size of power converter used in this system is 1 kW. The capital cost and replacement costs for this equipment is $500. The lifetime for one unit of converter is 15 years with the efficiency of 90%.

XII. Results and Discussion

The system simulation is done with HOMER software, and the optimal results were obtained for each case. Fig. 10 shows the optimization result for the renewable energy system. As shown in the figure the total Net Present Cost (NPC) is $53,108. Generator burns 798L of fuel per year and annual generator run time is 5885 hours. The total cost calculated with constant price of fuel, which is $0.108 per hour. The total fuel cost during a year will be $636. The renewable energy based system was also simulated in HOMERPRO software with three sensitivity variables. Solar irradiation, load, and diesel price and each of these variables has three different values. Fig. 11 shows the optimized results for the proposed system, which include the monthly average electric production of the system. Photovoltaic production is 84% with 14,142kWh/yr. Diesel generator production is 15% with 2,527kWh/yr, and the run time is reduced in the proposed system production. Also, the diesel generator will require less maintenance and operation cost and longer period of service before a replacement. The combination of *PV* system, and diesel generator able to reduce the pollution of gas emissions [16]-[18].

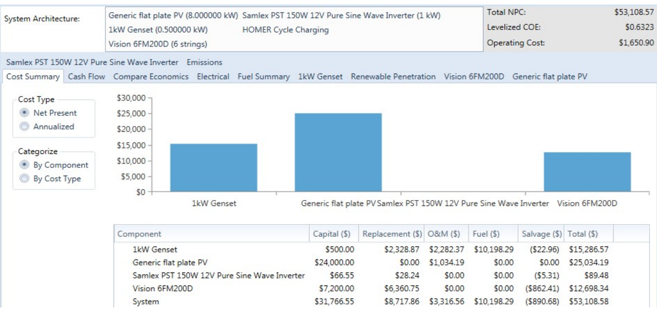

Fig. 10. Simulation results.

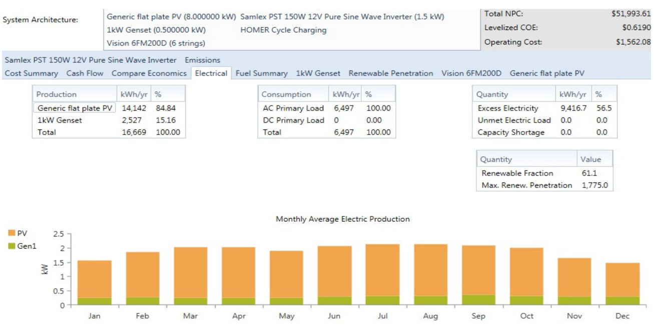

Fig. 11. Electric results for the system.

XIII. Conclusion

This paper has discussed the optimization, sizing, and operational strategy of hybrid renewable energy system, which refers to the minimum cost of Total Net Present Cost (TNPC). The result shows that the *PV* system, diesel generator, battery storage and converter brings an optimal configuration of hybrid renewable energy system applicable to be used as an off-grid Mobile Hospital. The conclusions was drawn from the results obtained from the analysis. There is a high potential of solar radiation resource in Libya, which can be used for supporting the renewable energy especially in terms of solar energy compared to wind turbine. Such a hybrid system for a Mobile Hospital is recommended for use in remote locations.

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