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Feasibility Study and Cost Analysis of Hybrid Wind-Solar Photovoltaic for Off Grid Area of Ajaokuta

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ABSTRACT: *This paper presents detailed feasibility study and cost analysis for implementing grid-connected Hybrid Wind-Solar PV on Ajaokuta distribution network. Raw data were gathered for wind speed of Ajaokuta L.G.A at 25 m height above sea level using anemometer, while pyranometer was employed to gather sun insolation data of the area at 25m height by Direct Measurement Insolation (DMI). The data were gathered for 60 days, also, extrapolated in MATLAB for five years for proper forecasting. The results modeled in HOMER simulation tools showed that a total of 85 kW and 138 kW can be harnessed through Wind Turbine and Solar PV respectively from the study area. The Hybrid Wind-Solar PV of 223 kW can be integrated into Ajaokuta distribution network to compensate for power instability in Ajaokuta distribution system. The net present cost of the system from HOMER is $27,409,335.74 with an annual operating cost of $625,788.82, the proposed system has the lowest Cost of Energy (COE) with a value of $0.3142 /kWh.*

Index Terms: *Renewable sources, Distributed Generation (DG), synchronization and grid-connected Hybrid Wind-Solar PV.*

I. Introduction

Energy is a foundation stone of the modern industrial economy. Energy provides an essential ingredient for almost all human activities. Modern energy services are a powerful engine of economic and social development. No country has managed to develop much beyond a subsistence economy without ensuring at least minimum access to energy services for a broad section of its population. Throughout the world, the energy resources available and their ability to pay largely determine the way in which people live their lives [1]. Data obtained from the Energy Commission of Nigeria (ECN) showed that the current power generation in Nigeria is far less than the national requirement [2]. The Presidential Task Force on power regularly publishes the electricity estimated peak demand and peak generation. The generation sub-sector presently includes 23 grid-connected generating plants in operation with a total installed capacity of 10,396 MW (available capacity of 6,056 MW) with thermal based generation having an installed capacity of 8,457.6MW (available capacity of 4,996 MW) and hydropower having 1,938.4 MW of total installed capacity with an available capacity of 1,060 MW [3]. This comprises of the privatized GenCos, Independent Power Producers (IPPs) and the generating stations under the National Integrated Power Project (NIPP). The peak energy demand of Nigeria is 23,800 MW [3]. This is close to four times higher than the peak power generation. There is growing concern that energy generation through fossil fuel are hazardous to both the environment and humans as such there is need to use renewable energy sources such as Wind Turbine, Small Hydro Plant and Solar Photovoltaic, which are eco-friendly to complement some of these increasing energy demands [4].

The use of Renewable Energy Sources (RES) will help to reduce dependence on fossil fuels and decrease internationally escalating energy prices [5]. The advantages of these renewable can be more enhanced when

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two or more RE sources are connected together to form a hybrid system. When these RE are connected close to the consumer they are termed Distributed Generation (DG). The combination of two or more DGs is termed Hybrid Distributed Generation (HDG), so that intermittency of sources involved in the hybrid system can be partially or completely overcome, ensuring continuity and quality of the electricity produced by the system. They become more profitable, efficient, reliable and stable when they are grid connected. Sometimes, it can be a stand-alone power system for remote settlement not connected to the national grid. There is need to integrate DG/HDG to Nigeria national grid to meet the increasing power demand. The major benefits of HDG can be divided into two major categories: economic and operational [6], from an economic point of view; Distributed generation reduces operational costs when installed near the customer load because it avoids upgrading or setting up a new transmission and distribution network, thereby providing a cost saving electricity. From the operational point of view, HDG guaranties reliability and stability of power supply and reduces power losses; also, HDG provides power support when load increases during peak demand, thus reducing interruption that may lead to system outages [7].

This paper carries out feasibility study of Ajaokuta Local Government Area (LGA) in Nigeria to ascertain viability of Wind Power and Solar PV in the area. Also, design an appropriate grid connected Hybrid Wind-Solar PV within the LGA. Feasibility studies of many locations in Nigeria have been well researched. [8] assessed the potential and economic viability of standalone wind generation system for off-grid rural communities located in each of the studied sites (i.e. Abuja, Bida, Ilorin, Jos, Lokoja, Makurdi and Minna) The Hybrid Optimization Model for Electric Renewables (HOMER) software optimizing tool was utilized to determine the optimal combination of system components that would yield the lowest life cycle cost. Sequel to the analysis for rural community utilization, a DG analysis that considered the possibility of generating wind power in the MW range in order to take advantage of Nigeria's tariff regime for embedded generation was carried out for each site. [9] Presented methods for solving optimal distribution network reconfiguration and optimal placement of distributed generation (DG) with the objective of reducing power losses and improving voltage profile with the least amount of time using a combination of various techniques. Meta-Heuristic Algorithm (MHA) was used to solve the problem of optimal DG placement. A Binary Particle Swarm Optimization Algorithm (BPSO) was presented for solving the network reconfiguration. [10] Proposed a static output feedback compensator designed for the grid connected to island mode transition and a dynamic output feedback.

II. Description of the Study Area

The selected town is the Steel Township in Ajaokuta LGA of Kogi state. The town is located on Latitude 7.53940 N and Longitude 6.63240 E. As shown in Fig.1.0

Fig.1.0: Google Map Showing Ajaokuta in Kogi State (www.google.ng>maps).

The highest elevation in the study area is the Drum level of the Thermal Power Plant (TPP) of Ajaokuta Steel Company, which is at 25 m above Mean Sea Level (MSL). This point was selected because of its considerable height of twenty-five meters above sea level, where the wind speed will be comparatively high. Sun insolation of the location was also taken at 25 m height and time to know the point where optimal Solar PV can be generated.

III. Wind Turbine

Wind turbines generator transform wind energy into electricity. The wind is a highly variable source, which cannot be stored, thus, it must be handled according to this characteristic. A general design of a wind turbine is shown in Fig. 2.0, where its main components are presented, the principle of operation of a wind turbine is characterized by two conversion steps. First the rotor extracts the kinetic energy of the wind, changing it into mechanical torque in the shaft; and in the second step the generation system converts this torque into electricity [12]. The nacelle contains the main components of the Wind Turbine (WT) such as: the electricity generator, gearbox and the rotor. The generator transforms the rotational mechanical energy delivered by the gears, into electrical energy.

The power in the wind is extracted by allowing it to blow past moving wings or blades that exert a torque on a rotor shaft. The amount of power transferred is expressed as:

$$P = \frac{1}{2} C_p A \boldsymbol{\rho} v^3 \qquad (1)$$

Where: P is power in watts, C_p is coefficient of performance, A is swept area of blade(s), m^2, $\boldsymbol{\rho}$ is density of air (kg/m^3) and v is average wind velocity (m/s), the wind power available to a wind turbine varies as the cube of the wind speed [13]. When the wind speed is doubled the power is multiplied eight times (power equation). As wind speed increases linearly with height above sea level, it is also a fact that extractable power available in wind increases with height.

Wind speed is the most important parameter in the design and study of wind energy conversion devices [13]. Because so much power is generated by higher wind speed, much of the average power available to a wind mill comes in short bursts. The consequence is that wind energy does not have as consistent an output as fuel-fired power plant. This is why it is customary to hybrid wind power with other RES to ensure reliability.

IV. Solar PV System

The Solar PV module is a DC power source that uses semiconductor cells. It generates direct voltage and current from sunlight that falls on the cells. Through the photovoltaic effect the energy contained in the sun light are converted directly into electrical energy [15]. This method of energy conversion presents some advantages, such as simplicity, modular construction, and flexibility on utilization, high reliability and low maintenance. The Solar PV is made up of a modeled PV array, boost converter controlled by incremental MPPT algorithm. Then it is connected to the DC link. This DC link connected to the grid side inverter. Represent a silent, sure, no pollutant and renewable source of electric energy. In order to interface the array to the power systems, it has to be conditioned first and a DC/AC inverter has to be used [16].

The output terminal of the circuit is connected to the load. The output current source is the different between the photocurrent I_P and the normal diode current I_D. Ideally the relationship between the output voltage V_{PV} and the load current I_P of a PV cell or a module can be expressed as $I_{PV,}$ if we assume that the current I_{sh} in shunt resistor R_{sh} is neglected [7].

$$I_{PV} = I_P - I_D = I_P - I_o \left[\exp\left(\frac{V_{pv+}\, iR_{SS}}{mkT_C}\right) - 1\right. \qquad (2)$$

Where I_P is the photocurrent of the PV cell (in amperes), I_o is the saturation current, I_D is the load current (in amperes), V_{PV} is the PV output voltage (in volts), R_{SS} is the series resistance of the PV cell (in ohms) and m, K and T_C represent respectively the diode quality constant, Boltzmann's constant and temperature.

V. The Hybrid System

HDG systems offer better performance, flexibility of planning and environmental benefits compared to the diesel generator based stand-alone system. HDG also give the opportunity for expanding the generating capacity in order to cope with the increasing demand in the future. Remote areas provide a big challenge to electric power utilities. HDG provide an excellent solution to this problem as one can use the natural sources available in the area e.g. the wind and solar energy and thereby combine multiple sources of energy to generate electricity. This paper carries out feasibility study and analyses the viability of grid-connected Hybrid Wind-Solar PV in the area.

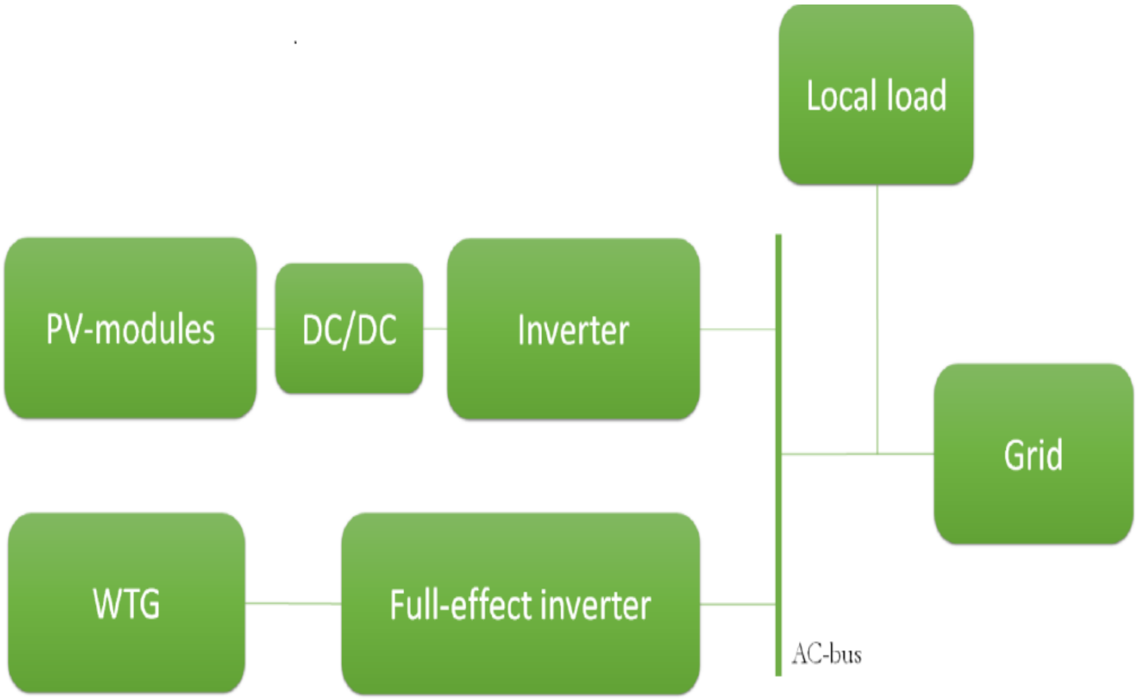

Fig: 5.0. Schematic of the Proposed System (Wind Turbine Generator and Solar PV)

VI. Data Acquisition

Data available at the electrical distribution unit of Steel Territory Administration (STA) showed that the study area an industrial town has 3675.36 MWh in March 2015 as the highest and 1193.91MWh in January 2018 as the least energy load demand. The monthly energy consumption of Ajaokuta electricity distribution network as gathered from Transmission Sub-Station (TSS) of Ajaokuta is shown in Table 1.0. Ambitions to alter the current electricity distribution and corresponding actions are backed socially. Because power supply in the study area is not efficient, occasioned by low voltage profile, poor conductor connection, which often results in frequent load shedding and power outages. Hence, additional power generator such as renewable energy systems is required to increase power generation, which will increase access to electricity supply, reduce the issue of load shedding and power fluctuations.

Table 1.0: Monthly Power Consumption of Ajaokuta Electrical Distribution Network between 2014-2018

MONTHS/YEARS	2014 (MWh)	2015 (MWh)	2016 (MWh)	2017 (MWh)	2018 (MWh)
January	3077.18	2746.85	2497.61	1924.73	1193.91
February	2604.67	2817.02	2147.86	1417.76	1308.12
March	3244.58	3675.36	2170.99	2081.52	1500.61
April	2843.28	1346.3	1604.88	2126.46	1441.96
May	2345.83	2333.18	2554.15	2200.72	1242.93
June	2063.52	1991.52	2031.84	2117.7	1315.83
July	1758.24	1967.88	2543.74	2147.81	1309.62
August	1943.28	1963.42	2098.08	1185.5	1472.46
September	1616.4	848.88	1583.28	1322.22	1258.34
October	2059.39	2025.17	2063.11	1365.76	1378.91
November	2041.92	2158.59	1939.68	1446.54	1436.18
December	2342.11	2573.5	1949.28	1359.35	1367.4

VII. (A) Wind Energy Resources

Wind speed data of the study area were downloaded for five years (2014 – 2018) from National Aeronautics and Space Administration (NASA) on 17th April, 2019. The summary of monthly average wind speed in meter per seconds at 20m and the corresponding clearness index data is shown in Table 2.0.

Table 2.0: Monthly Average Wind Speed Data at 20m Height and Insolation Clearness Index (from NASA) Downloaded 17th April 2019.

Years	2014		2015		2016		2017		2018	
Months	KT Clear	W20m (m/s)	KT Clear	W20m (m/s)	KT Clear	W20m (m/s)	KT Clear	W20m (m/s)	KT Clear	W20m (m/s)
January	0.55	2.655	0.55	2.954	0.51	2.976	0.6	3.074	0.52	2.631
February	0.54	2.903	0.52	2.901	0.48	2.494	0.46	3.089	0.55	2.234
March	0.51	2.511	0.49	3.075	0.4	3.072	0.48	2.956	0.46	2.939
April	0.49	3.015	0.47	3.080	0.39	2.891	0.53	2.826	0.48	3.003
May	0.51	2.568	0.52	3.044	0.52	2.788	0.52	3.052	0.42	2.721
June	0.5	2.755	0.48	3.024	0.4	3.021	0.41	3.007	0.45	2.903
July	0.47	3.031	0.46	2.898	0.38	3.056	0.39	2.866	0.38	2.992
August	0.42	3.001	0.41	2.706	0.34	2.982	0.38	2.725	0.34	2.927
September	0.41	2.284	0.42	2.493	0.45	2.912	0.4	2.338	0.38	3.042
October	0.54	1.916	0.46	2.141	0.44	2.824	0.5	2.461	0.51	3.001
November	0.58	2.095	0.61	2.076	0.63	3.089	0.6	2.741	0.55	2.971
December	0.61	2.341	0.59	3.293	0.62	3.023	0.53	2.987	0.53	2.783

Wind speed in meter per seconds (m/s) was collected from the study area by direct measurement for 60 days between 1st of March (59 + 1) and 29th of April (90 + 29) 2018, at 25m above sea level using anemometer and the daily average taken as shown in Table. 3.0. The wind speed data was used to estimate total extractable wind power for the study area.

Table 3.0: Wind Speed of the Study Area Collected Between 1st of March to 29th of April 2018 at 25m above Sea Level

Days	Day Wind Speed (m/s)	Night Wind Speed (m/s)	Daily Average Wind Speed (m/s)
ee59 + 1	2.50	2.90	2.70
59 + 2	2.60	3.10	2.85
59 + 3	3.00	2.80	2.90
59 + 4	2.90	2.90	2.90
59 + 5	2.40	2.80	2.60
59 + 6	2.60	2.50	2.55
59 + 7	2.50	3.70	3.10
59 + 8	2.90	3.20	3.05
59 + 9	2.40	3.30	2.85
59 + 10	2.20	2.80	2.50
59 + 11	2.40	2.90	2.65
59 + 12	3.20	3.80	3.50
59 + 13	2.50	2.70	2.60
59 + 14	2.60	3.20	2.90
59 + 15	2.70	2.90	2.80
59 + 16	2.80	2.40	2.60
59 + 17	2.50	3.50	3.00
59 + 18	2.60	2.80	2.70
59 + 19	2.60	3.00	2.80
59 + 20	2.90	2.90	2.90
59 + 21	2.50	2.70	2.60
59 + 22	2.40	2.90	2.65
59 + 23	3.20	3.90	3.55
59 + 24	2.60	3.30	2.95
59 + 25	3.10	2.80	2.95
59 + 26	2.80	2.80	2.80
59 + 27	3.00	3.00	3.00
59 + 28	2.90	3.70	3.30
59 + 29	2.70	2.40	2.55
59 + 30	2.30	2.80	2.55
59 + 31	3.10	3.00	3.05
90 + 1	2.80	2.60	2.70
90 + 2	2.60	2.40	2.50
90 + 3	2.90	2.70	2.80
90 + 4	2.50	2.60	2.55
90 + 5	2.80	2.80	2.80
90 + 6	2.70	3.00	2.85
90 + 7	2.50	2.70	2.60
90 + 8	2.40	2.80	2.60
90 + 9	2.80	2.70	2.75
90 + 10	2.40	2.50	2.45
90 + 11	2.60	2.70	2.65

90 + 12	2.70	2.70	2.70
90 + 13	2.60	2.80	2.70
90 + 14	2.80	2.70	2.75
90 + 15	2.70	2.60	2.65
90 + 16	2.60	2.80	2.70
90 + 17	2.40	2.60	2.50
90 + 18	2.70	2.70	2.70
90 + 19	2.60	2.50	2.55
90 + 20	2.30	2.50	2.40
90 + 21	2.40	2.40	2.40
90 + 22	2.60	2.50	2.55
90 + 23	2.70	2.60	2.65
90 + 24	2.80	2.90	2.85
90 + 25	2.90	2.90	2.90
90 + 26	2.80	3.00	2.90
90 + 27	2.90	3.00	2.95
90 + 28	2.60	2.80	2.70
90 + 29	2.80	2.80	2.80

Table3.0 shows that wind speed is mostly higher at night than the wind speed during the day. The average wind speed for each day is higher than 2.5 m/s minimum speed required to run a turbine. The data in Table 3.0 was extrapolated for five (5) years for proper forecasting. The extrapolation was carried out in MATLAB. Extrapolation was done using Neural Network equation. The resulting equation from regression line in neural network is $Y = (0.875)T + 0.17e^{-0.15}$, where T is the first extrapolated wind speed. This equation was applied to the initial average wind speed data in Table 3.0

Table 4.0: Wind Speed (m/s) Data for Year 2018

Days	Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
59 + 1	2.5	2.5807	2.6513	2.7131	2.7672	2.8145	2.8559	2.8921	2.9238	2.9515	2.9758	2.997
59 + 2	2.6	2.6682	2.7279	2.7801	2.8258	2.8658	2.9007	2.9313	2.9581	2.9816	3.0021	3.02
59+ 3	3	3.0182	3.0341	3.0481	3.0603	3.0709	3.0803	3.0884	3.0956	3.1018	3.1073	3.1121
59 + 4	2.9	2.9307	2.9576	2.9811	3.0016	3.0196	3.0354	3.0492	3.0612	3.0718	3.081	3.0891
59 + 5	2.4	2.4932	2.5748	2.6461	2.7085	2.7632	2.811	2.8528	2.8894	2.9214	2.9495	2.974
59 + 6	2.6	2.6682	2.7279	2.7801	2.8258	2.8658	2.9007	2.9313	2.9581	2.9816	3.0021	3.02
59 + 7	2.5	2.5807	2.6513	2.7131	2.7672	2.8145	2.8559	2.8921	2.9238	2.9515	2.9758	2.997
59 + 9	2.9	2.9307	2.9576	2.9811	3.0016	3.0196	3.0354	3.0492	3.0612	3.0718	3.081	3.0891
59 + 10	2.4	2.4932	2.5748	2.6461	2.7085	2.7632	2.811	2.8528	2.8894	2.9214	2.9495	2.974
59 + 11	2.2	2.3182	2.4216	2.5121	2.5913	2.6606	2.7212	2.7743	2.8207	2.8613	2.8968	2.9279
59 + 12	2.4	2.4932	2.5748	2.6461	2.7085	2.7632	2.811	2.8528	2.8894	2.9214	2.9495	2.974
59 + 13	3.2	3.1932	3.1873	3.182	3.1775	3.1735	3.17	3.167	3.1643	3.162	3.1599	3.1581
59 + 14	2.5	2.5807	2.6513	2.7131	2.7672	2.8145	2.8559	2.8921	2.9238	2.9515	2.9758	2.997
59 + 15	2.6	2.6682	2.7279	2.7801	2.8258	2.8658	2.9007	2.9313	2.9581	2.9816	3.0021	3.02
59 + 16	2.7	2.7557	2.8044	2.8471	2.8844	2.917	2.9456	2.9706	2.9925	3.0116	3.0284	3.043
59 + 17	2.8	2.8432	2.881	2.9141	2.943	2.9683	2.9905	3.0099	3.0268	3.0417	3.0547	3.066
59 + 18	2.5	2.5807	2.6513	2.7131	2.7672	2.8145	2.8559	2.8921	2.9238	2.9515	2.9758	2.997

59 + 19	2.6	2.6682	2.7279	2.7801	2.8258	2.8658	2.9007	2.9313	2.9581	2.9816	3.0021	3.02
59 + 20	2.6	2.6682	2.7279	2.7801	2.8258	2.8658	2.9007	2.9313	2.9581	2.9816	3.0021	3.02
59 + 21	2.9	2.9307	2.9576	2.9811	3.0016	3.0196	3.0354	3.0492	3.0612	3.0718	3.081	3.0891
59 + 22	2.5	2.5807	2.6513	2.7131	2.7672	2.8145	2.8559	2.8921	2.9238	2.9515	2.9758	2.997
59 + 23	2.4	2.4932	2.5748	2.6461	2.7085	2.7632	2.811	2.8528	2.8894	2.9214	2.9495	2.974
59 + 24	3.2	3.1932	3.1873	3.182	3.1775	3.1735	3.17	3.167	3.1643	3.162	3.1599	3.1581
59 + 25	2.6	2.6682	2.7279	2.7801	2.8258	2.8658	2.9007	2.9313	2.9581	2.9816	3.0021	3.02
59 + 26	3.1	3.1057	3.1107	3.1151	3.1189	3.1222	3.1251	3.1277	3.1299	3.1319	3.1336	3.1351
59 + 27	2.8	2.8432	2.881	2.9141	2.943	2.9683	2.9905	3.0099	3.0268	3.0417	3.0547	3.066
59 + 28	3	3.0182	3.0341	3.0481	3.0603	3.0709	3.0803	3.0884	3.0956	3.1018	3.1073	3.1121
59 + 29	2.9		2.9576	2.9811	3.0016	3.0196	3.0354	3.0492	3.0612	3.0718	3.081	3.0891
59+ 30	2.7		2.8044	2.8471	2.8844	2.917	2.9456	2.9706	2.9925	3.0116	3.0284	3.043
Average	2.6896	2.6896	2.7965	2.8401	2.8783	2.9117	2.9409	2.9665	2.9889	3.0085	3.0256	3.0406

The extrapolation results in appendix A of Table A1 were the input in HOMER software to determine the amount of wind energy extractable from the study area. The HOMER Software helped in the specification, design and simulation of hybrid system for electricity generation to fully meet and comply with quality, continuity and security of the energy demand.

VII. (B) Solar PV Resources

The solar PV resources assessment was based on sun irradiance data taken for the study area using pyranometer. The optimum solar irradiance of the study area was used to estimate total extractable solar power for the study area. It was analyzed for daily and monthly averages. Sun insolation of the study area and corresponding temperature were collected at 25m height above sea level by Direct Measurement Insolation (DMI) for 60 days between 1st of March (59 + 1) and 29th of April (90 + 29) 2018, using pyranometer. The data is shown in Table 5.0.

Table 5.0: Sun Insolation(W/m^2) of the Study Area (Ajaokuta) Collected between 1st of March to 29th of April 2018 for Sixty Days (Latitude: 7.5394^0 N, Longitude: 6.6424^0 E) and Corresponding Temperature in ^{0}C

Days/ Time	11.00 am W/m^2 (^{0}C)	12.00 noon W/m^2 (^{0}C)	01.00 pm W/m^2 (^{0}C)	02.00 pm W/m^2 (^{0}C)	03.00 pm W/m^2 (^{0}C)	04.00 pm W/m^2 (^{0}C)	Peak W/m^2 & ^{0}C
59 + 1	271 (23)	304 (23)	842 (26)	559 (26)	0	0	842 (26)
59 + 2	286 (24)	0	0	341 (24)	738 (26)	493 (25)	738 (26)
59 + 3	346 (25)	416 (26)	0	863 (27)	820 (27)	401 (26)	863 (27)
59 + 4	531 (25)	683 (26)	821 (27)	1267 (28)	631 (26)	483 (26)	1267 (28)
59 + 6	621 (24)	853 (27)	911 (27)	1095 (28)	842 (27)	520 (26)	1307 (29)
59 + 7	307 (24)	642 (26)	862 (27)	937 (27)	1054 (27)	736 (27)	1054 (27)
59 + 8	271 (24)	418 (25)	1036 (27)	1536 (29)	981 (27)	660 (26)	1536 (29)
59 + 9	467 (25)	521 (25)	1091 (27)	1341 (29)	997 (27)	396 (24)	1341 (29)
59+ 10	0	421 (26)	446 (26)	1007 (26)	0	0	1007 (26)

59+ 11	496 (25)	537 (25)	1352 (26)	1605 (30)	1044 (27)	708 (26)	1605 (30)
59+ 12	0	374 (22)	832 (25)	1165 (28)	732 (25)	329 (24)	1165 (28)
59+ 13	522 (24)	815 (27)	974 (27)	1270 (28)	1210 (27)	826 (27)	1270 (27)
59+ 14	267 (24)	522 (25)	874 (27)	520 (23)	0	0	874 (27)
59+ 15	577 (24)	1007 (28)	1203 (28)	1658 (28)	1149 (22)	870 (22)	1658 (28)
59+ 16	385 (24)	734 (26)	1073 (28)	1529 (29)	947 (27)	508 (26)	1529 (29)
59+ 17	422 (24)	631 (25)	928 (27)	0	537 (25)		
						802 (27)	928 (27)
59+ 18	296 (24)	531 (24)	467 (26)	935 (27)	1272 (28)	677 (27)	1272 (28)
59+ 19	321 (24)	729 (26)	820 (27)	1374 (28)	903 (27)	0	1374 (28)
59+20	0	477 (23)	355 (24)	561 (24)	271 (24)	208 (22)	561 (24)
59 +21	328 (23)	750 (26)	938 (27)	1472 (28)	1381 (28)	845 (27)	1472 (28)
59+ 22	428 (24)	938 (26)	1037 (27)	1182 (28)	1033 (28)	716 (28)	1182 (28)
59+ 23	305 (23)	628 (24)	910 (26)	1029 (26)	1104 (28)	821 (27)	1104 (28)
59+ 24	297 (23)	725 (25)	1037 (27)	1003 (27)	982 (27)	570 (26)	1037 (27)
59+ 25	317 (23)	592 (24)	821 (26)	1028 (27)	1291 (28)	743 (27)	1291 (28)
59+ 26	207 (22)	0	0	388 (22)	893 (26)	521 (24)	893 (26)
59+ 27	277 (22)	463 (23)	581 (24)	572 (24)	1248 (28)	801 (27)	1248 (28)
59+ 28	409 (23)	475 (23)	822 (25)	903 (26)	0	0	903 (26)
59+ 29	0	239 (22)	561 (23)	493 (22)	810 (24)	293 (23)	810 (24)
59+ 30	257 (22)	592 (23)	809 (24)	1320 (28)	1103 (28)	722 (26)	1320 (28)
59+ 31	307 (23)	601 (24)	912 (24)	1033 (28)	972 (28)	943 (28)	1033 (28)
90+ 1	286 (23)	473 (24)	1003 (27)	1307 (28)	1528 (29)	1294(28)	1528 (29)
90 + 2	0	377 (24)	729 (25)	234 (24)	733 (25)	701 (25)	733 (25)
90 + 3	376 (24)	683 (24)	805 (26)	1204 (28)	1023 (28)	925 (27)	1204 (28)
90 + 4	293 (23)	0	0	193 (22)	508 (24)	522 (24)	522 (24)

90 + 5	249 (23)	535 (24)	912 (27)	1104 (27)	1330 (28)	1326(28)	1330 (28)
90 + 6	302 (23)	631 (24)	1289 (28)	478 (26)	238 (24)	373 (24)	1289 (28)
90 + 7	0	0	293 (24)	578 (24)	729 (26)	846 (26)	846 (26)
90 + 8	375 (24)	563 (24)	820 (26)	910 (26)	582 (26)	300 (24)	820 (26)
90 + 9	277 (24)	799 (26)	813 (28)	1028 (28)	1438 (28)	1027(28)	1438 (28)
90+ 10	341 (24)	692 (25)	920 (26)	1028 (28)	917 (28)	713 (27)	1028 (28)
90+ 11	382 (25)	738 (26)	289 (24)	100 (24)	274 (24)	682 (26)	738 (26)
90+ 12	286 (24)	693 (25)	911 (26)	1371 (28)	1510 (28)	1287(28)	1510 (28)
90+ 13	304 (24)	388 (24)	713 (25)	1006 (26)	1392 (28)	1270(28)	1393 (28)
90+ 14	292 (24)	722 (26)	758 (26)	913 (27)	1035 (28)	1067(28)	1067 (28)
90 +15	274 (24)	382 (24)	265 (24)	173 (24)	0	0	0
90 +16	0	277 (23)	561 (24)	682 (25)	782 (27)	561 (25)	782 (27)
90+ 17	371 (24)	477 (24)	682 (25)	917 (26)	1008 (28)	1001(28)	1008 (28)
90+ 18	288 (24)	528 (25)	629 (25)	728 (26)	913 (27)	1219(28)	1219 (28)
90+ 19	298 (24)	528 (25)	417 (24)	710 (26)	1025 (28)	1004(28)	1025 (28)
90+ 20	302 (24)	477 (24)	610 (25)	1029 (28)	1302 (28)	1136(28)	1302 (28)
90+ 21	319 (24)	471 (24)	516 (25)	822 (27)	903 (27)	923 (28)	923 (28)
90+ 22	294 (24)	493 (24)	691 (26)	811 (27)	1102 (28)	1082(28)	1102 (28)
90+ 23	301 (24)	588 (25)	793 (26)	1039 (28)	926 (28)	933 (28)	1039 (28)
90+ 24	277 (24)	581 (25)	703 (26)	822 (27)	1002 (28)	993 (28)	1002 (28)
90+ 25	302 (24)	510 (24)	793 (26)	920 (27)	892 (27)	1034(28)	1034 (28)
90+ 26	295 (24)	379 (24)	619 (25)	688 (26)	714 (26)	471 (26)	714 (26)
90+ 27	326 (24)	599 (25)	833 (27)	893 (27)	1102 (28)	1009(28)	1102 (28)
90+ 28	298 (24)	611 (27)	892 (27)	920 (28)	1034 (28)	1104(28)	1104 (28)
90+ 29	305 (24)	582 (25)	811 (26)	947 (27)	1129 (28)	983 (28)	1129 (28)

The peak sun insolation in Table 5.0 was extrapolated for five years for proper forecasting of Solar PV available in the study area. MATLAB software was used to extrapolate resulting in regression line and equation Y = (0.99) T + (7.2) where T is the first sun insolation. This equation was applied to the initial peak sun insolation data in Table 5.0. The result for year 2018 is as shown in the appendix of Table 6.0.

Table 6.0: Sun Insolation Data for Year 2018

Days	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
59 + 1	842	840.78	839.57	838.38	837.19	836.02	834.86	833.71	832.57	831.45	830.33	829.23
59 + 2	738	737.82	737.64	737.47	737.29	737.12	736.95	736.78	736.61	736.44	736.28	736.12
59 + 3	862	860.58	859.17	857.78	856.4	855.04	853.69	852.35	851.03	849.72	848.42	847.14
59 + 4	1267	1261.53	1256.11	1250.75	1245.45	1240.19	1234.99	1229.84	1224.74	1219.69	1214.7	1209.75
59 + 5	1002	999.18	996.39	993.62	990.89	988.18	985.5	982.84	980.21	977.61	975.04	972.49
59 + 6	1307	1301.13	1295.32	1289.57	1283.87	1278.23	1272.65	1267.12	1261.65	1256.23	1250.87	1245.56
59 + 7	1054	1050.66	1047.35	1044.08	1040.84	1037.63	1034.45	1031.31	1028.2	1025.11	1022.06	1019.04
59 + 8	1536	1527.84	1519.76	1511.76	1503.85	1496.01	1488.25	1480.57	1472.96	1465.43	1457.98	1450.6
59 + 9	1341	1334.79	1328.64	1322.56	1316.53	1310.56	1304.66	1298.81	1293.02	1287.29	1281.62	1276.01
59 + 10	1007	1004.13	1001.29	998.48	995.69	992.93	990.2	987.5	984.83	982.18	979.56	976.96
59 + 11	1605	1596.15	1587.39	1578.71	1570.13	1561.63	1553.21	1544.88	1536.63	1528.46	1520.38	1512.37
59 + 12	1065	1061.55	1058.13	1054.75	1051.41	1048.09	1044.81	1041.56	1038.35	1035.16	1032.01	1028.89
59 + 13	1270	1264.5	1259.06	1253.66	1248.33	1243.04	1237.81	1232.64	1227.51	1222.43	1217.41	1212.44
59 + 14	874	872.46	870.94	869.43	867.93	866.45	864.99	863.54	862.1	860.68	859.27	857.88
59 + 15	1658	1648.62	1639.33	1630.14	1621.04	1612.03	1603.11	1594.28	1585.53	1576.88	1568.31	1559.83
59 + 16	1529	1520.91	1512.9	1504.97	1497.12	1489.35	1481.66	1474.04	1466.5	1459.04	1451.65	1444.33
59 + 17	928	925.92	923.86	921.82	919.8	917.81	915.83	913.87	911.93	910.01	908.11	906.23
59 + 18	1272	1266.48	1261.02	1255.61	1250.25	1244.95	1239.7	1234.5	1229.36	1224.26	1219.22	1214.23
59 + 19	1374	1367.46	1360.99	1354.58	1348.23	1341.95	1335.73	1329.57	1323.48	1317.44	1311.47	1305.55
59 + 20	561	562.59	564.16	565.72	567.27	568.79	570.3	571.8	573.28	574.75	576.2	577.64
59 + 21	1381	1374.39	1367.85	1361.37	1354.95	1348.6	1342.32	1336.1	1329.93	1323.83	1317.8	1311.82
59 + 22	1182	1177.38	1172.81	1168.28	1163.8	1159.36	1154.96	1150.61	1146.31	1142.04	1137.82	1133.65
59 + 23	1029	1025.91	1022.85	1019.82	106.8	1013.86	1010.92	1008.01	1005.13	1002.28	999.45	996.66
59 + 24	1037	1033.83	1030.69	1027.58	1024.51	1021.46	1018.45	1015.46	1012.51	1009.58	1006.69	1003.82
59 + 25	1028	1024.92	1021.87	1018.85	1015.86	1012.9	1009.98	1007.08	1004.21	1001.36	998.55	995.76
59 + 26	893	891.27	889.56	887.86	886.18	884.52	882.88	881.25	879.63	878.04	876.46	874.89
59 + 27	1248	1242.72	1237.49	1232.32	1227.19	1222.12	1217.1	1212.13	1207.21	1202.34	1197.51	1192.74
59 + 28	903	901.17	899.36	897.56	895.79	894.03	892.29	890.57	888.86	887.17	885.5	883.85
59 + 29	810	0	808.21	807.33	806.45	805.59	804.73	803.89	803.05	802.22	801.39	800.58
59 + 30	1320	0	1308.06	1302.18	1296.36	1290.59	1284.89	1279.24	1273.65	1268.11	1262.63	1257.2
Average	1130.76	1130.76	1122.59	1118.56	1114.58	1110.63	1106.72	1102.86	1099.03	1095.24	1091.49	1087.77

VII. Hybrid Wind-Solar PV Modeling

Fig.6.0, presents the overall component configuration of the designed system for the study area as implemented in HOMER. The program set-up includes all the simulations and possible arrangements that were tested for solar PVs and wind turbines, for several sensitivity value ranges of generation capacity, wind speed and solar irradiation. HOMER simulates operation of the considered system by making energy balance calculations for each of the 8760 hours in a year. For each hour, HOMER compares the energy demand in the hour to the energy that the system can supply in that hour and calculates the flow of energy to and from each component of the system. HOMER performs these energy balance calculations for each system configuration under consideration. It then determines whether a configuration is feasible, i.e., whether it can meet the electrical demand under the specified conditions and estimates the cost of installing and operating the system over the lifetime of the project.

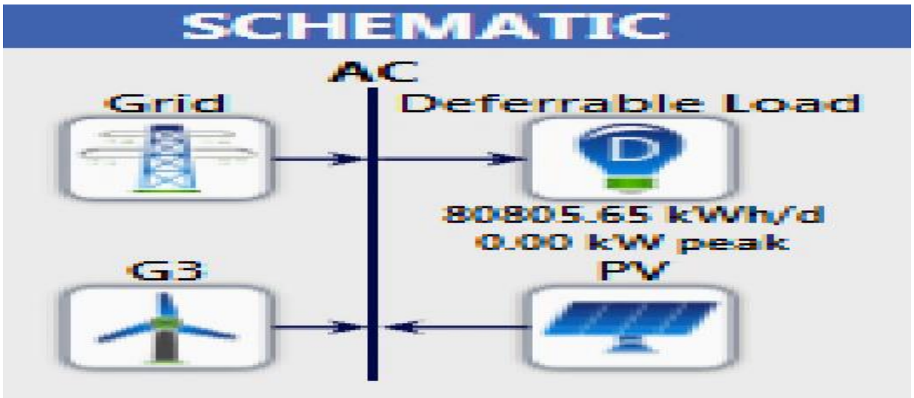

Fig.6.0: The Proposed Scheme in HOMER

VIII. Results and Discussion

This section presents the results of the feasibility study of Hybrid Wind-Solar PV analyses carried out in HOMER software. Fig.7.0. Shows the energy profile of Ajaokuta Steel Township electrical distribution as modeled in HOMER using Table 4.0 as input, being an industrial area the energy consumption was rather high. The highest in the year was in May with 3.82 MW and the least was in August with 2.06 MW.

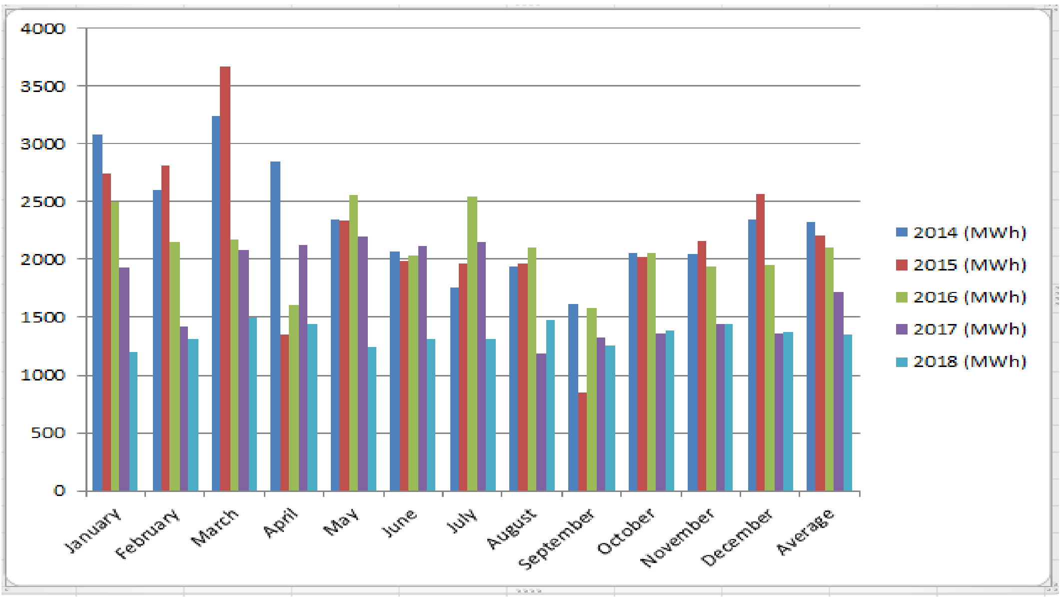

Fig.7.0 Monthly Energy Profile of Ajaokuta Steel Township as Modeled in HOMER

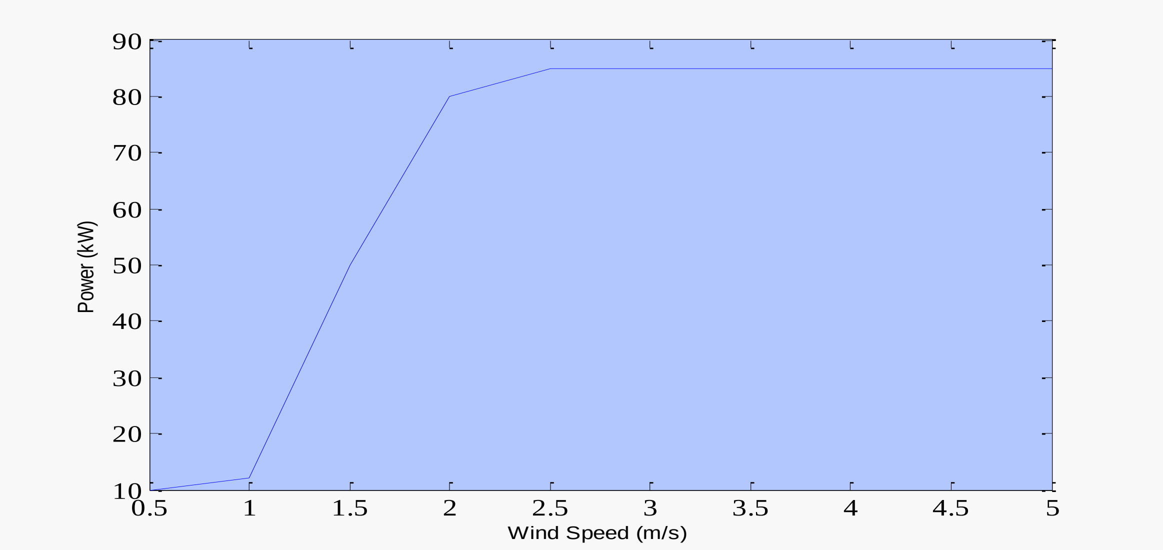

Fig.8.0. Wind resources of Ajaokuta Steel Township Simulation in HOMER

Fig 8.0, shows the maximum extractable power that can be gotten in the study area the total extractable Wind energy from the wind speed data collated from the study area is 85 kW.

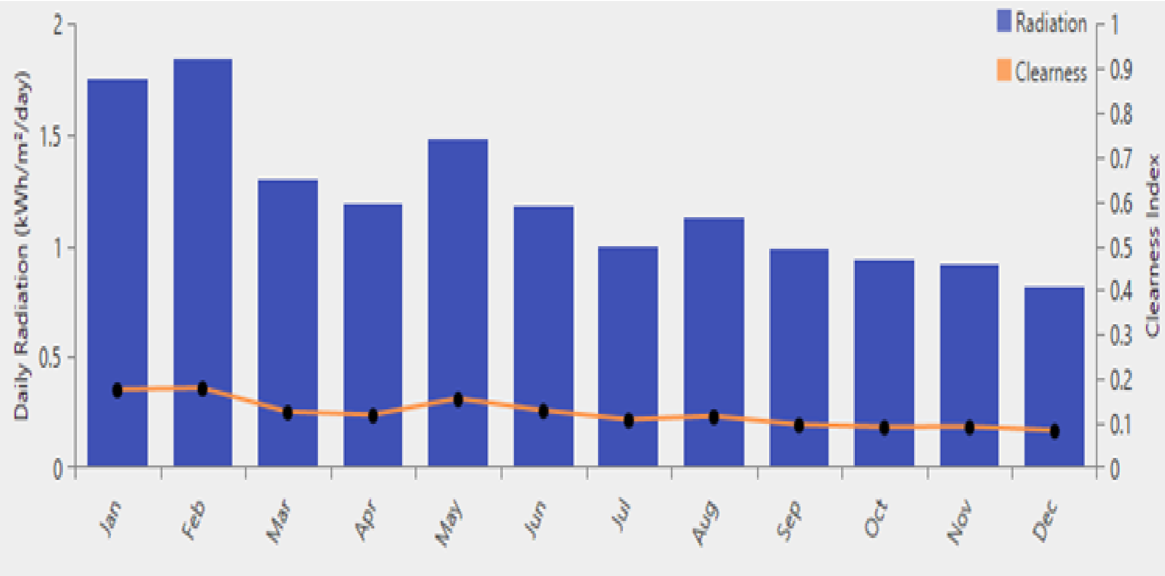

Fig.9.0. Solar Resources of Ajaokuta Steel Township as Modeled in HOMER

Fig.9.0. shows the simulation of daily solar radiation of the study area The total extractable power that can be harnessed from the solar radiation data is 138 kW. The Hybrid of Wind Turbine resources of 85 kW and Solar PV resources of 138 kW can be synchronized to the grid to compensate for the insufficient power in the distribution system.

IX. Cost Summary

The cost aspects of the system are discussed in this section. The net present cost of the system from HOMER is $27,409,335.74 with an annual operating cost of $625,788.82. The cost breakdown of the system is shown in Table 4.7. The cost of the proposed hybrid system is low compared to the second configuration with a net present cost (NPC) of $29,618,562.08. The proposed system has the lowest Cost of Energy (COE) with a value of $0.3142 /kWh. The total net present cost is the value of all the cost the project incur over its lifetime, minus the present value of all its revenue it earns over its lifetime. The cost summary includes capital cost, replacement cost, and operation and maintenance costs. Revenues include just the salvage cost for the standalone hybrid system.

Table 4.2: Cost Evaluation of the Hybrid System

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic1.5MW wind Turbine	9,0000,000.0	2,825,688.20	1,551,301.9	0.00	1,156,020.6	10,220,969.5
Generic Plate PV	11,292,324.1	0.00	842,477.16	0.00	0.00	12,134,801.27
System converter	492,992.98	209,164.02	0.00	0.00	39,366.78	662,790.21
System	**20,785,317.08**	**3,034,852.22**	**2,393,779.06**	**0.00**	**1,195,387.38**	**27,409,335.74**

From the cost summary in Table 4.2, it can be seen that the bulk of expenses is due to the Generic flat plate of Solar PV panel and the Generic Wind Turbine.

X. Conclusion

Efficient synchronization of Hybrid Wind-Solar PV into the national grid system is very essential in order to meet some of the increasing energy demand, also to enjoy green electricity from RES. This main focus of this study is to carry out feasibility study for implementing Hybrid Wind-Solar PV power system for Ajaokuta LGA. The feasibility analysis was carried out to ascertain practicality of Wind-Solar PV Hybrid in the study area using HOMER software. The results of the assessment made on the availability of energy resources in the study area showed that the proposed system is feasible. The annual average wind speed of the study area is 3.145 m/s with a total extractable Wind Turbine of 85 kW. The annual average solar insolation for the study area is 4.145 kWh/m^2/d with a total extractable solar power of 138 kW. This paper provides information: on sun insolation and wind speed data at 25m height above sea level This will form a good data base for the study area; on Hybrid of Wind–Solar Photovoltaic as viable alternative independent power supply for the study area. However, the steady and transient state stability analyses needs to be carried out for the study area to know the impact of integrating Hybrid Wind-Solar PV to Ajaokuta network.

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