Design Consideration of Solar PV- Diesel Hybrid System for Hospital in Myanmar

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ABSTRACT
Likes other developing countries, Myanmar is facing the energy demand problems. Energy from renewable energy (RE) resources is the best way to solve these problems. The hospital is electrified by using solar PV diesel hybrid power with battery backup system. The hourly solar radiation data measured at the site along with PV modules, generator, different sizes of batteries and converter were used to find an optimal power system for Okeshitpin hospital in Padaung Township, Bago Division. It may have different usage of electricity according to their function. Different usage time and load consumption for day load and night load are carefully considered and then to produce 20.941MWh of electricity annually and 57.02 kWh per day. In this research, author described to estimate two type ofsystems such as standalone solar and solar PV- diesel hybrid system with minimization of cost of energy depending upon the load demand and the meteorological data of the site location. The main objective of solar hybrid system is also to be used like solar standalone system in this hospital due to system cost, the cost of operation and maintenance and cost of logistic by minimizing diesel runtime and fuel consumption then waste energy of solar system to be reduced in emergency case as a backup source (generator).

Keywords – *Renewable energy, Solar PV, Backup generator,PV diesel hybrid*

I. INTRODUCTION
Traditionally the way communities are electrified is by connecting them to a centralized grid, but in areas where grid extension is prohibitively expensive, many are left without the prospect of connection to the grid anytime soon.Renewable energy is a term used to describe energy that is derived from naturally occurring resources such as sunlight, wind, tides, rain, and geothermal heat that are continually available to some degree or other all over the world[5]. Among them, solar energy is well-known as a suitable resource to minimize cost of energy.Recently, Hybrid Renewable Energy Systems (HRES), is gaining popularity because sources can complement each other to provide higher quality and more reliable power to customer than single source system [2]. The main drivers of a HRES are costs associated with conventional/traditional energy systems, reduction of emissions and optimization of systems. This system combines two or more electricity generation methods, like diesel engines and solar panels, into a single plant to reduce long term generation costs. The local utility company, (MEPE) suffers from frequent rolling blackouts, voltage swells, and excessive line loss. Given the large number of delicate research electronics in the hospital, it must have access to reliable and properly conditioned electricity. In this research, most optimal consideration will be got to design a solar-diesel hybrid power system to ensure reliable and improved power for the hospital. Hybrid power systems offer clean and efficient power that will in many cases be more cost-effective than solar standalone due to diesel generator will be used as a backup system.The high capital cost of PV hybrid power systems is affected by technical factors as well as some nontechnical factors, so the effect of each factor shall be considered in the performance study of this system. Thus, optimum sizing for different components gives economical and reliable benefits to the system. For this option, this paper will focus on the optimum system design with minimizing the electricity cost and also provides the design calculation and financial analysis of the PV diesel hybrid.

II. COMPONENTS DESCRIPTION OF SYSTEM DESIGN
This section consists of two parts: The first one is the standalone solar and the second is solar diesel hybrid system. The following components are included in the system designs:

- Site and data description
- Solar panels
- Battery bank
- Inverter
- Diesel Generator

A. Site and data description
The data collection site (18.6002N, 95.153E) at Padaung Township, Bago Division is a cottage hospital which is located

on the highway leading to Yangon Division.Load is important consideration in any power generating system. The entire system design is based on the size of the load. The loads influence on every aspect of efficiency and reliability of the system. Power needed by a load, as well as energy required over time by that load, is important for system sizing [10]. The total daily load average of Okeshitpin Hospital is 57.5kWh per day. This hospital l's load profile is shown in figure1.

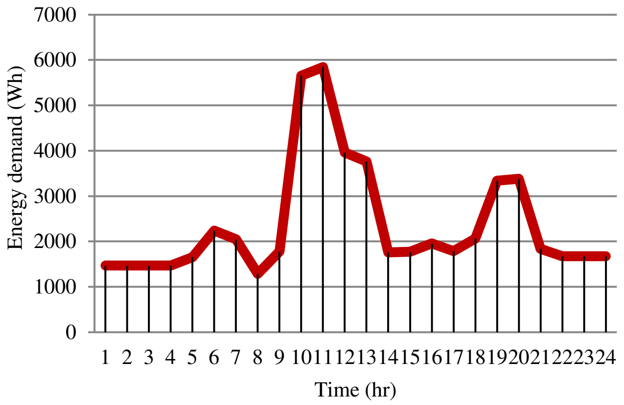

Figure1. Hospital's load profile

B. *Solar radiation profile*

Solar resource indicates the amount of global solar radiation that strikes earth's surface. Solar radiation for this study area was obtained from the NASA Surface Meteorology and Solar Energy Website [4]. An average solar radiation of 4.935 kWh/m^2/day and clearness of the atmosphere and which is expressed by the fraction of the solar radiation that is transmitted through the atmosphere to strike the surface of the earth. Clearness index and solar radiation for the hospital in Bago Division is shown in Table I.

TABLE I.
CLEARNESS INDEX AND SOLAR RADIATION FOR THE HOSPITAL

Month	Clearness Index	Daily Radiation (kWh/m^2/d)
January	0.684	5.26
February	0.683	5.9
March	0.661	6.44
April	0.626	6.6
May	0.489	5.31
June	0.347	3.78
July	0.352	3.82
August	0.352	3.73
September	0.437	4.36
October	0.514	4.59
November	0.587	4.63
December	0.662	4.88
Average	0.53	4.935

Solar Radiation data is important to get optimal design for the site under consideration.

The latitude and longitude of Okeshitpin, Padaung Township, Bago Division are 18.6°N and 95.153°E respectively. The hourly solar radiation is collected for year from NASA website [4]. The highest daily solar radiation is 6.6 kWh/m2/day in April and average solar radiation is 4.935 kWh/m2/day. Figure 2 shows the solar irradiation withclearness index for a year that is used for the proposed system.

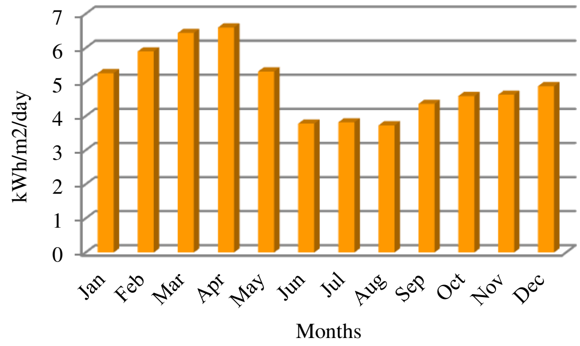

Figure 2. Solar resource

C. *Solar panels*

A solar panel (also solar module, photovoltaic module or photovoltaic panel) is a packaged connected assembly of photovoltaic cells. The solar panel can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications. Each panel is rated by its DC output power under standard test conditions (STC), and typically ranges from 100W to 450W [10]. As a single solar panel can produce only a limited amount of power, most installations contain multiple panels. A photovoltaic system typically includes an array of solar panels, an inverter, and sometimes a battery and or solar tracker and interconnection wiring. In proposed system computation, to be considered about 165 crystalline panels, each have a maximum power output of 300W, 165 modulesfor standalone system and will be reduced until 105 modules for hybrid system type.

D. *Battery Bank*

A battery bank is basically meant for the storage of energy produced by the solar panels to provide backup power in case of power failure. In the proposed system, to be selected 100 quantities, 12, 260Ah in standalone design and 60 quantities in hybrid system design in equations of section III respectively.

E. *Inverter*

A solar inverter, or PV hybrid inverter, converts the variable direct current output of a photovoltaic (PV) solar panel into a utility frequency alternating current that can be fed into a commercial electrical grid or used by a localoff-grid electrical network [11].It is a critical component in a PV system. We considered two types of inverters, one is 60kW power rating for solar only and the next one is 40kW power rating for hybrid system.

F. Diesel Generator

The main part of the PV diesel hybrid system is the diesel generator. The configuration of this system is based on adding the PV module, the converter and the battery storage to the diesel generator without considering grid connection. Power rating 10kVA must be considered PV hybrid system for nighttime as the emergency condition and to release waste of solar energy for twenty-four hour not need.

III. SYSTEM PERFORMANCE AND EQUATIONS OF PV-DIESEL-BATTERY HYBRID ENERGY

This section will be described equations in system to be used. Data quantities were shown in previous section for solar and hybrid system. Then system performance of two systems will be mentioned.

A. Ampere Hour Method

$$\text{Daily load consumption (Ah/d)} = \frac{\text{demand load consumption}}{\text{power conversion efficiency} \times \text{nominal system voltage}} \quad (1)$$

$$\text{Corrected Ah load consumption(Ah per day)} = \frac{\text{daily load cosumption}}{\text{wire efficiency} \times \text{battery efficiency}} \quad (2)$$

B. Battery Sizing

$$\text{Required battery capacity} = \frac{\text{corrected Ah/day} \times \text{days of autonomy}}{\text{maximum depth of discharge} \times \text{derate factor}} \quad (3)$$

$$\text{No. of parllael batteries} = \frac{\text{required battery capacity}}{\text{selected battery capacity}} \quad (4)$$

$$\text{No. of series batteries} = \frac{\text{System Voltage}}{\text{Battery rated voltage}} \quad (5)$$

$$\text{System battery capacity} = \text{no of parallel batteries} \times \text{selected battery capacity} \quad (6)$$

$$\text{Usable battery capacity} = \text{system battery capacity} \times \text{maximum depth of discharge} \quad (7)$$

$$\text{Number of days that storage battery} = \frac{\text{Usable battery capacity}}{\text{Corrected Ah/day consumption}} \quad (8)$$

C. Array Sizing

$$\text{No. of parallel module} = \frac{15\% \text{ of usable battery capacity}}{\text{module derate factor} \times \text{module rated current}} \quad (9)$$

$$\text{No. of series module} = \frac{\text{Batter loss factor} \times \text{nominal battery voltage} \times \text{no. of series batteries}}{\text{highest temperature at module voltage}} \quad (10)$$

$$\text{Total no. of modules} = \text{no of series modules} \times \text{no of parallel modules} \quad (11)$$

$$\text{Charging time to full battery} = \frac{\text{Usable battery capacity}}{\text{Array rated current}} \quad (12)$$

D. Converter

To select inverter sizing, 25% of actual load will be considered.

E. System Performance

For the design and computation of the proposed solar standalone system we are proposed to use crystalline solar panels. About 165 modules, each having a maximum power output of 300W at Standard Test Conditions (STC) (1000W/m^2 of solar irradiance, 25˚C cell temperature and 1.5AM) are proposed to be used. The total number of 120 batteries are used with each a 12V, 260Ah for solar PV standalone system. As the solar irradiance keeps varying during the day the output of the solar panels is not constant and keeps varying and cannot be effectively used to charge the battery bank, which is used to store the energy produced. To overcome this problem a 60kW inverter is utilized and efficiency is 95% that it will convert DC from the battery to usable AC supply.

Moreover, generator to be rated in kilo-volt-amperes (kVA) for diesel only system. In a 100% efficient system kW equal to kVA. However electrical systems are never 100% efficient and therefore not all of the systems apparent power will be used to produce a useful work output. International standards rate generators as having a power factor of 0.8. Power factor is very important for matching the size of actual load to a generator. But Diesel generator will not be used twenty-four hour because fuel consumption is more expensive and unreliability as a long time. To achieve minimizing diesel runtime and fuel consumption the generator only runs as needed to recharge the battery and to supply excess load. If battery is not used that is not fully recharged and then shut down. Therefore, fuel consumption cannot be minimized due to variable loads in diesel only system

The main system is the solar hybrid power system makes use of the solar PV to produce electricity that can be supplemented by diesel generator. So, solar-diesel-battery hybrid power system is used 105 modules each having a maximum power output of 300W at STC. A 40kW inverter is utilized here with discarded charging functionality from AC main supply and will also enable the system to function as an uninterruptible power source. The output of solar panels is not constant due to the solar irradiance keeps varying in a day. Therefore, this inverter will be used for hybrid type. The battery bank capacity is 187kWh, (60 batteries*12V per battery, 260Ah). The battery bank should not be discharged below 50% of its capacity doing so reduces its life considerably. If the battery bank is fully charged from the solar energy and the solar panels are still producing energy which cannot be further fed into the battery bank then an inverter will help to resolve this issue and generator's fuel consumption will be decreased. Then generator sizing will be selected about 10kVA power rating by combining solar sizing. This is proposed to be reduced cost of energy and fuel consumption

F. Advantages of Solar-Diesel Hybrid System

The solar hybrid system developed with a combination of solar with battery and diesel generator shown in figure 3. As an off-grid power generation, the hybrid system offers clean and efficient power that will be more cost-effective in many cases than sole diesel systems.As a result, renewable energy options have increasingly become the preferred solution for off-grid power generation. The benefits of this system are

- Improved reliability
- Improved energy services
- Reduced emissions and noise pollution

- Continuous power
- Increased operational life
- Reduced cost
- Efficient use of energy

IV. RESULTS AND DISCUSSION

Theseresults were obtained for different system types, starting from the solar standalone to complete PV-diesel hybrid system with battery backup.This result predicts the production of cottage hospital only load demand in twenty years. Different types of system solutions have been investigated that are described in Table II.

TABLE II
CALCULATION RESULTS OF DIFFERENT SYSTEM

Components	Solar PV only	PV-Diesel hybrid
PV	300W,165 nos, 49.5kW	300W, 105 nos, 31.5kW
Battery	260Ah,12V, 100 nos	260Ah, 12V, 60 nos
Inverter	60kW, 1 nos	40kW, 1nos
Charge Controller	251.9A, 240V,1 nos	160.3A, 240V,1 nos

TableIII shows costs of components for solar standalone and PV-diesel hybrid system. These types of costs are capital, pole, labor, operation and maintenance, wire costs and fuel, HDBC for diesel and total system costs. When the two systems are compared, system costs to be found a little different. Therefore, Diesel hybrid system can also be used such as standalone due to this include backup generator source.

TABLE.III
SYSTEM COSTS OF TWO SYTEM FOR TWENTY YEARS

Costs of components	Solar only	PV-Diesel
PV	$16,848.59	$10,729
Batteries	$35,211.27	$26,408.45
Inverter	$5,281.69	$1,193.66
Pole	$1,408.45	$316.91
Controller	$880.28	$211.27
Labor	$1,760.56	$352.12
Wires	$1,901.42	$704.23
Maintenance	$737.44	$140.85
Fuel	0	$37,445.88
Pole, Maintenance & HDBC 10	–	$1,081.69
Diesel generator		$1,056.34
Total System Costs ($)	$64,029.70	$79,640

Figure 3 shows total system costs of two systems in Ok eshitp in hospital for twenty years. The cost difference shows significant contribution of the PV generator to the energy and the hybrid system to be included. The PV-diesel hybrid system focuses with solar only system in ten years.Although hybrid system is more expensive, this can be capitalized in lifetime ten years.

Therefore, this should be used for proposed hospital due to backup generator source.

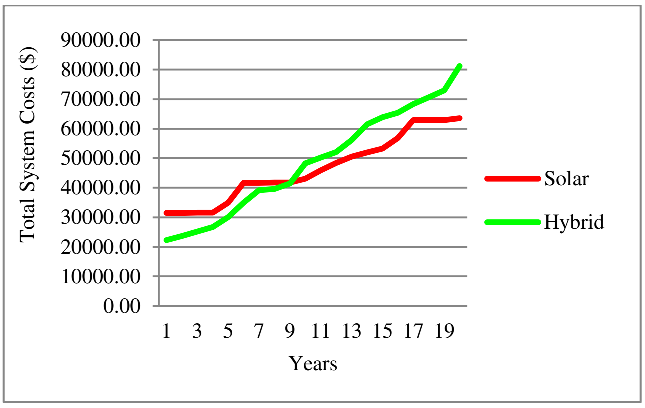

Figure3.Total system costs of energy for twenty years

V. CONCLUSION

Solar-diesel hybrid system among two types of systems has a great potential as one of renewable energy technologies for off-grid power generation. The hybrid technology offers solution to off-grid power generation in terms of reducing operation, maintenance and logistics problem and cost, providing twenty-four hours reliable supply at an effective cost as well as preserving the nature. Solar Hybrid system is also economical and optimal type like standalone PV system more than other systems due to the waste of energy that has not to be needed for the hospital's layout such as meeting, X-Rays and Laboratory rooms in night time. Hybrid system can also be used due to their capitalize costs focus on solar only system costs in ten years ago.

VI. ACKNOWLEDGMENT

The author wishes to acknowledge especially thankful to Dr. Soe Winn, Professor and Head of Electrical Power Engineering Department, Pyay Technological University, Daw Hay Mar Htun, Lecturer of Electrical Power Engineering Department, Pyay Technological University, U Than ZawHtwe, Lecturer of Electrical Power Engineering Department, Yangon Technological University U ThetNaung Win, M.E.(Solar Energy), MPEI, Moscow, Russia, Lecturer of Electrical PowerEngineering Department, Mandalay Technological University, for their guidance, criticisms, encouragement comments, suggestions and correction on this paper. Moreover, the author is also grateful to Ministry of Electric Power, Myanmar for giving a chance to study in Myanmar. Finally, I would like to acknowledge the love and support given to me by my parents.

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