

Renewable Energy Resources Hybridization as an Efficient and Cost-Effective Alternative for Electrification



K. R. Kamil^{1*}, A. O. Yusuf², S. A. Yakubu³, S. B. Seriki⁴

¹Department of Electrical/Electronic Engineering, University of East London, London, United Kingdom.

²Department of Computer Engineering, University of Ilorin, Ilorin, Nigeria.

³Nigerian Building and Road Research Institute (NBRI), Abuja, Nigeria.

⁴Solar Force Nigeria Limited, Abuja, Nigeria.



ABSTRACT: Majority of electricity generation in Nigeria comes from fossil fuels, with about two-thirds of thermal power derived from natural gas and the rest from oil, resulting in the emission of carbon dioxide (CO_2). With the prevailing global climate change, shifting to renewable energy would reduce the greenhouse gas emission which would be the salvaging option to help our degrading environment. The aim of the resource's hybridization process is to generate enough electricity that would help the supplementing for the inadequate electricity supply in the local province at the least detrimental effect on the environment. This work discusses the renewable energy potential of Nigeria and raises the possibility of having Nigeria electricity grid powered by small, medium and large-scale renewable energy systems. The hybridised power generation system simulations were done using HOMER simulation software. The hybridisation of the resources was able to generate 149,313 kWh/yr to adequately sustain the estimated electrical load of 126,027kWh/yr. Conclusively, cost effectiveness of the individual and hybridised systems was also considered.

KEYWORDS: Renewable Energy, Solar, Wind, Micro-Hydro, Hybridization

[Received Jan. 22, 2021; Revised May 18, 2021; Accepted Aug. 4, 2021]

Print ISSN: 0189-9546 | Online ISSN: 2437-2110

I. INTRODUCTION

Access to sustainable energy remains key pre-essential factor enhancing growth and development of the universe. In line with this declaration, the year 2012 was proclaimed as 'The International Year of Sustainable Energy for All' at the United Nation General Assembly (UN, 2012). They reiterated the convincing need for speedy access and exploration of much better and proficient present-day energy management and services in a better way to accomplishing economic advancement and to achieve the millennium development objectives (Sachs, 2012). The positive reaction to the global temperature change is to replace present-day energy sources with other options termed "Alternative Energy" to generate electrical power with very minimal greenhouse gasses emission and their usage is inexhaustible because of their infinite availability (Islam et al, 2012). "Alternative Energy" are energy sources that possess little or no atmospheric hazard when they are in use. These energy sources are always renewed through natural processes making their availability continuous, and they are termed "Renewable Sources". Carbons exhaust that comes out of renewable resources remains low when compared to other conventional sources, some renewable sources include geothermal, wind, biomass, solar and hydro. The renewable resources have their reserve renewed annually based on a human time scale with available quantity varying for different geographical locations (Kusakana et al, 2009).

With many of the previous study using one or two resources for the hybridization, this study aims at developing an efficient and effective electrification format that can accommodate three hybrid renewable power systems for a specified area. It will involve an analysis of some electrical power supply systems and their hybridization as an alternative for the supply of electricity.

Furthermore, according to (Tijjani et al, 2012) summarizes the small hydro power potentials in Nigeria, its present status and investment opportunities. Nigeria is endowed with so many resources both human and natural. The need to harness these resources in serving the human needs is paramount. Renewable energy remains the cleanest, most reliable and inexhaustible energy type and Nigeria is blessed with almost all types of renewable energy resources. One of the most readily available renewable energy resources is small hydro. Nigeria had the potentials of over 277 dispersed small hydro sites capable of generating electric power of about 734.2MW out of which only 30MW has been harnessed in 2005, and the potential as at today is estimated to reach 3,500MW (Tijjani et al, 2012). Accordingly, the off-grid supply is a better alternative option, where renewable energy sources are used either individually or integrated into a hybrid form (Ani Vincent, 2013). Access to renewable energy at times do not favor some topographical area because the individual renewable source may be minimal or unavailable and also the means to access or harvest the natural resources

*Corresponding author: kehinde.kamil@nbri.gov.ng

that can be used in generating energy could be constrained (Abdulrazak et al, 2010).

With many of the previous study using one or two resources for the hybridization, this study aims at developing an efficient and effective electrification format that can accommodate three hybrid renewable power systems for a specified area. It will involve an analysis of some electrical power supply systems and their hybridization as an alternative for the supply of electricity.

II. METHODS

The comprehensive evaluation and appraisal on each of the considered renewable energy sources would be carried out as a standalone, after which there will be considerations on the best way, they can be combined for optimal performance of the hybrid to meet up the targeted load. Hence, the total estimated electricity demanded and the available renewable resources are the major elements that determine the extent to which the hybridization process attains eventual satisfaction. The arrangements for carrying out the analysis are shown in Figure 1.

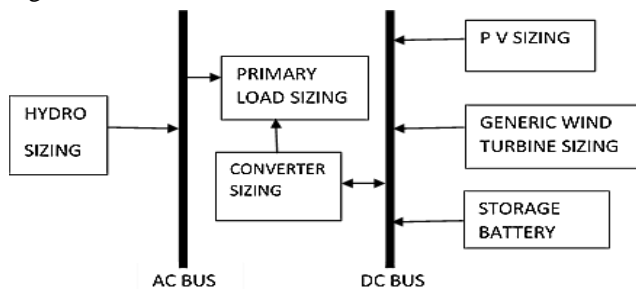


Figure 1: The Schematic Layout of the Hybrid Renewable Energy System.

A. Electrical Power Consumption Analysis (Primary Load)

Considered for this analysis, a survey was commissioned by Nigeria Energy Support Program (NESP, 2014) covering 51 rural residential households in Chanchaga, Minna Niger State in the year 2014. The aim of the survey was to assess energy efficiency and it suggested the ranges for the electrical power consumption by the household's circuitries (NESP, 2014).

The household electrical energy consuming gadgets include electronic appliances and electrical devices utilized inside the house. Considering domestic electrical load assessment on the assumed regular electrical energy consumed in lightning, powering and supplying other daily basic electricity consuming utilities are shown in Figure 2.

The total household loads are then classified into three:

1. The house lighting circuitry: which comprises of the lightning outlets, fans, toilet and kitchen fan extractor etc.
2. Powering circuitry: which entails the outlet sockets for ironing, electrical kettle and water heater, water pumping machine, mobile load and semi-mobile loads.
3. Ring main unit: comprises the high voltage loads that are connected directly to the distribution board which include the cooker control unit.

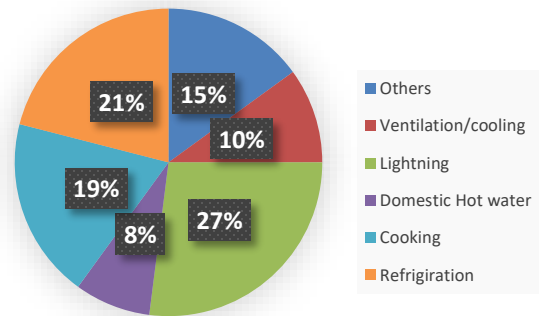


Figure 2: Breakdown of household energy usage of building energy efficiency guideline (NESP, 2014).

B. Hourly Electricity Consumption

The appraised hourly wattage consumption by of one of the households is as illustrated in Figure 3. Interpreting the result means that there is higher electricity consumption from 6 am till around 1 pm when most house are unoccupied because of occupants are mostly at work except on weekends and 8 pm to 10 pm during night consumption before sleeping and the remaining period with low electrical power expended at off peak consumption. The AC peak load was estimated to be 21.70 kW. The yearly electricity consumption of 51 households as projected by the survey is 126,000 kWh/year with an average of 345 kWh consumed on daily basics (NESP, 2014).

C. Solar and Wind Resources

The northern part of Nigeria is characterized to have hot humid atmospheric weather. Minna located in Niger State on a latitude of (09.65°N) and longitude of (06.47°E) was considered in this study. The data for solar and wind resource for the location under consideration was obtained from Nigerian Metrological Agency (NIMET, 2016) and validated on the National Aeronautics and Space Administration website (NASA, 2016), the details are as shown in Table 1. The data in Table 1 shows the atmospheric data of solar radiation of Minna, Niger State obtained from the NASA metrological statistics. The NIMET and NASA meteorological statistics were utilized in attaining a necessary record of the location's atmospheric conditions which includes, the measure of the hourly speed and direction of the moving air (wind), global horizontal solar irradiance, the average moisture content (humidity) and the temperature of the atmosphere (NASA, 2016).

D. Hydro Resource

River Chanchaga considered in this study is located in the southern part of Niger State. It is flanked within latitudes 6°31N to 6°36N as well as longitudes of 9°31E to 9°36E as presented in Figure 4. The river is considered to have a good flow of water during the raining season but the low flow of water during the second half of the season (i.e., dry season). Consequently, integrating or erecting of a micro-hydropower plant would have limitations because of the inconsistent feature (i.e. availability of running water) common with rivers in the northern part of Nigeria (NGSA, 2014).

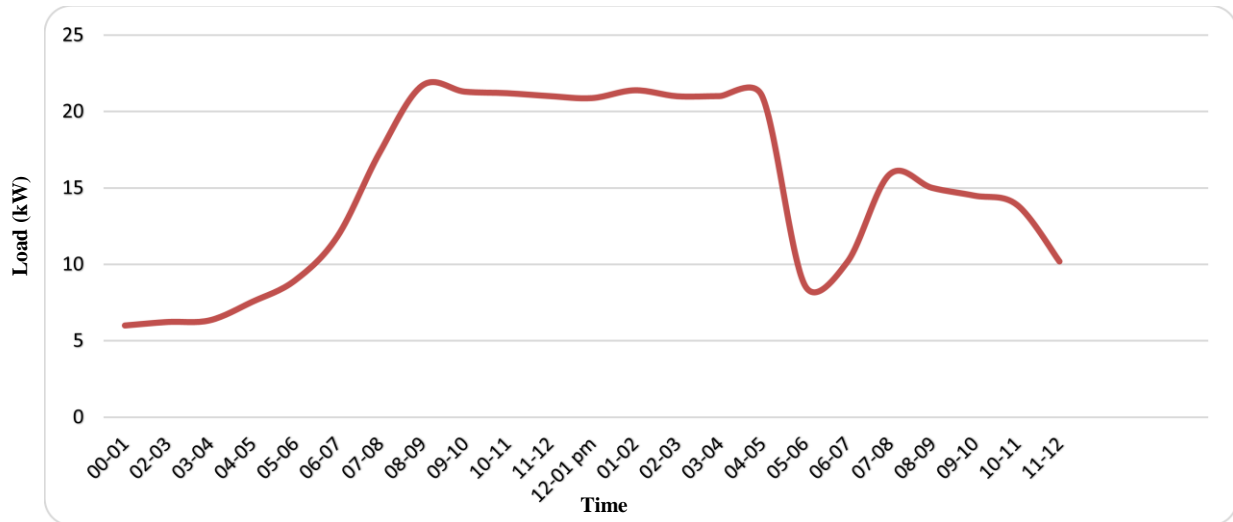


Figure 3: Daily and hourly Load Profile of Building Energy Efficiency in Building (NESP, 2014).

Table 1 Atmospheric data of solar radiation for Minna on and longitude 06.47E (NASA, 2016).

MONTH	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE
SOLAR RADIATION (kWh/m ² /d)	3.72	6.01	6.26	6.12	6.73	5.17
MONTH	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
SOLAR RADIATION (kWh/m ² /d)	4.64	4.36	4.82	5.42	5.49	5.73

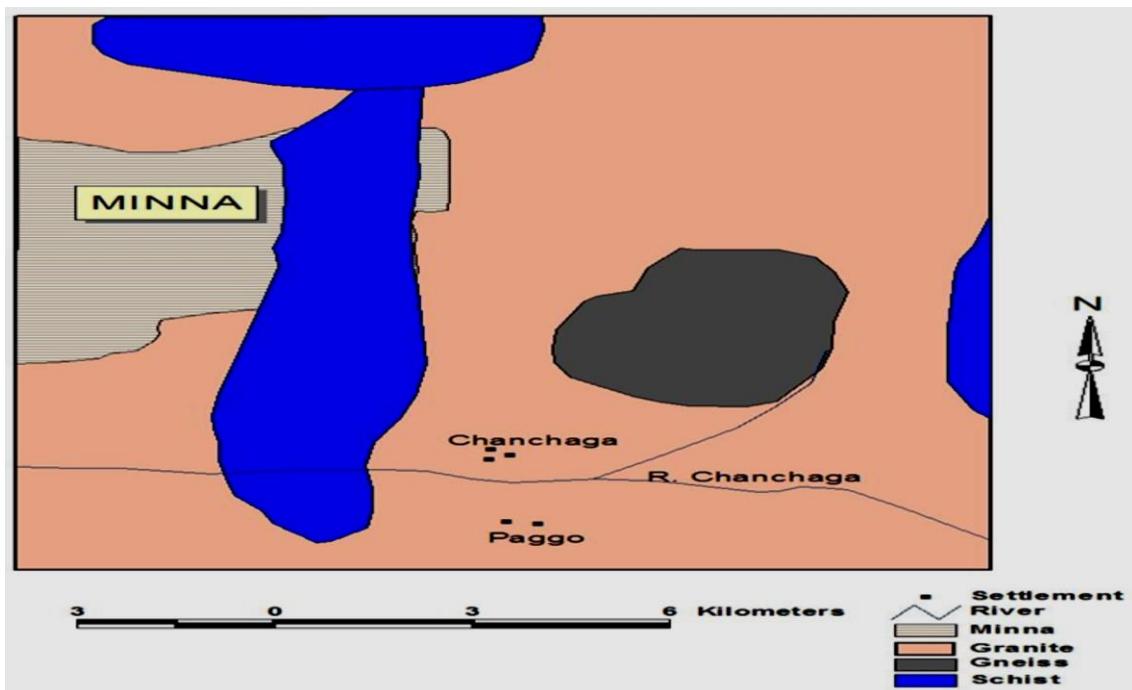


Figure 4: Geological map of part of Minna showing river Chanchaga (NGSA, 2014).

Mode of operation of all hydroelectric power plants typically remains the transformation of waterfalls kinetic energy to electrical energy. Hydro turbines are usually submerged in the river for generation to take effect. Turbines usually have the capability of generating 2-15 kWh/day of electricity starting from a water height as low as 1 meter, which subsequently meets daily residential usage (Amadi and Yisa, 2012). The monthly average flow rate of the river was obtained from Nigerian Geological Survey website (NGSA, 2016).

E. Renewable Energy Sizing using Available Resources

1.) Micro hydropower system sizing

The foremost essential component needed to install a micro hydropower plant is the turbine. Pelton hydroelectric turbine is commonly used when the generation is not enormous (NGSA, 2014). The height of the considered river Chanchaga is 7 meters and its volumetric flow rate is averaged to be $0.1884 \text{ m}^3/\text{s}$ or 188.375 L/s (NGSA, 2014). Calculating for the hydraulic power and the electrical power obtainable using the average flow rate and head of river Chanchaga is as estimated in Eq. (1):

$$P' = Q \times g \times h \times \rho \quad (1)$$

Where P' the hydraulic power in watts, g is the gravity in meters per square second square, ρ is the specific density of water in gram per cubic centimeter, Q is the water flow rate in cubic meters per second and h is the head of the river in meters.

$$P = P' \times \varepsilon_{\text{turbine}} \quad (2)$$

P is the electrical power that can be generated and $\varepsilon_{\text{turbine}}$ is the turbine efficiency.

With the water height at 7 meters, Q is $0.1884 \text{ m}^3/\text{s}$, g is 9.8 m/s^2 and density ρ is the 1000 kg/m^3 , $P' = (0.1884 \times 9.81 \times 7 \times 1000) = 12937.428 \text{ W}$ which is equivalent to 13 kW .

To calculate for the electrical power noting that theoretical Betz conversion efficiency limit of 59.3% that applies to obtainable power from a wind turbine does not apply to hydraulic turbines because of many variations in the designs and also considering the water flow rate, so the efficiency may exceed Betz limit (International Electrotechnical Commission, 2005).

The Considered Pelton turbine in this study is categorized under impulse turbine. It has small power turbine that can generate up to 20 MW power output with the efficiency of the turbine going up to 95% in some cases (International Electrotechnical Commission, 2005).

$P = 12937 \times 0.90 = 11643.3 \text{ W}$, the electrical Power P obtainable equals 11.6 kW approximately. An inductor generator is considered due to its flexible rotor speed as to when compared with the constant speed characteristic of the synchronous generator.

2.) Photovoltaic system sizing

Generating electricity from the solar source greatly rely on how enormous the sun is radiating, the daily solar sunshine

hours and the type of panels considered. Minna is blessed with adequate and sufficient solar resource i.e. with solar intensity going up to $6.26 \text{ kWh/m}^2/\text{d}$ in the month of March, therefore incorporation of the energy resource to generate electrical power was considered in this study.

Erection of a photovoltaic system would require a photovoltaic module, charging controller that prevents overcharging or draining of the battery, an inverter to convert the DC generated power to AC and a storage system i.e., battery that stores the direct current absorbed by the panel from solar irradiating on it. The schematic diagram of the connection is as shown in Figure 5.

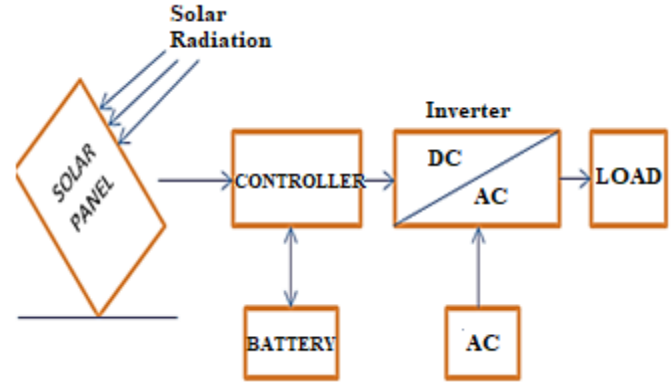


Figure 5: Photovoltaic system block diagram.

The load demand helps in estimating the capacity of the controller. Photovoltaic system design is always carried out in a way to meet the load demand for example in this study the daily load demand is 345 kWh/day . Considering the available solar resource, the worst case for solar radiation is in August with about $4.29 \text{ kWh/square meter/ day}$.

Estimating for the size of the photovoltaic panel that will be required to harvest the solar resource in Minna Niger State and also the storage system required to accumulate the generated electrical power is as expressed in Eq. (3).

$$E_{dc} = \frac{E_{ac}}{\sigma_{\text{inverter}}} \quad (3)$$

Where E_{dc} denotes the DC battery energy, E_{ac} represent the AC energy and σ_{inverter} is the efficiency of the inverter. According to a study carried out by Chul-Young Park et al at Korea Institute of Energy technology, the efficiency of the inverter ranges from 90 to 95 % with 0.9 assumed, system efficient solar radiation of 0.18, the area of a photovoltaic (PV) module is 0.6 m^2 , module voltage (Vm) of 18 V , array current is 4 A . A nominal system (Vn) voltage is taken as 220 V based on the standard voltage used in Nigeria.

$E_{dc} = \frac{345}{0.9} = 383.33 \text{ kWh}$, The area (A) of the panel is also expressed in Eq. (4).

$$A = \frac{E_{dc}}{\sigma_{\text{system}} \times R} \quad (4)$$

where R is the kWh solar radiation in kWh/day

$$A = \frac{383.33}{(4.29 \times 0.18)} = 496.413 \text{ m}^2$$

$$\text{total number of cells } (tc) = \frac{A}{A_{pv}}, \quad (5)$$

where A_{pv} denotes the area of the area of PV module.

$$tc = \frac{496.413}{0.6} = 827.35 \text{ approximately } 828 \text{ cells.}$$

$$\text{total series modules } (sm) = \frac{v_n}{v_m} \quad (6)$$

$$sm = \frac{220}{18} = 12.22 \text{ approximately } 12 \text{ modules}$$

$$\text{total parallel modules } (pm) = \frac{tc}{sm} \quad (7)$$

$$pm = \frac{828}{12} = 69 \text{ modules}$$

Array current = total number of parallel module \times module current (8)

$$\text{Array current} = 69 \times 4 = 276A$$

Calculating for the size of the battery to consider, with the loss of the storage system presumed to be 20%, peak radiating hours of the sun assumed to be 3.5 hours which take place when the sun rays incline or strike the panel at the right angle, so it depends on the inclination angle of the sun rays on the panel. The maximum discharge depth (D_d) is assumed to be 60% while the nominal voltage of the battery cell (V_c) is 12V with a system loss (S_L) of 0.2.

$$\text{storage days} = 9.43 - (1.9 \times \text{peak hours of sun}) + (0.11 \times \text{peak hours of sun}) \quad (9)$$

$$\text{storage days} = 9.43 - (1.9 \times 3.5) + (0.11 \times 3.5) = 3.165 \approx 3 \text{ days}$$

$$\text{total Ah per day} = \left(\frac{E_{dc}}{v_n} \right) \times SL \quad (10)$$

$$\text{total Ah per day } (Ah) = \left(\frac{383.33 \times 10^3}{220} \right) \times 0.2 = 348.5Ah$$

$$\text{battery capacity } (Ah) = \frac{Ah}{D_d} \quad (11)$$

$$\text{battery capacity } (Ah) = \frac{348.5 \times 3}{0.6} = 1742.5Ah$$

Considering tolerance and other minor factors 2000Ah battery would be suggested.

$$\text{number of cells in series} = \frac{v_n}{v_c} \quad (12)$$

$$\begin{aligned} \text{Calculating for number of batteries in series} \\ = \frac{220}{12} = 18.3 = 19 \end{aligned}$$

\therefore 19 batteries would be suggested for the design in this study.

3.) Wind power system sizing

The wind turbine transforms energy possessed by the wind in motion (i.e. kinetic energy) to mechanical energy, thereafter it is converted to electrical energy by the generator. Weibull function is used to examine the expected power output that can be generated from the wind distribution in Minna. Under constant acceleration, the kinetic energy possessed by an

object with mass (m) and velocity (v) is the work done (w) by the object when it moves from its rest point to other distance (s) with the influence of an applied force (F). Therefore, the work done in displacing the rotor blade from rest is expressed in Eq. (13).

$$E = W = F \times s = m \times a \times s \quad (13)$$

From newton third equation of motion, $v^2 = u^2 + 2as$ (14)

Since the initial velocity of the rotor is zero, $u = 0$

$$a = \frac{v^2}{2s} \quad (15)$$

Substitute equation (15) in equation (13):

$$E = \frac{1}{2}mv^2 \quad (16)$$

Eq. (17) is the kinetic energy of the turbine rotor when it is in motion.

Calculating for the power in the wind which is the rate of change of energy with time:

$$P = \frac{dE}{dt} = \frac{1}{2}v^2 \frac{dm}{dt} \quad (17)$$

The rate of change of mass flow rate, $\frac{dm}{dt}$

$$\begin{aligned} &= \rho \times A \times V \\ P &= \frac{1}{2}v^2 \frac{dm}{dt} = \frac{1}{2} \times \rho \times A \times v^3 \quad (18) \end{aligned}$$

where $\frac{dm}{dt}$ is the mass flow rate and $\frac{dx}{dt}$ = velocity (v), which is the rate of change of distance

Betz Limit or Betz' law (1919), proposed that in an ideal world, no wind turbine can convert more than 59.3% of the kinetic energy of the wind (kinetic) into mechanical energy that rotates the rotor (US Department of Energy, 2016). Supposedly, the maximum obtainable efficiency from all wind turbine system design is 0.59 which means 59% of the energy possessed by the wind is attainable by the wind turbine. The efficiency is termed Power Coefficient i.e. $C_{pmax} = 0.593$. Therefore, the available power ($P_{available}$) is expressed in equation (19),

$$P_{available} = \frac{1}{2} \times \rho \times A \times v^3 \times C_{pmax} \quad (19)$$

The standard radius of a wind turbine for harvesting small average wind speed is supposed to be around 50m according to a report by royal academy of engineering on wind power calculation (US Department of Energy, 2016). The power coefficient is considered to be 0.50 assuming only 50% of the kinetic energy of the winds is attainable by the turbine, the average speed of the wind in the considered location is 2.14 m/s and lastly, the standard density of air is 1.292 kg/m³. Calculating for the swept area of the turbine from the length of the blades by making use of the equation of the area of a circle is as expressed in equation (20).

$$A = \pi r^2 \quad (20)$$

$$A = 3.142 \times 50 \times 50 = 7855 \text{ m}^2$$

$$\begin{aligned} \text{Power Available} &= 0.5 \times 1.292 \times 7855 \times 2.14^3 \times 0.50 \\ &= 24934 \text{ Watts} \approx 25 \text{ kW} \end{aligned}$$

Therefore, a 25-kW wind turbine system is to be considered for installation together with the other sized systems in the

design.

F. Electrical Load Data Inputs

The input windows of HOMER have been designed to reduce the effort needed to enter data that describes loads, component performances and resources. Figure 6 depicts the designation of the hourly/daily, monthly and yearly reference point of the domestic load profile. Homer is a proficient software for combining and synthesizing the 8760 hourly values of the electrical load for a whole year, using this hourly load profile and accumulating random variability factors, (Islam et al, 2012). From Figure 6, for each hour, HOMER compares the electrical and thermal load in an hour, to the energy that the system can supply in that hour. From Figure 6, for each hour, HOMER compares the electrical and thermal load in an hour, to the energy that the system can supply in that hour. The load values in Figure 6 are for January with extrapolation carried out for the remaining 11 months by HOMER. It shows a daily peak kilowatts consumption of 21.7

kW, an average kilowatt per day of 345 kW/d and a seasonal profile chart was plotted for the monthly average electrical load.

HOMER helps in generating the remaining default values using the daily input load per hour enabling the analysis to start quickly. With all the design parameters fed to HOMER, the simulation can now be carried out to know how optimal the power generated is to the yearly electricity demand by the households. HOMER simulates set of possible combinations of these variable. Table 2 shows the ratings of the combined sources.

III. HOMER SIMULATION RESULTS AND SYSTEM COST ANALYSIS

With all the specifications for the components considered for the electrical power generating system inputted into HOMER, the hybrid schematic of the whole system is as shown in Figure 7. The power output of the PV panel and wind turbine is in DC, for that reason they are connected to the DC

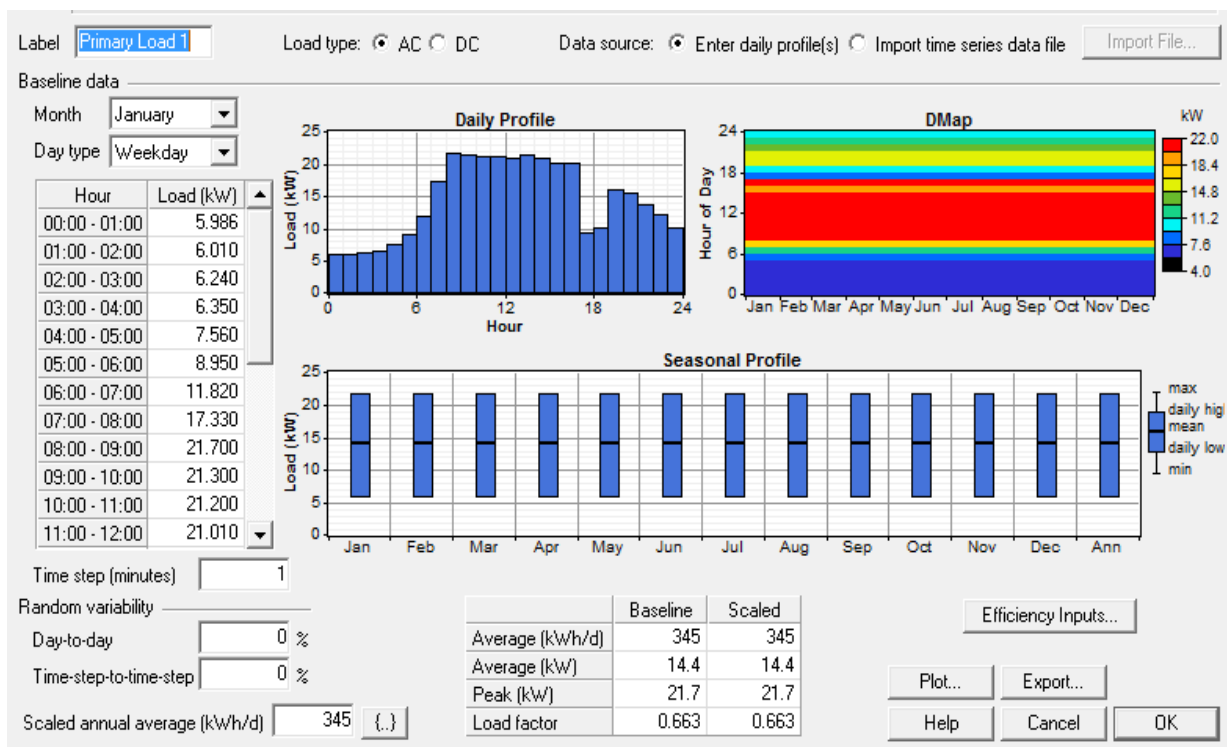


Figure 6: Hourly Electrical Load Demand Curve.

Table 2 Sizes of the complete hybrid scheme.

Converter capacity (kW)	Project Battery strings	PV Capacity (kW)	Generic Wind Turbine (kW)	Micro-Hydro (kW)
25	19	27	25	11.6

bus bar while the output of the micro-hydro generator is AC so it was connected to the AC bus bar as depicted in the schematic of Figure 7. The storage batteries help in storing electrical energy generated from the PV. The power converter helps in inverting DC output voltage in the DC bus bar to AC before it can be used on any electrical load, Figure 8 depicts the simulation result on HOMER.

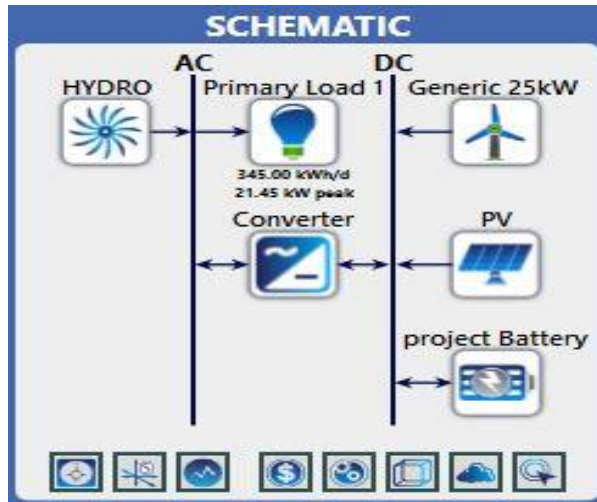


Figure 7. HOMER schematic diagram of the hybrid system

IV. RESULTS AND DISCUSSION

A. Economics and Life Cycle Cost of the System

From the simulation result in Figure 8, hybridization of the solar, wind and hydro generates a total of 149,319 kWh/yr. The hydro source generated the enormous percentage from the total electricity. The simulation also shows that the micro-hydro source generates a total of 92,614 kWh/yr (taking 62% of the entire power generated) throughout the year. The photovoltaic source seems to be evenly distributed with a total generation aggregates of 45,971 kWh/yr holding for the 31% ratio of the total generation and lastly, the wind source could only generate a small quantity of 10,733 kWh/yr owning for its small ration of 7% out of the total electrical power generated throughout the year.

It can be concluded that the generated 149,319 kWh/yr from the hybridization of the renewable sources exceeds the estimated AC electrical power of 126,027 kWh/yr consumed by the households for a year duration.

B. Hybrid of Solar and Wind Sources

From the simulation result in Figure 8, the total power generated from the available wind resource in the considered province (Chanchaga in Niger State) is small (10,733 kWh/yr) but the solar generation (92,614 kWh/yr) is quite enough and steadily distributed throughout the year. In the quest to meet up with the total energy demand of 126,027 kWh/yr in the location, eight different 25 kW wind turbine would need to be

serially combined thereby enhancing the generation as estimated below:

The expected energy generation from the proposed installation of eight 25kW wind turbine is $= 8 \times 10,733 = 85,864$ kWh/yr.

The solar source could generate 45,971 kWh/yr. Therefore, the combination of the two sources yields $= 45,971 + 85,864 = 131,835$ kWh/yr.

A total of 131,835 kWh/yr generated is optimal enough to efficiently meet up with the 126,027 kWh/yr estimated energy demand.

C. Hybrid of Micro-Hydro and Wind Sources

Considering the micro-hydro and wind sources alone for the electricity supply would also demand the use of a greater number of wind turbines as estimated below:

From Figure 8, the micro-hydro source of electricity generation output was 92,614 kWh/yr. Four wind turbines will have to be connected serially to increase the power out of the wind source from 10,733 kWh/yr to 42,932 kWh/yr. Therefore, the hybrid of the two source yields $= 92,614 + 42,932 = 135,546$ kWh/yr.

The calculated 135,546 kWh/yr is the expected power output from the hybridization of the two resources to be able to optimally sustain the estimated 126,027 kWh/yr electricity needed yearly by the estimated electrical load.

D. Hybrid of Micro-Hydro and Solar Sources

Emphasis was paid to the hybridization of the micro-hydro and solar source because of their high individual electricity production ratio as shown in Figure 8 and Figure 9. It makes them a better alternative to wind source in the considered location. The simulation was carried out with HOMER for the combination and the result is as shown in Figure 9.

From the simulation result above, a total of 138,585 kWh/yr was generated from their hybridization which is still more than the required 126,027 kWh/yr by the load in a year without the need of enhancing or adjusting the sources. A verdict can also be drawn that with the energy sources complimenting for one another adequate electrical power can be generated to meet up with the total energy demanded in the province.

E. System Energy Cost Analysis

1) Micro hydro system

Hydro system installations cost is usually site-specific i.e., to make a proper estimation of the total cost that would be needed for the installation of any hydro system requires a physical examination of the site and the available hydro resource. Consequently, the construction cost usually varies widely, depending on the type and size of the system, access to the site and manual labor cost (NEADB, 2014). Given the

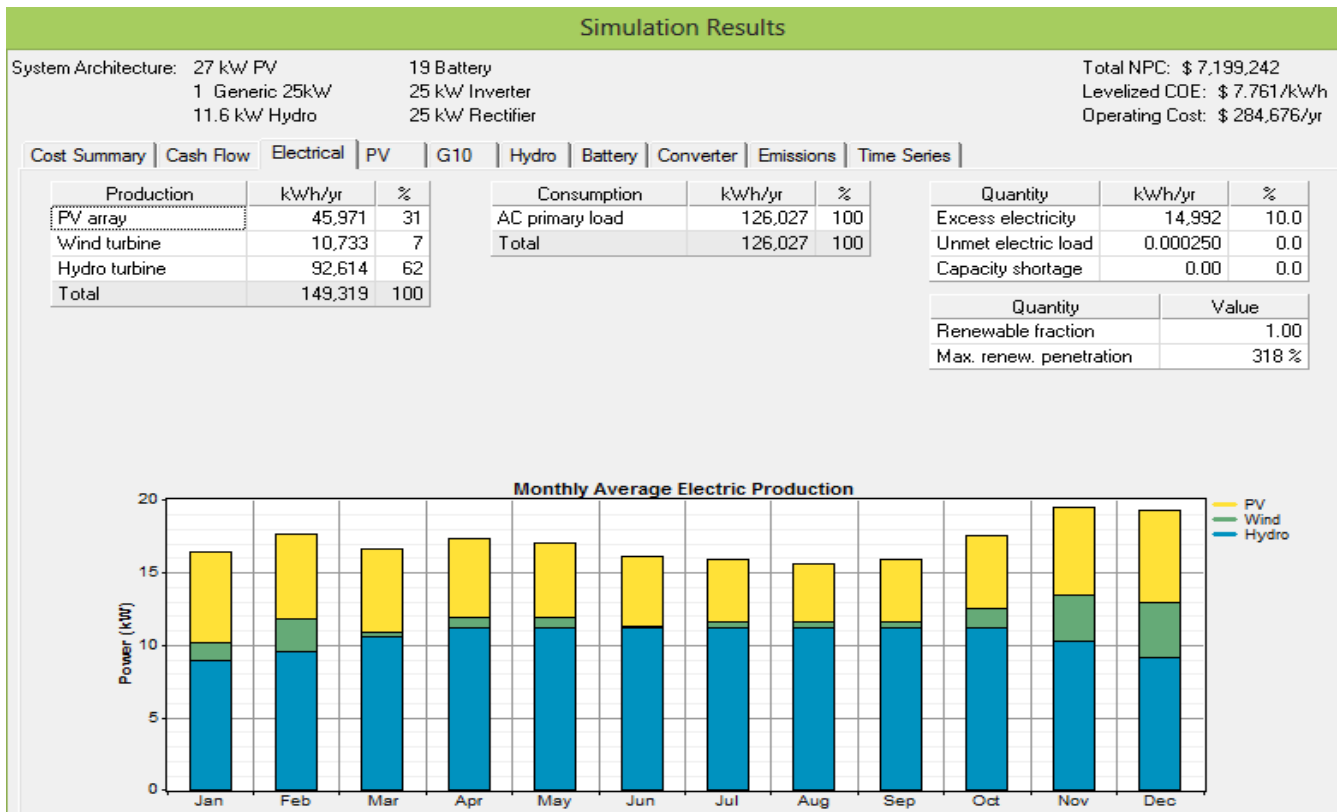


Figure 8: Simulation result showing monthly electricity generated from the hybridization of resources.

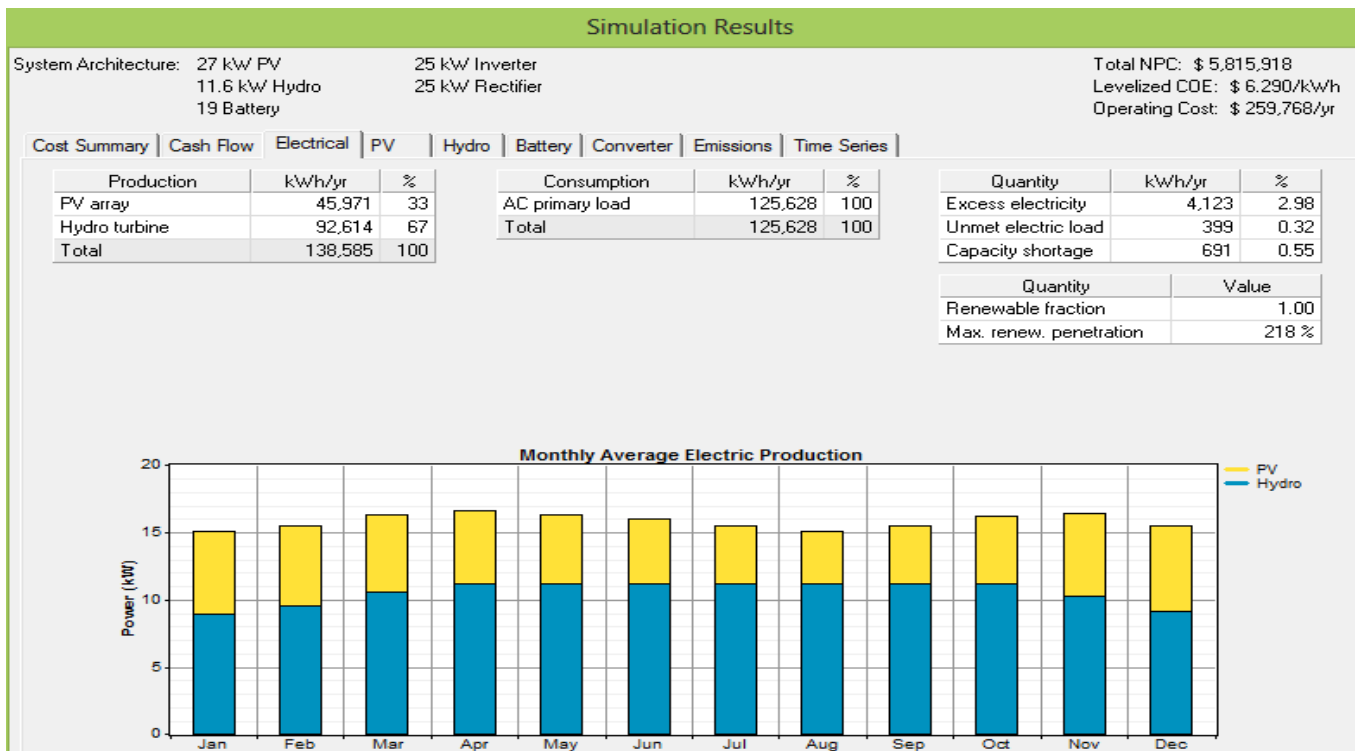


Figure 9: Hybridization of micro-hydro and solar sources.

sized micro-hydro system in this study, an **11.7 kW** micro hydro was projected to be constructed which cost about **12,000 pounds** to install the micro-hydro system in the considered location using the suggested price range. The amount is still reasonable considering the **92,614 kWh** of energy expected to be generated per year by the PV system gotten from the simulation result.

2.) Wind turbine system

According to the America Wind Energy Association (AWEA, 2016), a wind turbine is categorized as small wind turbine if the rated power is under 100 kW. A small wind turbine is always more expensive than the big wind turbine if one compares their installation cost per rated watt. For onshore, wind turbine cost is usually within the range of 3 dollars per wattage of rated power while offshore cost around 9 dollars per rated wattage of power (AWEA, 2016). Considering the **25 kW** wind turbine estimated for in this study which cost around **38,000 pounds** if wattage is expected to go for 3 dollars. This amount does not justify for the minimal power output of **10,733 kWh/yr** resulting for the wind turbine in the considered location gotten from the HOMER simulation carried out. This is because the wind resource is not as enormous as other considered renewable sources for the hybrid design.

3.) Photovoltaic System

Among roughly 38,000 residential and commercial PV systems installed in 2011, the median installation price was 6 dollars per wattage for systems of 10kW or less, 5.63 dollars per wattage for systems of 10-100kW and 4.87 per wattage for systems larger than 100 kW (US Department of Energy, 2012). In view of the **27 kW** photovoltaic system sized in this study, it should cost about **115,000 pounds** using the price range suggested by the department of energy. The price is averagely okay for the good ration of **45,971 kWh/yr** generated by the PV system in the considered location. Worth noting is that the installation cost of a PV system might be higher but it has the least running and maintenance cost.

Price justification on solar PV system can also be drawn looking at a report published by Anergy Solar Limited on a 24kW micro-grid solar project commissioned recently by Bank of Industry (BOI, 2016) in a rural province in Gombe State located in the northern part of Nigeria. The project installation cost was 44 million naira (95,000 pounds) and is expected to provide electricity to about 100 households in the rustic agrarian village (BOI, 2016). The report stresses the fact that an average 5kVA generator consumes 1 litre of fuel per hour at an effective cost of 100 naira (0.2 pounds) per hour. That results to 2,400 naira (6 pounds) per day to run the generator, and presumably 876,000 naira (1,950 pounds) per

annum excluding the cost of maintenance and depreciation on the generator. In 25 years, that amounts to 21.9 million naira (48,666 pounds) which is about 11 times the cost of the most expensive photovoltaic system (BOI, 2016).

The installed photovoltaic system usually has a long-life span with some in usage for about 30 years, with only the storage system having to be changed or upgraded (Tijjani et al, 2012). So, for the fact that solar resource is well distributed in Nigeria as compared to wind vindicates its higher installation price making its choice for electrical power generation is more appealing and better appreciated.

V. CONCLUSION

The main goal of the study is to optimally generate sustainable electricity to supply the electrical load has been achieved because the generated electricity of 149,319 kWh/yr from the hybridization of the resources was more than the required electricity by the estimated load. The micro-hydro and solar combined generation proportion of 138,585 kWh/yr. was more than the required 126,027 kWh/yr. by the estimated electrical load to be serviced. From the cost analysis it was observed that, the installation cost of the hydro and solar system was averagely better than that of wind turbine system if related to its least generation ratio of 10,733 kWh/yr.

However, more knowledge and understanding on alternative energy sources and their hybridization has been acquired i.e., it is made obvious from this study that Nigeria is abundantly blessed with renewable energy resources giving her high potentiality if they are appropriately harnessed to tackle the current lingering energy supply crises. Renewable energy exploration remains the feasible alternative to enhance the steady supply of electricity to a large percentage of her population presently denied of energy access especially people residing in the remote rural communities.

REFERENCES

- AbdullRazak, N.; M. bin Othman and I. Musirin. (2010).** Optimal sizing and operational strategy of hybrid renewable energy system using homer. IEEE Conference Publications, 11490145(978-1-4244-7127-0): 495 - 501.
- Amadi, K. and Yisa, D. (2012).** Renewable Energy Technologies: Cost Analysis Series. International Renewable Energy Agency, 1, (3-5).
- America Wind Energy Association (AWEA), (2016).** In: AWEA Clean Power Conference and Exhibition, Indianapolis, 56.
- Ani Vincent, A. (2013).** Simulation and Optimization of Hybrid Diesel Power Generation System for GSM Base Bulletin: Federal Government of Nigeria. Station Site in Nigeria. Electron. J. Energy Environ, 129-131.
- Bank of Industry (BOI), (2016).** From Millennium Development Goals to Sustainable Development Goals. The Bank of Industry), 4-5.
- Bhattacharyya, S. (2012).** Review of alternative methodologies for analyzing off-grid electricity supply. Renewable and Sustainable Energy Reviews, 16(1), 677-694.

Federal Ministry of Power Works and Housing (FMPWH), (2016). Energy Efficiency In buildings (EEB) in a selected Sub Sectors of the Nigeria Building Sector: Development of recommendations for intervention to promote energy efficiency. Abuja: Federal Government of Nigeria, 1-14.

HOMER, (2015). Renewable Energy. Intelligent Systems and Control (ISCO), 2015 IEEE 9th International Conference on, (15506348), 1-6.

International Electrotechnical Commission, (2005). In: Electropedia (Energy Technologies), 1st ed. United Kingdom: Wood Bank Communication, 313-329.

Islam, A. S.; M. Rahman; M. Mondal and F. Alam. (2012). Hybrid energy system for St. Martin Island, Bangladesh: An optimized model. Procedia Engineering, 49, 179-188.

Kusakana, K.; J. L. Munda and A. A. Jimoh. (2009). Feasibility study of a hybrid PV-Micro Hydro system for rural electrification. IEEE AFRICON, 978-1-4244-3919-5/09, 1-5.

Nigeria Center for Energy Efficiency and Conservation (NCEC), (2016). National Energy Action Plan. Lagos: Federal Government of Nigeria, 11-14.

Nuclear Energy Agency Data Bank (NEADB), (2014). National Energy Masterplan. Abuja: Federal Government of Nigeria, 109-121.

Nigeria Energy Support Program (NESP), (2014). Building Energy Efficiency Guidelines for Nigeria (BEEGN). Abuja: Federal Government of Nigeria, 2(3), 1-9.

Nigeria Geological Survey Agency (NGSA), (2014). How is 100% renewable energy possible for Nigeria? Global Energy Network Institute (GENI), (619) 595-0139.

Nigeria Metrological Survey Agency (NIMET), (2016). Nigeria Climate Review, 8.

Sachs, J., (2012). From Millennium Development Goals to Sustainable Development Goals. The Lancet, 379(9832), 2206-2211.

The National Aeronautics and Space Administration (NASA), (2016). Centre for Aerospace Information Masterplan, 54, 1-10.

The National Renewable Energy Laboratory (NREL), (2010). The Potential for Wind, Hydro and Solar Energy in Nigeria, 34(3), 3.

Tijjani, A.; K. M. Usman; and R. Kela. (2012). Potentials of Small Hydro Power in Nigeria: The Current Status and Investment Opportunities. International Journal of Scientific & Engineering Research, Volume 3(ISSN 2229-5518), 87-104.

United Nation (UN), (2012). ‘The International Year of Sustainable Energy for All’ United Nation 2012 General Assembly, 12(2), 3493-3498.