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RENEWABLE ENERGY SYSTEMS AS AN APPLICATION FOR THE REDUCTION OF CO_2 EMISSIONS

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ABSTRACT

The main objective of this paper is to analyze the level of Carbon dioxide (CO_2) emission. This study was conducted at a hypothetical primary health care in Sokoto state, Nigeria. The study compared the electrification of the clinic between a PV/diesel hybrid system and a diesel-only system. The proposed hybrid system is evaluated using HOMER (Hybrid Optimization Model for Electrical Renewable) software to optimize renewable-based hybrid systems to determine the most economical system configuration in terms of cost, renewable energy contribution, and greenhouse gas emissions. HOMER simulates the operation of a system by making energy balance calculations for each of the 8,760 hours in a year. For each hour, HOMER compares the electric and thermal demand in the hour to the energy that the system can supply and calculates the flow of energy from each system component. Twenty years of solar radiation data (2000 to 2020) was obtained from NIMET (Nigerian meteorological agency) and analyzed using the software. Also, the cost of components was taken from the online site of manufacturing and equipment suppliers (solar wholesalers). The results show that solar energy contributed 70% while diesel generators contributed 30% to the hybrid system. While for the Generator system, only the same load and project lifetime, the net present cost (NPC), cost of operation (CO) & levelised cost of energy (LCOE) of the generator only are double the hybrid system. The Diesel consumption and CO_2 emissions of the generator are also four (4) times the hybrid system.

Keywords: Photovoltaic (PV), Generator, Hybrid system, Homer, CO_2 emission,

INTRODUCTION

By 2050 the energy demand could double or even triple as the global population grows and developing countries expand their economies. All life on Earth depends on energy and the cycling of carbon. Energy is essential for economic and social development and poses an environmental challenge (Bakura & Mayyama, 2017). There are concerns that emissions from fossil fuels will lead to changing climate with possibly disastrous consequences (Herbert *et al.*, 2020). Carbon dioxide is the second most abundant greenhouse gas after water vapor. Carbon dioxide constantly circulates in the environment through various natural processes known as the carbon cycle (Augustine, 2019). Human activities significantly increase the amount of carbon dioxide released to the atmosphere by burning fossil fuels (such as coal, oil, and natural gas), solid wastes, wood and wood products to heat buildings, drive vehicles, and generate electricity (ESRL, 2020). At the same time, the number of trees available to absorb carbon dioxide through photosynthesis has significantly been reduced by deforestation, the widespread cutting of trees for lumber, or clearing land for agriculture (Berner, 2021).To stabilize atmospheric carbon dioxide concentrations, global emissions would need to be cut significantly by 70 to 80 percent(Bird, 2020). The solution to the above problem is using renewable energy, such as solar photovoltaic, as an energy source.

However, one of the main problems of standalone systems such as solar is the fluctuation of energy supply, resulting in intermittent delivery of power and causing problems of supply continuity (Girma, 2019). The use of standalone hybrid systems can avoid this. A hybrid generation system is a system combing two or more energy sources, operated jointly, including (but not necessarily) a storage unit and connected to a local AC distribution network (mini-grid) (Bakura, 2016). Combining renewable energy conversion technology devices, such as photovoltaic, wind turbine or hydro generators, with combustion generators and battery storage, it is possible to competitively generate electricity in rural or remote areas. The combination of renewable and conventional energy technology compares both technical and economic performance favorably with fossil fuel-based and conventional grid rural area power supplies (IRENA, 2019). Over the present year, hybrid technology has been developed and upgraded its role in renewable energy sources. The benefits it produces for power production cannot be ignored and must be considered. Many isolated loads try to adopt this kind of technology because of the benefits that can be received compared to a single power system (Terefe, 2020).

RESEARCH METHODOLOGY

This research uses a diesel generator to choose solar PV energy. The Hybrid System components consist of an electric Load, Renewable energy (Solar) and other components, such as PV, batteries, and converters, which are part of the system. The proposed hybrid system is shown below.

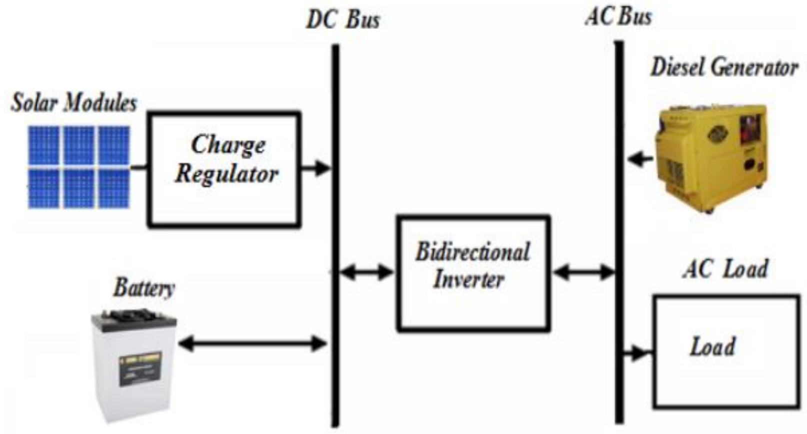

Figure 1: Schematic diagram for the standalone hybrid power supply system

Determination of the load profile is the first step in the design of any electric power system. Nature and hours of operation of loads are the parameters that determine the load profile. In order to use HOMER optimization software, one has to provide some inputs such as hourly load profile, monthly solar radiation, the initial cost of each component(renewable energy generators, diesel generators, batteries and converters), cost of diesel fuel, etc. Twenty years (2000 to 2020), solar radiation data was obtained from NIMET (Nigerian meteorological agency) for the location.

The capital costs of each component were taken from solar Wholesalers, which are available online. In this research, primary health care (in Sokoto) has been considered. The fundamental Load parameters quantities, capacity, and operation hours have been calculated aside. So the load data were synthesized by specifying typical daily profiles and then adding some provision for starting of 25% (Dabai *et al.*, 2012).

Components considered for standalone solar PV with Diesel hybrid power system.

The PV panel selected has a rated power of 250 kW DC, a slope of 13^0, and a lifetime of 20 years. The battery chosen was the Surrette S6-460 AGM type with a nominal capacity of 500Ah, nominal voltage of 6V and lifetime of 10 years. It is a deep-cycle battery commonly used for renewable energy applications. Because it has thicker plates and is designed to be discharged as low as 80% and recharged repeatedly. While the converter selected has a 14kW rated capacity and a lifetime of 15 years. It considers the costs of components as part of the economics of the system. Also, components operation and maintenance cost was taken into consideration after the initial capital cost. A summary of components data supplied to the software is presented in Table 1., below.

Table 1: Input data to HOMER

Components	PV	Generator	Battery	Converter
Size	250kW	1Kw	500Ah	1kW
Capital ($)	$910	$700	$385	$590
Replacement($)	$910	$600	$380	$590
O &M ($)	0	0.05$/yrs	$100	40$/yr
Quantities (kW)	10,16,18,20	6,8,10,12,15	8,10,12,14,16,20	4,10,12,14
Size considered	16kW	8kW	20	14kW
Lifetime	25yrs	15000hrs		15yr

Load profile

Load profile study and determination are the first steps for the design of any electric power system. Nature and hours of operation of loads are the parameters that determine the load profile. A sequence of powers represents the daily load profile, considered constant over a time-step of 1 h. The used load profile (Figure 2) denotes the consumption of the maternity clinic. The system load is assumed to be constant during the working hours from 6 am-6 pm, which is peak due to the medical equipment assumed to be all in use. However, after the working hours from 6 pm-6 am, all the equipment will be off, so only bulbs and fans will remain at used; that brings the load down to 2kW. This system is expected to be constant daily, monthly and annually.

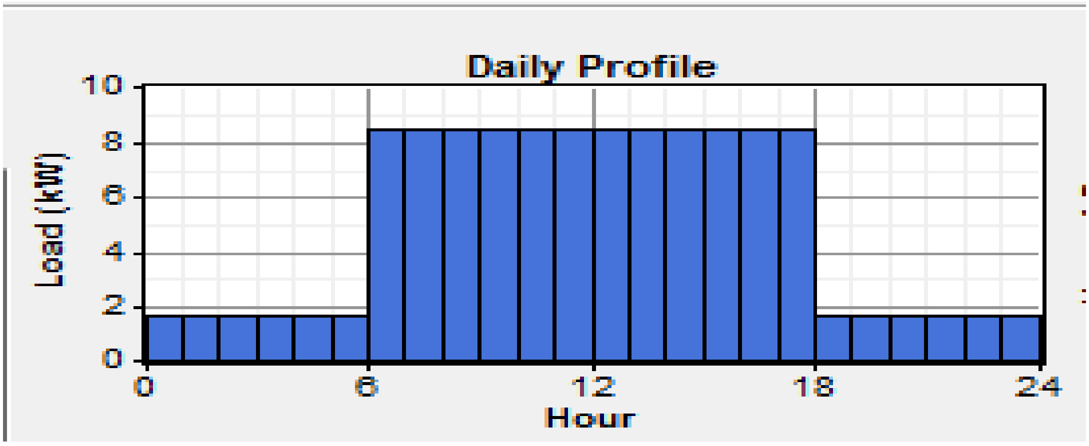

Figure 2: Daily load profile

RESULTS AND DISCUSSION

Table 2: Categorized optimization results

PV (kW)	Gen. (kW)	Battery S6-460	Conv. (kW)	Inn. capital($)	Operation Cost($/yr)	Total NPC($)	COE ($/kWh)	Diesel (L)
20	8	20	14	39,760	14,322	204,032	0.403	5,553
20	8	20	12	38,580	14,458	204,410	0.404	5,701
20	8	24	14	41,300	14,327	205,632	0.406	5,292
20	6	24	12	40,260	14,776	206,001	0.407	5,073
20	10	8	14	36,540	14,368	206,024	0.407	6,861

HOMER performs different hourly simulations over and over in order to design an optimal hybrid system. Simulations have been conducted considering different values for solar radiation, minimum renewable fraction, and diesel price, providing more flexibility in the experiment. The optimization result for solar radiation parameters of 6.43 kWh/m^2/day and diesel price 1.2$/liter (915.7 NGN) is economically more feasible with a minimum Cost of energy (COE) of 0.403$/kWh and a minimum Net present cost (NPC) of $204,032. The most feasible system is the hybrid system comprised of a 20 kW PV array, a diesel generator with a rated power of 8 kW and 20 storage batteries in addition to 14 kW converters. The total NPC is $240,032 (1831708119.52 NGN), the initial capital cost is $39,760 (30341253.6 NGN), and the operating cost per year is $14,322 (10929261.4). This system's energy cost is $0.403/kWh (307.5 NGN). However, in the long run, the cost shall be reduced due to low operation and maintenance costs, improved system management, less logistical costs and the system's lifetime. Thus, this being the most feasible and optimal system (among many others), can be an attractive solution for implementation.

Table 3: Component (resource) contribution

Component	Production (Kwh/Yr)	Fraction
PV Array	38,872	70%
Generator	16,653	30%
Total	55,524	100%

The table above shows the percentage contribution by each renewable component. With PV array produced 38,872kWh/yr while the generator produced 16,653kWh/yr of the total electrical production. This represents 70% solar and 30% generator, respectively.

Greenhouse Gas Emissions

Table 4 below shows different emissions of gases between the PV/diesel hybrid system and the Diesel system only. The various gases are tabulated according to their quantity in kilograms per year. The result shows that the Diesel system's emission is only four (4) times the emissions in the hybrid system. Thus the hybrid system is more environmentally friendly than Diesel only system.

Table 4: Emissions by PV/Diesel hybrid system and Diesel only

Emission	PV/Diesel Hybrid (Kg/Yr)	Diesel Only (Kg/Yr)
Carbon Dioxide	14,624	57,079
Carbon Monoxide	36.1	141
Unburned Hydrocarbon	4	15.6
Particulate Matter	2.72	10.6
Sulfur Dioxide	29.4	115
Nitrogen Oxides	322	1,257

CONCLUSION

Solar photovoltaic hybrid systems are suitable for electrification in these regions because this research shows that the optimal hybrid PV/diesel system has minimized the NPC, CO, & LCOE by 50% and the fuel consumption & CO_2 emission by 75% compared with the Diesel generator power system. Renewable energy technologies, such as photovoltaic hybrid systems, can provide an economical option for meeting the energy demands for electrification in Sokoto regions. Photovoltaics (PV), in particular, needs more research and improvement, especially for home appliances where small incremental steps can make a difference in energy consumption.

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