



GLOBAL JOURNAL OF RESEARCHES IN ENGINEERING: F
ELECTRICAL AND ELECTRONICS ENGINEERING
Volume 21 Issue 1 Version 1.0 Year 2021
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

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GJRE-F Classification: FOR Code: 290901p



OPTIMIZATION OF WIND/PHOTOVOLTAIC HYBRID RENEWABLE ENERGY SYSTEMS FOR TELECOMMUNICATION NETWORKS IN NIGERIA

Strictly as per the compliance and regulations of:



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I. INTRODUCTION

a) Background of Study

Energy is the ability to do work; and it is fundamental to mankind, because human activities depend on one form of energy or another. Energy sources can be classified into renewable and non-renewable. Nigeria is country rich in both renewable energy and non-renewable energy resources for electricity production. However, almost all energy consumed in Nigeria comes from non-renewable energy sources such as coal, natural gas, and oil.

Despite the abundance of these energy resources in Nigeria, the country is in short supply of electrical power. Only about 60% only of the nation's over 199 million has access to grid electricity and at the rural level, where about 70% of the population live, the availability of electricity drops to 15%. Nigeria requires per capital power capacity of 1000 Watts per person or power generating/handling capacity of 170,000 MW as against the current capacity of 7000 MW. This will put Nigeria slightly below South Africa with per capita power capacity of 1047 Watts, UK with per capita power capacity of 1266 Watts and above Brazil with per capita

power capacity of 480 Watts, China with per capita power capacity of 260 Watts. Okafor and Uzuegbu (2018)

Currently Nigeria has per capita power capacity of 32.57 Watts and this is grossly inadequate even for domestic consumption. A high proportion of Nigerian's total energy output is still generated from fossil fuels such as oil and coal, which are treats to the environment due to emission of carbon dioxide. Okafor and Uzuegbu (2018).

It can be said that with figures given Nigeria as a developing country is faced with serious energy crises. Nigeria has been unable to meet the energy needs of their citizens. But, in developed countries, the use of non-renewable energy sources for electricity has been reduced from year to year in advanced countries. So there is a need to find another source to produce stable electricity generation in Nigeria. To achieve the goals of development, a strong energy sector is essential. In a quest to realize this, there is need to turn to different sources of energy which among them are renewable energy sources.

With the continuous increase in energy demand (particularly the electricity), and its environment concerns, the development of alternative energy resource to the conventional fossil generation has become a critical topic world widely and cannot be over emphasised. (Maczulak, 2010) and (Anaya-Lara, 2009).

In Nigeria for instance, Okafor and Uzuegbu (2018) including other experts in the field of energy resources for electricity generation, offer the following as solutions to resolving the challenges facing successful renewable energy adoption in Nigeria. The development of renewable energy services is linked to many other sectors such as telecommunication, agriculture, small scale industrial enterprises and poverty alleviation, thus it is recommended that, renewable energy related projects have a greater likelihood of success if implemented in tandem with activities in these sectors to ensure sufficient demand for the energy services providers.

The Federal Government approved the National Energy Policy (NEP) in 2003 to articulate the sustainable exploitation and utilization of all viable energy resources. The policy is hinged on private sector development of the energy sector. The key elements in the national

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policy position on the development and application of renewable energy and its technologies are as follows (Balaet al, 2000):

1. To develop, promote and harness the Renewable Energy (RE) resources of the country and incorporate all viable ones into the national energy mix
2. To promote decentralized energy supply, especially in rural areas, based on RE resources
3. To de-emphasize and discourage the use of wood as fuel
4. To promote efficient methods in the use biomass energy resources
5. To keep abreast of international developments in RE technologies and their applications

Relying in this framework, renewable energy has come to fill the gap; and hence can completely become alternative energy resources for the conventional energy resources. Renewable energy is important because of the benefits it provides. The key benefits which are that renewable energy technologies are clean sources of energy that have a much lower environmental impact than conventional energy technologies.

b) Problem Statement

Despite the policy frame work for electricity production with renewable energy in Nigeria, the use of energy has still been majored on the generation from the cheap but environmental unfriendly energy resources-oil and gas. For electrical energy production, the use of centralized power plant is not encouraging due certain reliability factors such as vandalization of gas pipeline and power lines, voltage drop due to overload, frequent faults due to aging equipment and so and so forth. This factors has contributed in reducing energy production.

Most Nigerian based industries in an effort to help themselves and their businesses relied on diesel generator for electricity supply. A study by Tyler's (2002) showed that of "232 Nigerian based firms, 97% owned private generators and operated them for 67% of their production time" (Tyler's, 2002). This cannot be economical, considering the operational cost associated with diesel generator, such as increase in diesel price, lack of maintenance personnel, scarcity and transportation, coupled with environmental impact.

Using a more sustainable approach for electricity generation (such as renewable energy hybrid system), will not only be profitable to the industries but also increase national energy mix can production; and encourage in decarbonizing the environment. Again, development of mini grids or decentralized power plants with the use of viable renewable energy resources can encourage reliable and sustainable power production and supply.

c) Research Aim

The aim of this project is to perform optimization of hybrid Wind/Photovoltaic renewable energy system for telecommunication industries in Port Harcourt.

d) Objectives of the Research

The specific objectives are stated as follows:

1. To investigate renewable energy potentials in Nigeria
2. To study selected two renewable energy resources(Wind and Solar PV) for power generation
3. To perform a design and load profile construction of the two selected renewable energy resources
4. To perform a comparative analysis of the selected energy schemes with a fossil generation system in terms of energy production, cost, based on Net-Present-Value(NPV)
5. To perform a sensitivity analysis of the optimized hybrid system

e) Significant of the Research

Renewable energy technologies are increasingly used to address energy shortages and to expand the range of services in both rural and urban areas.

Electrical energy has been seen as one important source of energy due to its higher transmissible power, its ability to readily transform to other forms of energy and the human capability to facilitate its storage. Electricity plays vital roles in our daily lives such as in cooking our food, hitting our water, powering our personal computer and many more. Energy is a very important catalyst for economic development of any country. Despite the importance of energy to socio-economic development, Nigeria has not being able to generate the maximum required amount of energy it needs for her population. It is important that the viability of this clean and sustainable resources be studied so that Nigeria can take advantage of global partnerships in the development of framework to support the technology.

f) Scope of the Research

There are so many renewable energy resources in Nigeria. But the project shall be limited to analysis of technical and economic impact of hybrid Wind/solar PV energy resources in Nigeria. The research location shall be SOUTH-SOUTH REIGION. The research shall not discuss grid connected renewable energy sources, where the use of power electronic such as STACOM device for the control of power is involved. And the research shall not develop a physical system.

II. LITERATURE REVIEW

a) Introduction

Nigeria is rich with both conventional and non-conventional energy resources as illustrated in table 3.1.

Table 3.1: Energy Sources in Nigeria

Energy Resources In Nigeria	
Energy type	Reserve estimates
Crude oil	36 billion barrels
Natural gas	185 trillion cubic feet
Coal	2.75 billion metric tons
Hydro	14.7.0MW
Solar Radiation	3.5-7.0 KWh/m ² /day
Wind energy	2.0 – 4.0
Biomass	144 million tons/year
Waves and tidal energy	150,000
	$\frac{TJ}{16.6 \times 10^6 \text{ ton / yr}}$

Source: Energy commission of Nigeria (ECN)

Source of electric power was first known in Nigeria in 1896 when a 30 KW, 50 Hz, single phase locomotive generator was installed in Ijora, Lagos, the then seat of British colony. In 1924, with the increasing population, a three phase, 50 Hz system of power system became known and electric power were been distributed in few cities of the country by some isolated generating stations like Cameroon's Development Corporation (CDC), African Timber and Plywood Company (ATPC) and Nigeria Electrical Supply Corporation (NESCO), In 1952, Electricity Corporation of Nigeria (ECN) was established and this gave birth to the Ijora Power Station which had 10 MW coal-fired turbo-generators, (Atandare, 2007).

Coal and hydropower and has been the source the nation's energy until when the activities of oil exploration started in 1950s.

Due to the environmental risk in the use of oil and gas and other forms of fossil generations, attention has been shifted globally to the use of renewable generations. Apart from attack on the environment, hike in oil price and security is another factor.

b) Review of Wind and Solar Potentials in Nigeria

Wind Energy Wind is a natural phenomenon related to the movement of air masses caused primarily by the differential solar heating of the earth's surface. Sambo (2005) State that seasonal variations in the energy received from the sun affects the strength and direction of the wind. The ease with which aero turbines transform energy in moving air to rotary mechanical energy suggests the use of electrical devices to convert wind energy to electricity. Wind energy has also been utilized, for decades, for water pumping as well as for the milling of grains.

Globally, Nigeria is located within low to moderate wind. Ojosu and Salawu (1989) carried out the most comprehensive nationwide study on wind energy availability and potential in Nigeria. The study uses Data on Wind speeds and directions for 22 meteorological Stations from the Nigerian Meteorological office, Oshodi near Lagos. The meteorological data are based on the

3-hourly records of wind for periods ranging from 12 to 33 years (1951 – 1983)

Other studies on the wind energy potentials for a number of Nigerian cities shows that the annual wind speed ranges from 2.32 m/s for Port Harcourt to a figure of 3.89 m/s for Sokoto. The maximum extractable power per unit area, for the same two sites was estimated at 4.51 and 21.97 watts per square metre of blade area, respectively. And when the duration of wind speeds greater than 3 m/s is considered than the energy per unit area works out as 168.63 and 1,556.35 kWh per square metre of blade area, again for Port Harcourt and Sokoto. (Sambo, 1987)

Ojosu and Salawu estimated the maximum energy obtainable from a 25m diameter wind turbine with an efficiency of 30% at 25m height to be about 97 MWh/year-for Sokoto, a site in the high wind speed regions, 50 MWh year- for Kano, 25.7 MWh year-1 for Lagos and 24.5 MWh year-1 from Port Harcourt. Table 2.2 shows the wind energy densities for other sites. (Ojosu and Salawu, 1990).

Table 2.1: Wind energy Density Estimates at 25 metre Height (Ojosu and Salawu, 1990)

Station	Mean wind speed at 25m Level (ms)	Monthly mean Wind Energy KWh/yr.	Annual Wind Energy KWh-2 year	Annual Wind energy from a wind Energy turbine in KWh year -1	
				Dia = 10m	Dia = 25m
Benin City	2.135	2.32	27.86	2,187.81	13,673.78
Calabar	1.702	1.12	13.42	1,053.69	6,587.53
Enugu	3.372	7.83	93.91	7,375.75	46,097.96
Ibadan	2.620	4.15	49.78	3,909.79	24,436.19
Ilorin	2.078	1.23	14.73	1,157.06	7,230.57
Jos	4.430	16.05	192.64	15,129.60	94,559.98
Kaduna	3.605	9.91	188.88	9,36.81	58,355.08
Kano	3.516	8.57	102.86	8,078.61	50,491.28
Lagos	2.671	4.36	52.32	4,099.78	25,682.52
(Ikeja)					
Lokoja	2.235	2.60	31.21	451.23	15,320.17
Maiduguri	3.486	8.42	101.01	7,933.61	49,583.17
Minna	1.589	1.05	12.60	989.60	6,185.01
Makurdi	2.689	4.44	53.27	4,183.51	26,148.85
Nguru	4.259	14.48	173.74	13,645.19	85,284.42
Oshogbo	1.625	1.07	12.81	1,006.60	6,288.09
P.H.	2.640	4.17	49.98	3,925.48	24,533.88
Potiskum	3.636	9.44	113.25	8,894.35	55,591.46
Sokoto	4.476	16.47	197.68	15,525.75	97,035.94
Warri	2.027	2.02	24.20	1,900.66	11,879.15
Yelwa	3.360	7.76	93.13	7,314.88	45,714.59
Yola	1.824	1.45	17.34	1,361.88	8,511.75
Zaria	2.891	5.32	63.88	5,017.26	31,357.02

Although use of wind energy for water supply has been known and used for hundreds of years, in recent times efforts have been directed largely towards the use of wind power for the generation of electricity and in the past twenty years or so rapid changes in technology have occurred and major wind powered generating plants have been installed, especially in the rural areas of the developed countries.

According to Balaet *al* (2000), Nigeria is endowed with an annual Average daily sunshine of 6.25 hours, ranging between about 3.5 hours at the coastal areas and 9.0 hours at the far northern boundary. Similarly, it has an annual average daily solar radiation of about 5.25 KW/m²/day, varying between about 3.5 kWm²/day at the coastal Area and 7.0kW/m²/day at the northern boundary. Nigeria receives about 4.851x 10¹² KWh of energy per day from the sun. This is equivalent to about 1.082 million tones of oil Equivalent (mtoe) per day, and is about 4 thousand times the current daily crude oil reduction, and about 13 thousand times that of natural gas daily production based on energy unit. This huge energy resource from the sun is available for about 26% only of the day. The country is also characterized with some cold and dusty atmosphere during the harmattan, in its northern part, for a period of about four

months (November-February) annually. (Balaet *al*, 2000).

Based on the land area of 924 x 10³ km² for the country and an average of 5.535 kWh/m²/day, Nigeria has an average of 1.804 x 10¹⁵ kWh of incident solar energy annually. This annual solar energy insolation value is about 27 times the nation total conventional energy resources in energy units and is over 117,000 times the amount of electric power generated in the county in 1998 (Chendo, 2002). In other words, about 3.7% only of the national land area is needed to be utilized in order to annual collect from the sun an amount of energy equal to the nation's conventional energy reserve.

Similarly, Okafor and Uzuegbu (2018) indicates that Nigeria is endowed with an annual Average daily sunshine of 6.25 hours, ranging between about 3.5 hours at the coastal areas and 9.0 hours at the far northern boundary. Similarly, it has an annual average daily solar radiation of about 5.25 KW/m²/day, varying between about 3.5 kWm²/day at the coastal Area and 7.0kW/m²/day at the northern boundary. Nigeria receives about 4.851x 10¹² KWh of energy per day from the sun. This is equivalent to about 1.082 million tons of oil Equivalent (mtoe) per day, and is about 4 thousand

times the current daily crude oil reduction, and about 13 thousand times that of natural gas daily production based on energy unit. This huge energy resource from the sun is available for about 26% only of the day.

c) *Review of Related Works on Hybrid Wind-Solar PV System*

Obuah and Alalibo (2017) performed a comparative analysis of Hybrid Photovoltaic/Diesel Energy System for Oil and Gas Industries in Nigeria. Their studies was based on a system that has low investment cost for the project life cycle of 25 years. The result of their studies shows that the cost of PV components with battery storage device was relatively high, but the system constituted a significant advantage when incorporated with diesel generation. Their research was commendable and educating as the approach for load sizing was thoughtful. However, their studies did not carry out sensitivity analysis of the hybrid system.

In 2014, Afrouziet *al*, (2014) researched on the viability of renewable energy resources for hybrid of hydro, solar and wind. Their studies was based on a supposed remote residential area consisted of a total of 30 consumers, where each consumer needed loads of 2kW peak making a total or maximum of 60kW peak demand. Using HOMER for the studies, a PV/Wind-/Diesel Hybrid Energy System with was optimized based on system components with cheapest cost. However, their studies show that HOMER Diesel Hybrid Energy System with HOMER was the most economical one.

Similarly, Hassan *et al* (2016) made a research on Optimization of P/Wind/Diesel Hybrid Power System in HOMER for Rural Electrification of Muqdadiyah a rural region of Diyala State of Iraq. The research considered two renewable resources, namely, solar photovoltaic (PV) and wind turbine (WT), using a computer simulation and optimization of hybrid power generation system, HOMER. Their results show that it's not economically viable for a wind turbine to generate the electricity. But then a hybrid system comprising of PV and Diesel provided the solution to electrify the selected area resulted in a least- cost combination of the hybrid power system at a cost of about (\$0.321/kWh).

III. MATERIALS AND METHODS

a) *Materials*

The section of this work will take into details the materials needed in actualizing this study; Load Profile Datasheet, Metrological Datasheet, HOMER Pro Software and the simulation network

i. *Homer*

HOMER is a computer-based program provided by NREL which can give assistance in the tasks to configure, simulate, evaluate and optimize several choices of designs of various systems for distributed electricity generation and consumption units.

HOMER allows for a basic comparative analysis of several alternatives for electrification, and estimates impacts of changes in loading parameters, impact on the environmental and potential emission of greenhouse gases.

Below are presented the task of the HOMER software needed for this study:

- Simulation of the system operation (energy balance for each of the 8760 hours of the year) comparing the energy demand and the capacity of the system to supply the energy on that hour, deciding for every hour how the generators operate and the loads of discharges of the batteries;
- Calculation of the energy balance for each proposed system that we want to consider, after the configuration is deemed feasible; and
- Estimating the costs of investment, equipment replacement, fuel, maintenance and operation.
- The final goal is basically to identify the lowest cost system capable of meeting the electricity demand of a particular consumer unit, urban or rural residence, community, company or industry.

b) *Network Block Diagram*

The figure below represents the block diagram for the network to be simulated

i. *Facility Network Diagram*

The block diagram below represents the proposed network of having the Gen on the AC Bus while the PV and battery bank on the DC bus, the converter converts the DC power to AC for the load and the AC to DC from the Gen to charge the battery when the needs arises.

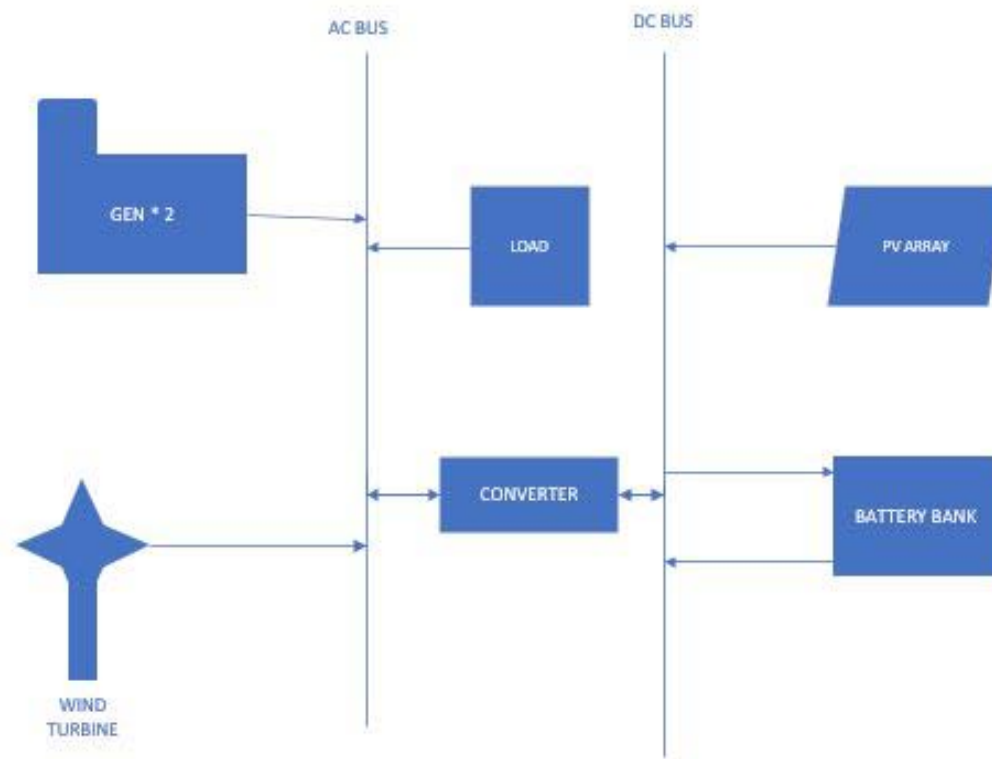


Figure 3.1: Block diagram

ii. Facility Simulation Parameters

The facility parameters to be used for simulation are shown on the table below.

Table 3.1: Simulation Parameter

S/N		
1	SITE ID	B1602
2	Co-ordinate	7.16938 9.28465
3	IHS ID	HIS_CRR_0751E
4	REGION	PHC
5	STATE	CROSS RIVER
6	VENDOR	HUAWEI
8	TENANTS	9 MOBILE
9	DG 1	20KVA
10	DG 2	20KVA
11	PEAK CURRENT	63 A
12	PEAK POWER	14490

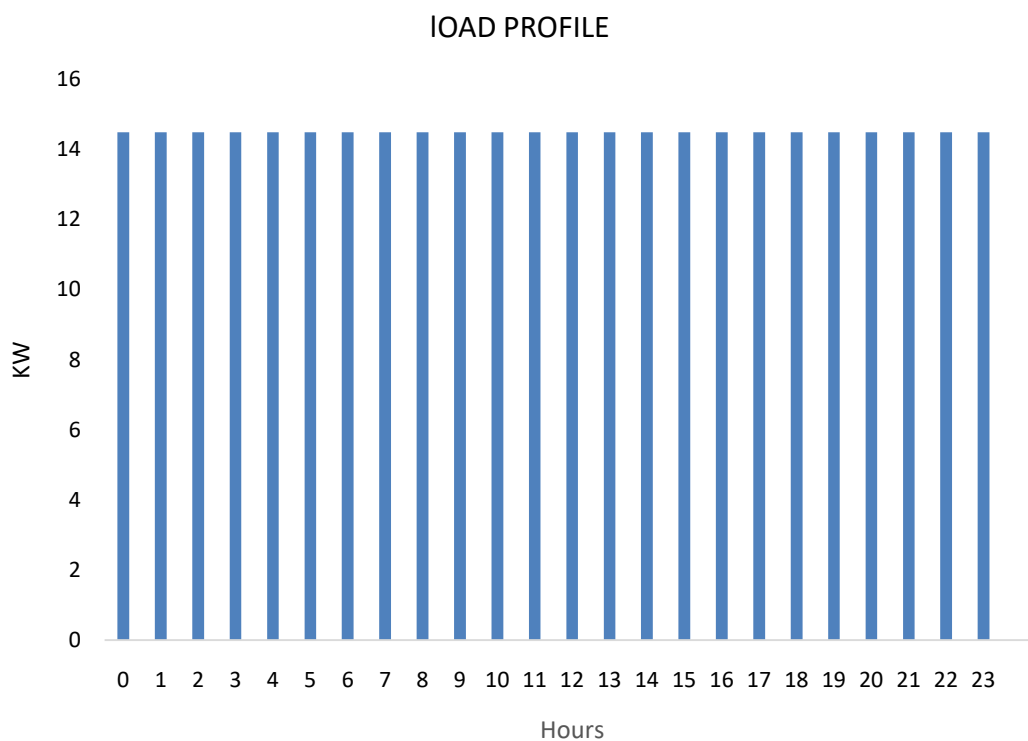


Figure 3.6: Load profile (source NASA 2020)

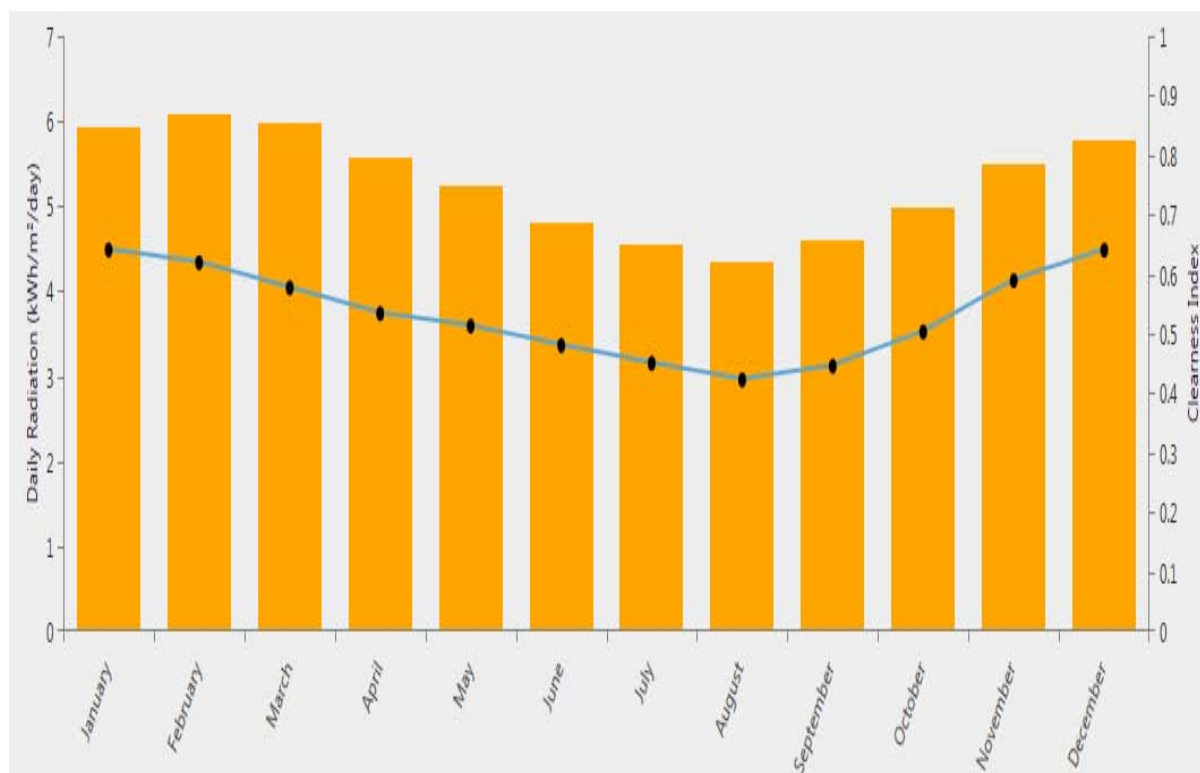


Figure 3.7: Solar Resources (Source: NASA 2020)

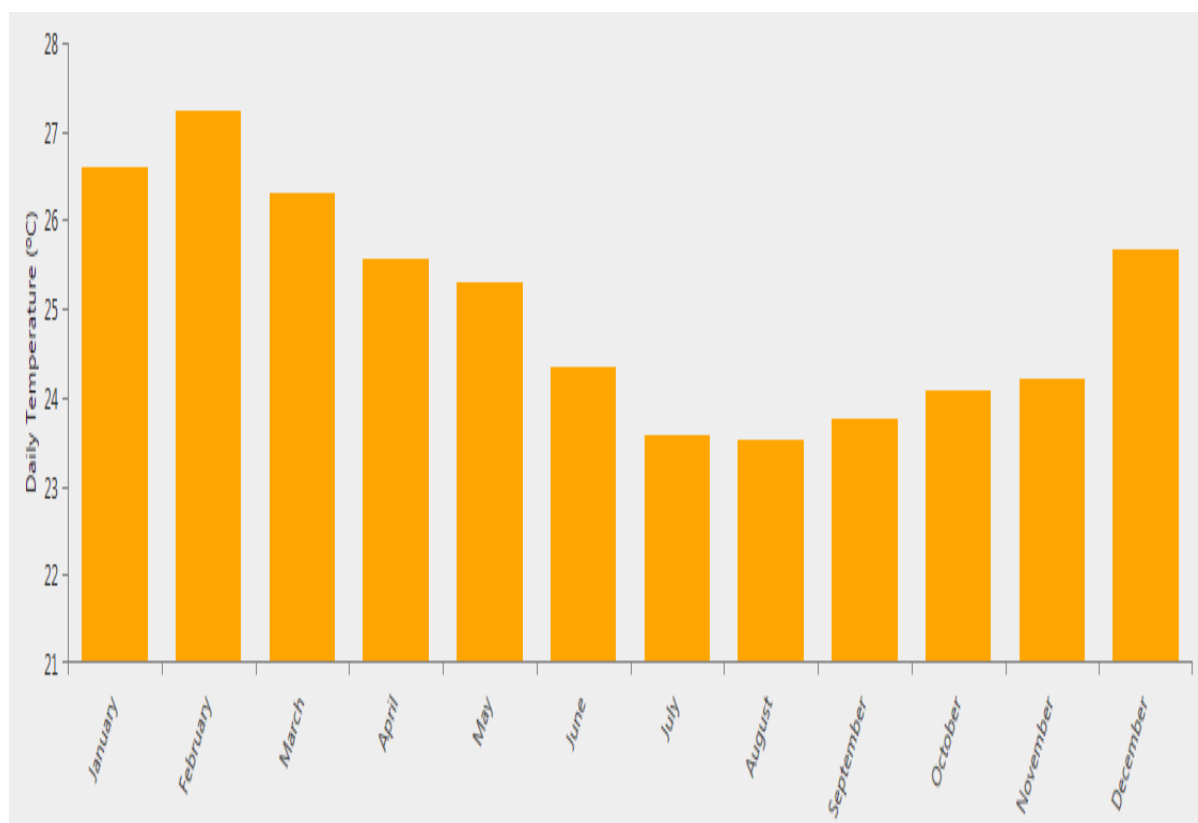


Figure 3.8: Temperature Resource (Source: NASA 2020)

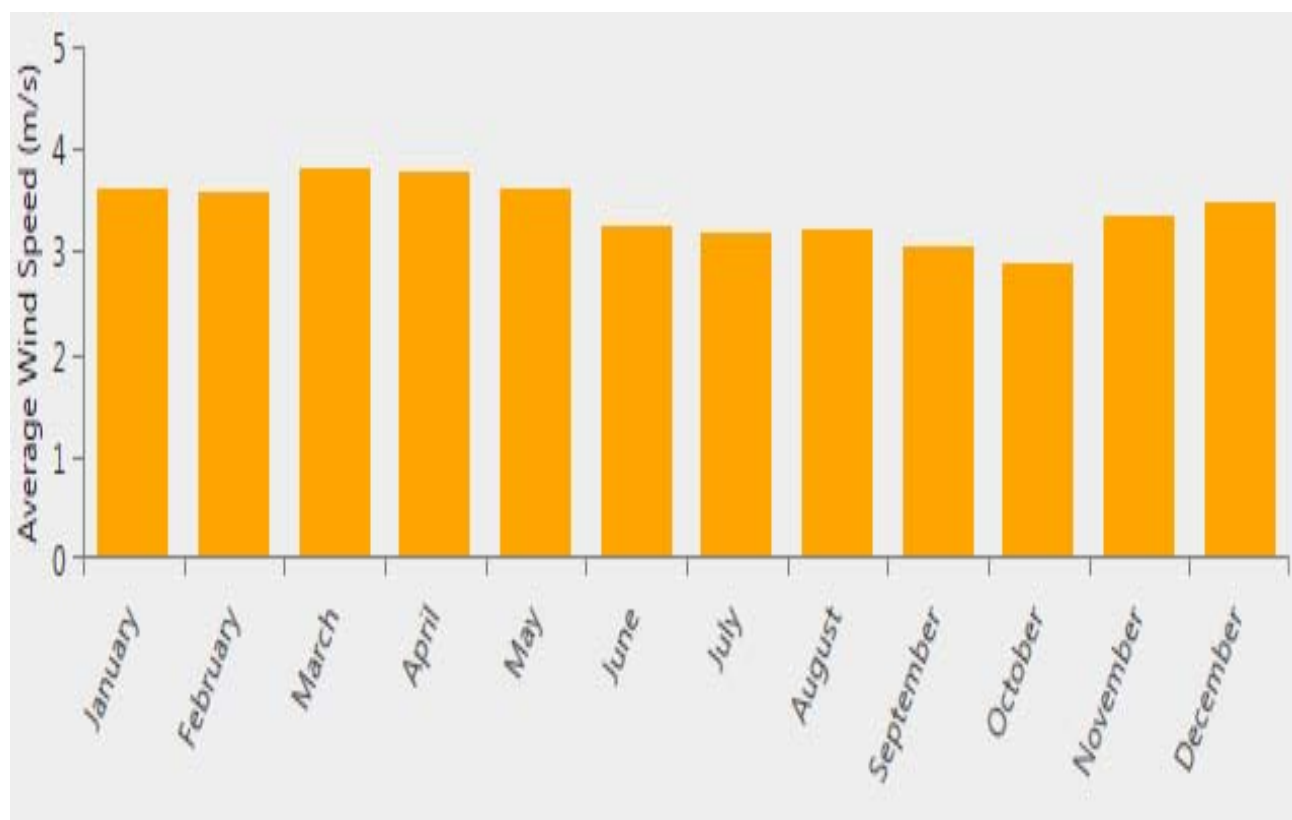


Figure 3.9: Solar speed (Source: NASA 2020)

HOMER Model Equations

iii. PV array Output

$$P_{PV} = Y_{PV} f_{PV} \left(\frac{\bar{G}_T}{\bar{G}_{T,STC}} \right) [1 + \alpha_p (T_c - T_{c,STC})] \quad (3.1)$$

Where:

Y_{PV} = PV array rated capacity

f_{PV} = De-rating factor [%] of the PV

\bar{G}_T = Incident solar radiation on the PV [kW/m²]

$\bar{G}_{T,STC}$ = Incident radiation at standard test conditions [1 kW/m²]

α_p = Temperature coefficient of power [%/°C]

T_c = PV cell temperature in the current time step [°C]

$T_{c,STC}$ = PV cell temperature under standard test conditions [25°C]

Source: HOMER Energy

Equation above is simplified thus below if temperature coefficient of power is assumed to be zero

$$P_{PV} = Y_{PV} f_{PV} \left(\frac{\bar{G}_T}{\bar{G}_{T,STC}} \right) \quad (3.2)$$

Source: HOMER Energy

iv. Maximum Battery Charge Power:

This is used by HOMER to compute what amount of power that can absorb by the storage bank.

$$P_{batt.cmax, kbm} = \frac{kQ_1 e^{-K\Delta t} + Qkc(1 - e^{-K\Delta t})}{1 - e^{-K\Delta t} + c(k\Delta t - 1 + e^{-K\Delta t})} \quad (3.3)$$

Where:

Q_1 = Available amount of energy [kWh] in the storage at the beginning of the time step.

Q = Total amount of energy [kWh] in the storage at the beginning of the time step.

c = Storage capacity ratio [unit less].

k = Storage rate constant [h⁻¹]

Δt = Length of the time step [h]

Source: HOMER Energy

v. Maximum Amount of Power Discharge from Storage:

The maximum amount of power that the storage bank can discharge over a specific length of time is given by the Kinetic Storage model equation:

$$P_{batt.dmax, kbm} = \frac{-kcQ_{max} + kQ_1 e^{-K\Delta t} + Qkc(1 - e^{-K\Delta t})}{1 - e^{-K\Delta t} + c(k\Delta t - 1 + e^{-K\Delta t})} \quad (3.4)$$

Where:

Q_1 = Amount of energy [kWh] available in the Storage Component at the beginning of the time step

Q = Total amount of energy [kWh] in the Storage Component at the beginning of the time step

Q_{max} = Total capacity [kWh] of the storage bank

c = Storage capacity ratio [unit less]

k = Storage rate constant [h⁻¹]

Δt = Length of the time step [h]

IV. RESULTS AND DISCUSSION

a) Basic Simulation Terms

i. Net Present Cost (NPC)

(The net present cost) or (Life-cycle cost) of a Component is the present value of all the costs of installing and operating the Component over the project lifetime, minus the present value of all the revenues that it earns over the project lifetime. HOMER calculates the net present cost of each Component in the system, and of the system as a whole.

ii. Cycle Changing Dispatch Strategy

The generator is always operated at its rated capacity when in operation and the excess energy is used to charge the batteries.

iii. Salvage Value

Salvage value is the value remaining in a component of the power system at the end of the project lifetime.

iv. Annualized Cost

The annualized cost of a component is the cost that, if it were to occur equally in every year of the project lifetime, would give the same net present cost as the actual cash flow sequence associated with that component.

v. Levelized Cost of Energy (COE)

Level zed cost of energy (COE) as the average cost per kWh of useful electrical energy produced by the system.

b) Presentation of Data

The tables below show the Homer input Data and the optimization values

Table 4.0: Diesel Generator Data

S/N	Diesel Generator (GEN)	Sample Rate
1	Manufacturer	Homer
2	Capacity	Generic
3	Capital	16KW
4	Replacement	N2700,000.00
5	Electric Bus	N2700,000.00
6	Fuel Diesel	AC
		N224/L

Source: Authors Research

Table 4.1: Wind Turbine

S/N	Generic flat PV	Sample Rate
1	Manufacturer	Homer Generic
2	Capacity	1 KW
3	Capital	N352,500.00
4	Replacement	N352,500.00
5	Electric Bus	DC
6	Capacity Optimization	0KW 10KW 20KW 30KW

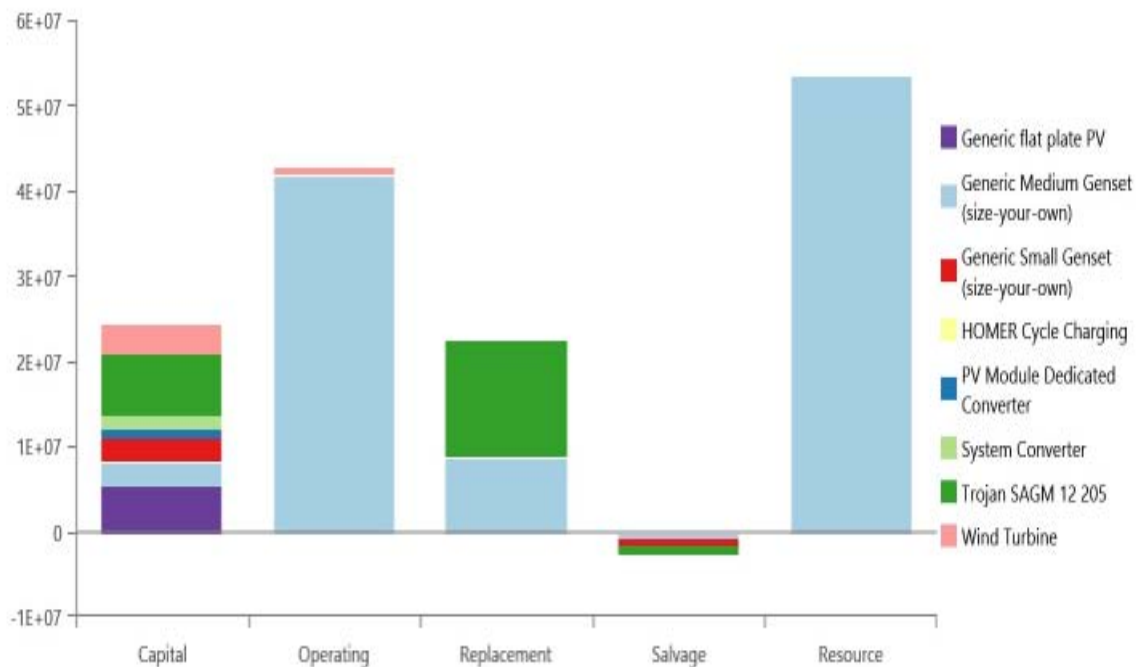
Table 4.7: System Architecture

Component	Name	Size	Unit
Generator #1	Generic Medium Genset (size-your-own)	16.0	kW
Generator #2	Generic Small Genset (size-your-own)	16.0	kW
PV	Generic flat plate PV	30.0	kW
Storage	Trojan SAGM 12 205	15	strings
Wind turbine	Wind Turbine	10	ea.
System converter	System Converter	20.0	kW
Dispatch strategy	HOMER Cycle Charging		

Source: Authors Research

The system architecture for the design is summarized on the above table. The size of the two 2 generators are 16KW, the PV module is 30KW, the battery storage for the system is of 15 strings, the

system converter is rated at 20KW while the wind turbine is of 10. and it also uses cycle changing dispatch strategy



Graph 4.0: System architecture

The above graph shows the system cost summary

Table 4.8: Net Present Costs

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Generic flat plate PV	₦5.40M	₦0.00	₦0.00	₦0.00	₦0.00	₦5.40M
Generic Medium Genset (size-your-own)	₦2.70M	₦41.8M	₦8.69M	-₦524,657	₦53.6M	₦106M
Generic Small Genset (size-your-own)	₦2.70M	₦0.00	₦0.00	-₦1.13M	₦0.00	₦1.57M
HOMER Cycle Charging	₦5,000	₦0.00	₦0.00	₦0.00	₦0.00	₦5,000
PV Module Dedicated Converter	₦1.08M	₦0.00	₦0.00	₦0.00	₦0.00	₦1.08M
System Converter	₦1.60M	₦0.00	₦0.00	₦0.00	₦0.00	₦1.60M
Trojan SAGM 12 205	₦7.20M	₦0.00	₦13.7M	-₦1.11M	₦0.00	₦19.8M
Wind Turbine	₦3.53M	₦978,734	₦0.00	₦0.00	₦0.00	₦4.50M
System	₦24.2M	₦42.7M	₦22.4M	-₦2.76M	₦53.6M	₦140M

The NPC for 15yrs period is ₦140M that is ₦ (5.40M + 106M + 1.57M + 5000 + 1.08M + 1.60 M + 19.8M + 4.50M).

Table 4.9: Annualized Costs

Name	Capital	Operating	Replacement	Salvage	Resource	Total
Generic flat plate PV	₦551,733	₦0.00	₦0.00	₦0.00	₦0.00	₦551,733
Generic Medium Genset (size-your-own)	₦275,866	₦4.27M	₦888,069	-₦53,606	₦5.47M	₦10.9M
Generic Small Genset (size-your-own)	₦275,866	₦0.00	₦0.00	-₦115,287	₦0.00	₦160,579
HOMER Cycle Charging	₦510.86	₦0.00	₦0.00	₦0.00	₦0.00	₦510.86
PV Module Dedicated Converter	₦110,347	₦0.00	₦0.00	₦0.00	₦0.00	₦110,347
System Converter	₦163,476	₦0.00	₦0.00	₦0.00	₦0.00	₦163,476
Trojan SAGM 12 205	₦735,644	₦0.00	₦1.40M	-₦113,117	₦0.00	₦2.03M
Wind Turbine	₦360,159	₦100,000	₦0.00	₦0.00	₦0.00	₦460,159
System	₦2.47M	₦4.37M	₦2.29M	-₦282,010	₦5.47M	₦14.3M

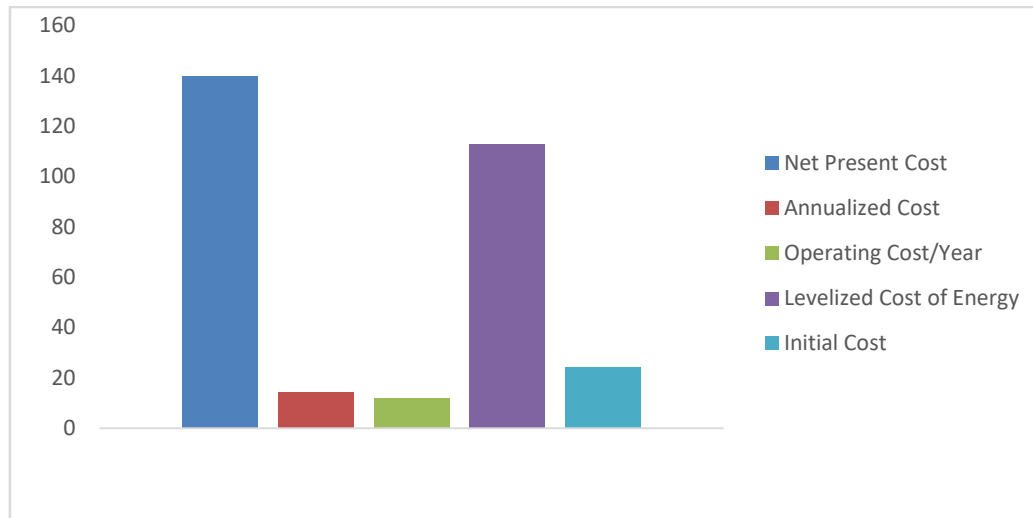
The annualised cost of the grid system is ₦143.M

Other results generated by the HOMER software on grid but not related to cost are attached in appendix A

c) Discussion of Findings

Table 4.10: Optimization Table

S/N	OPTIMIZATION	GRID SYSTEM COST
1	Net Present Cost	₦140 million
2	Annualized Cost	₦14.3 million
3	Operating Cost/Year	₦11.8 million
4	Levelized Cost of Energy	₦112.83
5	Initial Cost	₦24.2 million



Graph 4.1

The above table and graph show the configuration hybrid configuration of the above system for a period of 15years life time with a dispatch strategy of "Cycle Charging".

15 year operational cost analysis

$$₦11,800,000 \times 15\text{years} = ₦177,000,000$$

Adding the operational cost to the initial setup cost of ₦24,200,000

$$₦177,000,000 + ₦24,200,000 = ₦201,200,000$$

V. SUMMARY, CONCLUSION AND RECOMMENDATIONS

a) Summary

This study examined the comparative cost analysis for improving power supply through off-grid solar energy utilization in Nigeria.

Chapter 1 introduce the importance of power supply as it cuts across all aspect of life ranging from residential, commercial and industrial uses. It equally looks at its effect on living standard and the world economy

Chapter 2 was used to review different papers that discusses history/issues concerning Nigeria power supply and its framework. Nigeria solar energy potentials, site identification and the components needed to build a solar plant.

Chapter 3 discusses the method and material used in carrying the research. How the research data

were obtained and how/which software was used to analyzed the data

Chapter 4 dealt with data presentation and the analysis of the data using HOMER Energy.

b) Conclusion

The comparative cost analysis shows that the following parameters:

- Net Present Cost (NPC)
- Annualized Cost
- levelized Cost of Energy (LCOE)
- Operating Cost/Year

Are lower or cheaper for the PV/Generator Network compared to Grid/Generator network. The only setback observed was the huge initial cost of setting up the PV system but at the long run it is still better when compared to using just grid or fossil.

The economic analysis demonstrated that government and other organization should invest in off-grid renewable (Solar) energy power plant to improve the standard of living and bring down the cost of doing business.

c) Recommendations

Based on this study, the followings are recommended

1. Domestication of mechanization of solar/wind energy components and equipment in the country and technology advancement should be encouraged by the government.

2. Government should introduce policies like interest free low loan or loan with minimal interest rate to encourage large organizations, institutions, estate, etc. to build their own power generating plant with the excess power generated sold to the grid.
3. Finally, renewable resources are enormous in Nigeria, identifying the best sources to be harness in different part of the country is key to increase power generation and sustain economic growth.

d) *Contribution to Knowledge*

This study has established that there is comparative cost advantage of solar energy utilization in improving power supply in Nigeria as well as helping in global warming by reducing use of fuel which constantly deplete the ozone layer most especially if the right policies are introduced by government.

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