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DESIGN OF A HYBRID POWER SUPPLY SYSTEM FOR RIVERS STATE UNIVERSITY

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ABSTRACT
This research work presents a viability study of a grid-connected hybrid power supply system for the Rivers State University campus located in Port Harcourt City in Rivers state, Nigeria. Port Harcourt city receives an abundant amount of solar radiation all through the year. Hence, a hybrid system comprising of PV, Battery, Utility and Diesel Generator is considered and optimum sizing of the various component in the hybrid system is done using the HOMER software. The electrical load collected from the central substation control panel of the campus records a load profile Average peak load of 2040KW.The hybrid system is designed to equate the peak load at a minimum cost. The simulation results displayed a hybrid system of 2040KW PV system, batteries with the capacity of 708 Ah and Utility was found as the optimum hybrid configuration and it can supply the electricity at a minimum cost of #40.76 kw/h.
The total net present cost of the project 8.98 billion naira and it requires initial capital investment of 22.2 million naira to implement the project.
The conclusion from this study was that incorporating hybrid to the power supply system contributed in the reduction of the operating cost.

KeyWords
HOMER, Photovoltaic Cell (PV), Micro-grid, Hybrid, Rivers State University

1. INTRODUCTION

The growth of any country depends mainly on the energy supply it has or in use. Electricity is necessary for industrial and domestic activities. Electricity helps to increase the public standard of living in the economic or social sector of a country In the world today most of the energy demands are fulfilled by non-renewable sources of energy which not only is in short supply but is polluting as well.
The rising interest in unconventional environmentally friendly energy sources has been increasing since the last few years. Renewable energy is an energy source that is presently considered because of its high potential. Considering renewable energy resources can entirely endure the reduction of petroleum and other non-renewable energy sources, as well as the production of environmentally unfriendly elements produced from fossil fuels burning [1]. Renewable energy systems such as biogas, micro hydro, photovoltaic, and hybrid systems can offer cost effective electricity generation in a community. Renewable energy systems are said to also have a

positive impact on the environment, economic, social, and political problem of the world nowadays.
Power unavailability is one major factor that thwarts the growth of a region. It is the most common problem regarding the execution of the socio-economic development plans in a country or region. One of the ways of solving this problem is by making use of alternative sources of power like harnessing electricity from renewable energy resources.
Renewable energy technologies like solar power are more and more gaining interest. Fossil fuels are still dominating in the power sector, even though their amount of generation is likely to decline. [2]
Hence, renewable energy sources are capable of offering an economical and sustainable energy systems. The hybrid micro-grid system is also gaining more attention, based on its capability to secure the link of feeding the load with electric power in different operating conditions, and its optimum utilization for available resources within the community.
The need in improving the performance of the power grid yields an attention to hybrid micro-grid power systems, which comprise of numerous types of power sources. These systems have good technical and economical features.
The hybrid micro-grid power generation system is considered the most effective solution to overcome the problem of power shortage and to meet the Load demand.
In addition, micro-grids give more significant advantages like the best supply-and-demand matching and optimized usage of green power sources. Prioritizing the power supply for crucial demands is yet another advantage for local micro-grid alternatives.
In this study a hybrid micro-grid power supply system will be designed to supply continuous, reliable, effective and efficient power to the Rivers State University Campus. The hybrid micro-grid would be integrated into the universities power supply system.
The Diesel Generators, utility Grid (PHED), Photovoltaic Arrays as energy sources, Batteries as storage device and converter for converting power produced from the energy Sources are the components that makes up the hybrid micro-grid system. The Load Demand analysis of different periods and sessions will be carried out and also load profile of the University campus will be examined. This was used to design a hybrid micro-grid power system for the university campus.

2. MATERIALS AND METHODS

A. Materials

The listed materials will be employed to carry out this study; Load Profile Datasheet, Metrological Datasheet, HOMER (hybrid optimization of multiple energy resources) Software and University Master Plan.

i. Specific Study Area

The study area is the Rivers State University Campus Located South-South Nigeria, Port Harcourt city in Rivers State.
Its topographical directions are 4° 47' 21" North, 6° 59' 55" East. Port Harcourt is a district that is limited in the west by the Atlantic Ocean, by this there is an adequate measure of wind asset because of the ocean breeze from the Atlantic Ocean.
The region also has a sufficient amount of solar resource because Nigeria is located within the equator, which results in a higher solar radiation level. Its geographical coordinates are Latitude 4.801540699999999 North and Longitude 6.9782191 East.

Figure 2.1(a): Location of Rivers State University on the Map

Figure 2.1(b): Google Earth View of Rivers State University[3]

B. Methods

i. Simulation of hybrid micro-grid power supply system

The fundamental Input Data for the reproduction on HOMER programming are as per the following; Daily Load Demand Data (Week-days and Weekends), Month to month Load Demand Data, Study Area geological directions, Metrological Data, Costs (Operational, Maintenance and Capital Cost).

ii. Load Profile Data Survey and Analysis

Figure 2.2: Daily Load Profile Data for RSU

The load profile data were obtained from the control panel at the central substation.

iii. Metrological Data

The Metrological Data was obtained from NASA Surface Metrology and Solar Energy database. It is presented as shown in Figure 2.4

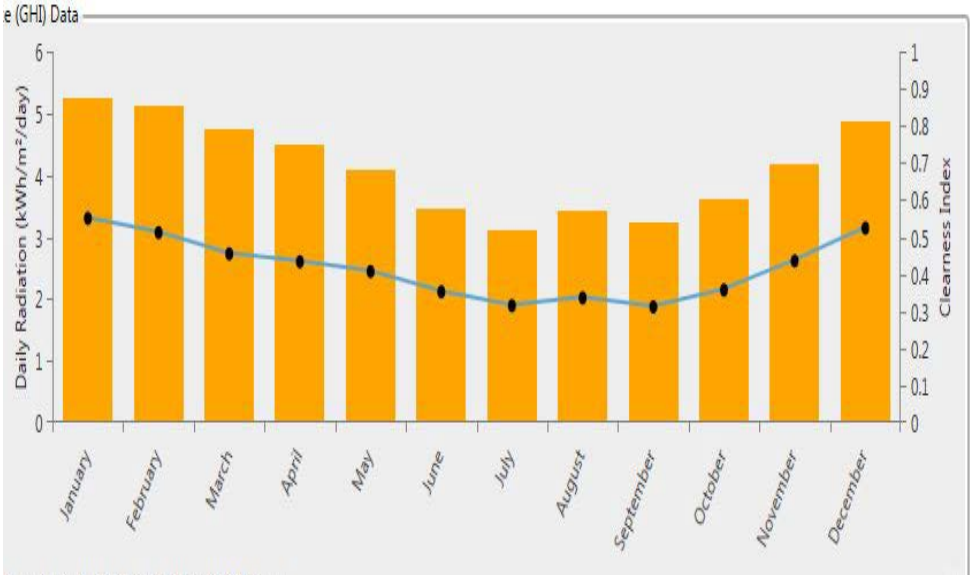

Figure 2.4: Annual Radiation [4]

iv. Equipment's Considered

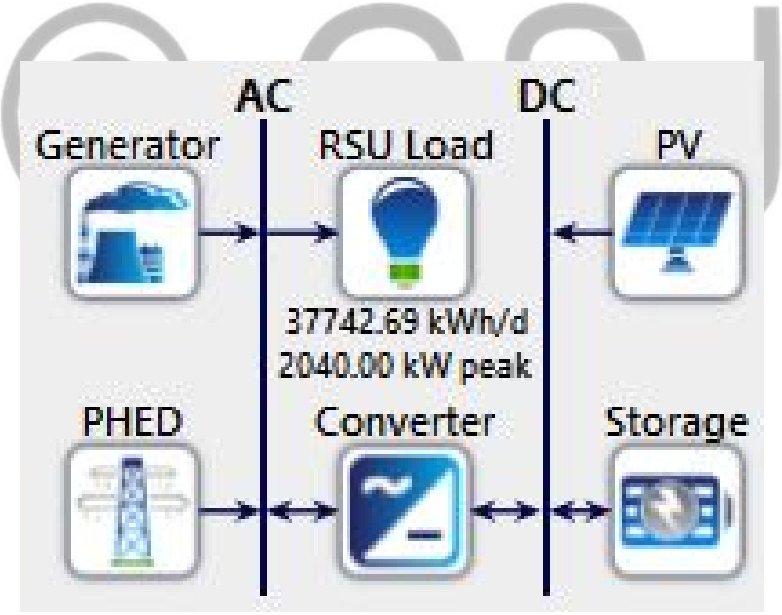

Figure 3.7: Diagram of the Hybrid-Micro grid of RSU

The hybrid micro grid consists of the interconnection of the Diesel Generator, PV, Utility Grid and a Storage system (Batteries). All these were used to equate the recorded load demand of the study area.

Table 2.1: Technical Details of the Components.

The following technical characteristics were inputted into the HOMER software for the simulation .

PV System		
Model		Generic Flat Plate PV
Peak Power		2040KW
Derating Factor		80%
Slope		4.80°
Azimuth		0°
Ground Reflectance	20%	
Temperature Coefficient		−0.500 %/℃
Nominal Operating Temperature		47℃
Efficiency at Standard Condition		13%
Lifetime		15years
Battery		
Nominal Voltage		720 V
Nominal Capacity		708 Ah
Lifetime Throughput		2,549,988KWh
Round Trip Efficiency		96%
Min. State of Charge		0%
Float Life		15years
Maximum charge rate		1 A/Ah
Maximum charge current		1884.8A
Batteries per string		(720 V DC Bus)
Diesel Generator		
Lifetime (Operating Hours)		90,000 hr
Minimum Load Ratio		30%
Fuel		Diesel
Fuel Cost		#231
Converter		
Lifetime		15years
Efficiency		95%
Economics		
Annual Interest Rate		5.17%
Project Lifetime		25years
System Fixed Capital Cost		#20,000,000
System Fixed O & M Cost		#500,000

Table 2.2: Components Cost

Component	Size	Capital Cost #	O & M Cost #/year	Replacement Cost #
PV System	2040KW	2,000,000	0.00	2,000,000
Battery	708Ah	1,000,000	0.00	1,000,000
Diesel Generator	2050KW	360,000,000	36,000,000	360,000,000
Utility	999,999KW	PHED Tariff Rate #48.20		
Converter	2000KW	4,000,000		
	400KW	2,000,000		

3. RESULTS AND DISCUSSION

A. Optimization Results

The simulation of the hybrid micro-grid power supply system was carried out using the HOMER software, the hybrid micro-grid power supply system which comprised of PV-Utility-Diesel Generator and storage battery as a backup. To develop an optimum combination of the hybrid components that can be employed as a hybrid system model, the simulation model was done repetitively by fluctuating parameters that have a regulatory result over the output.
The simulation , shows the result of the keyed in parameters either in a general form in which the top rated system configuration are itemized agreeing to their net present cost (NPC) or in categorized form in which only the most cost effective configuration is considered from each system type.

Architecture											Cost		
					PV (kW)	PV-MPPT (kW)	Generator (kW)	Storage	PHED (kW)	Converter (kW)	Dispatch	COE (₦)	NPC (₦)	Operating cos (₦/yr)
					2,040	1,900		6	999,999	2,000	LF	₦40.75	₦8.98B	₦560M
					2,040	1,900			999,999	2,000	CC	₦40.76	₦8.98B	₦560M
									999,999		CC	₦48.63	₦10.7B	₦669M
								6	999,999	400	LF	₦48.63	₦10.7B	₦669M
					2,040	1,900	2,050	6	999,999	2,000	LF	₦123.84	₦27.6B	₦1.72B
					2,040	1,900	2,050		999,999	2,000	CC	₦123.85	₦27.6B	₦1.72B
							2,050		999,999		CC	₦133.13	₦29.3B	₦1.83B
							2,050	6	999,999	400	LF	₦133.13	₦29.3B	₦1.83B

Figure 3.1: HOMER Optimization Results for Hybrid Micro grid Analysis

Table 3.1: System Configuration In Relation to the Cost of Energy

Photovoltaic	Diesel Genera-tion	Grid	Storage	COE (#)	NPC (#)	Operating Cost (#/yr)
PV	-	GD	ST	40.75	8.98Billion	560Million
PV	DG	GD	ST	123.84	27.6Billion	1.78Billion
-	DG	GD	ST	133.13	29.38	1.83Billion

From the optimization results of the feasible and optimal system configuration of the system components as shown in Figure 3.1 Total NPC and COE with different levels are obtained. The levelized cost of energy ranges from #40.75 KW/h to #123.94 KW/h. The current energy tariff rate from the Port Harcourt Electricity distribution Company is #48.20 KW/h for class A2.

The optimization result indicated that PV/Battery/Utility hybrid system was the optimum system with the capacity of 2040KW PV system, Batteries of 708 Ah. The system required a converter of 2040KW. The total net present cost of this system is 8.98 Billion Naira. The hybrid system can supply electricity at a cost of #40.75 KW/h.

The renewable fraction of this system is 16.2% hence 83.2% is supplied by Utility and diesel generators. The dispatch strategy for the configuration was "load following".

Based on the results shown in figure 3.1, it shows that a configuration with renewable resources is more economical than a configuration involving a Diesel generator.

The simulation results displayed various operating conditions and cases of the designed hybrid micro grid power supply system for Rivers State University. The results indicated that when the system considers a case of PV /Storage/Grid the operating cost for a year is #560,000,000,then for a case of only Grid the operating cost for a year was #669,000,000 but the disadvantage of that scenario was that power from the grid is not reliable.

In another configuration considering Generator/Grid/Storage the operating cost for a year was 1.74 Billion Naira.

In essence this show that the case of PV-Grid-Storage Battery as backup combination was more cost effective in providing continuous power supply for an institution like Rivers State University.

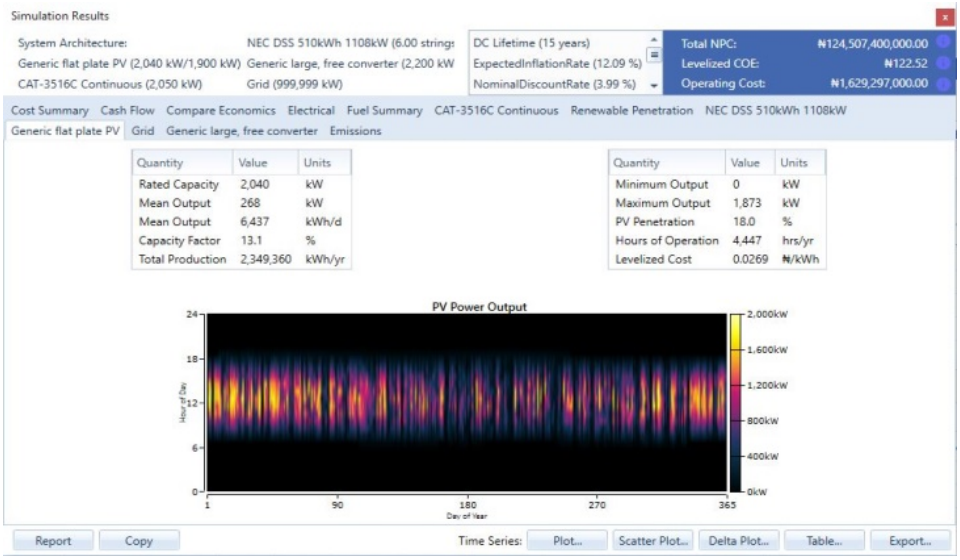

Figure 3.2: PV Power Output Result

The PV system has a Maximum Power output of 1873KW as displayed in the simulation result above.

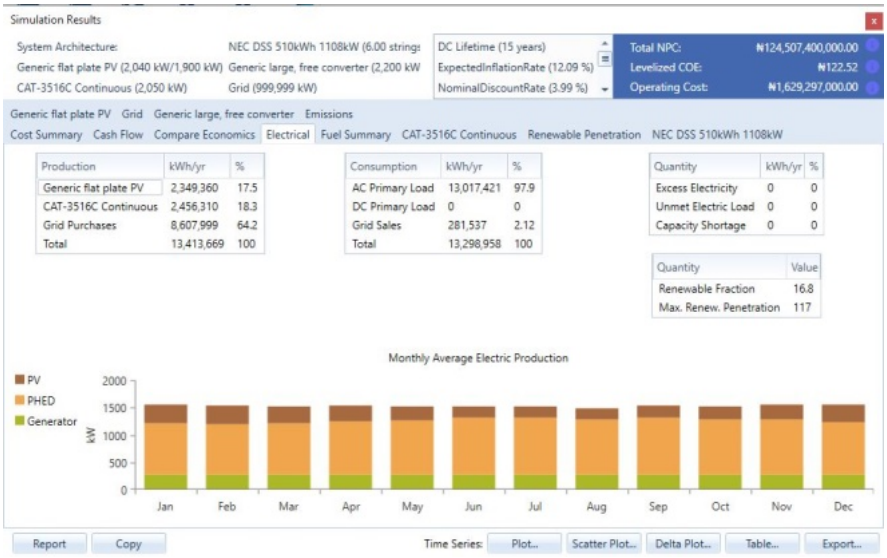

Figure 3.3: Monthly Average Electrical Production (PV/PHED/Generator)

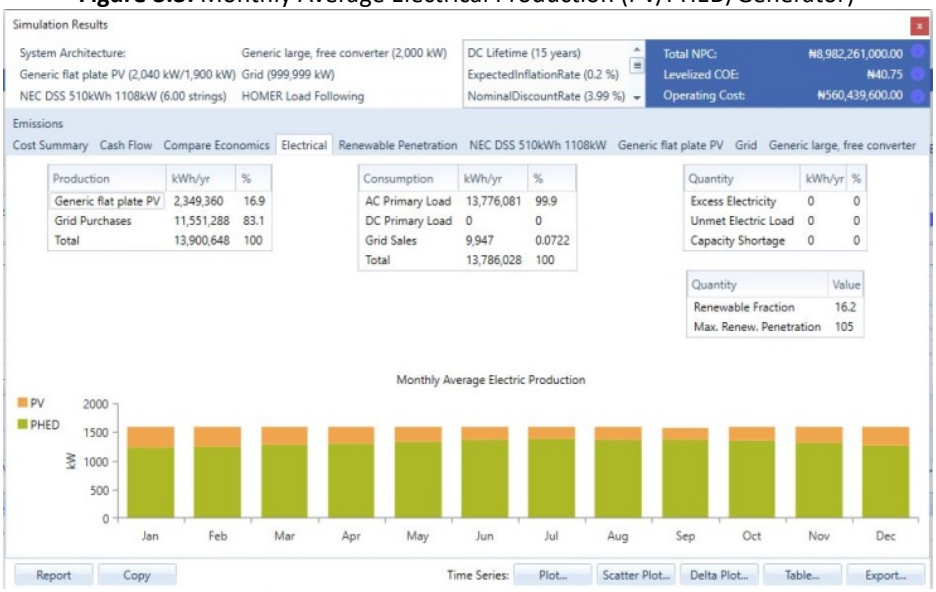

Figure 4.4: Monthly Average Electrical Production (PV/PHED)

4. CONCLUSION

This research work offers a feasibility study of a grid-connected hybrid power supply system for the Rivers State University campus located in Port Harcourt City in Rivers state, Nigeria. Port Harcourt city receives an abundant amount of solar radiation all through the year. Hence, a hybrid system involving PV, Battery, Utility and Diesel Generator is considered and optimum sizing of the various component in the hybrid system was carried out using HOMER software. The electrical load collected from the central substation control panel of the campus recorded a load profile Average peak load of 2040KW.The hybrid system is designed to equate the peak load at a minimum cost. The simulation results displays a hybrid system of 2040 KW PV system, batteries with capacity of 708 Ah and Utility was found as the optimum hybrid configuration and it can supply the electricity at a minimum cost of #40.76 kw/h. The total net present cost of the project was 8.98 Billion Naira and an initial capital investment of 22.2 million naira is required to

implement this project. This work is unique based on the fact that most research works considered off grid system while the present work analyzed a grid connected system which would be used to supply power to the university campus.

The conclusion from this study is that incorporating hybrid to a power supply system would contribute in the reduction of the operating cost.

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