UTILIZATION OF WIND ENERGY POTENTIAL AS AN INTEGRAL TOOL FOR POWER GENERATION

YAHAYA M.N., HALILU A., ZUMARU Z.A., BANDE A.M.
Department of Physics with Electronics, Federal University Birnin Kebbi, Kebbi State Nigeria.
mnaziru.yahaya@fubk.edu.ng

Abstract - The aim of this research is to analyse and provide realistic insight that will improve the provisions and investment in wind energy as potential source of energy for electricity generation. The data used for this assessment were obtained from the central database of Nigeria Meteorological Agency Abuja, which includes average wind speed, and direction per day of the selected location, measured at the anemometer height of 10 m, over a period of eleven years (2011-2021). The maximum monthly mean wind speed was found in January and December with a value of 4.9 m/s, and annual extractable energy was found to be 347.97KWh/M^2. On average, the annual wind speed through eleven years was found in the range 3.88 - 4.00 m/s. The results revealed that, the wind resource in the study area fall within range and category 3.00 which is considered as marginal or unsuitable for higher wind power development and an excellent for water pumping and small scale electricity generation.

Keyword: Utilization, Greenhouse Gases Emissions, Carbon Neutrality, Sustainable, Wind speed.

1. INTRODUCTION

Wind energy has been proven as a potential mean of power generation; many projects were executed and situated along residential, government institution and other higher institution of learning across different location of the country. The country growing population at faster than it power demand, results in diversification of power sources to compliment hydro sources which still inadequate to substantially address power shortages in a country with over 200 million people with an average generating capacity of 4GW. Many Nigerian were left without electricity and where available with limited hour of supply especially in rural communities [1, 2, 3].

Many projects have been completed using solar energy in rural communities as well as with government higher institutions of learning, while little attention has been on wind energy, except for the 10MW land base in a village in the Katsina state [3].

A comprehensive investigation and assessment of surface wind were carried out by on Statistical Evaluation of Surface Wind Method for Electrification in Kebbi State, Nigeria and revealed that surface wind due to its abundance in significant amount throughout the year all over the state with highest recorded values obtained in 2009, 2010 and 2011, if well –harnesses and utilizes it could serve as a good prospect for power generation in the study area and its environs. Wind energy has been utilized since the most punctual human advancement to grind grain, pump water from a deep well and power boat. With the ongoing flood of petroleum product costs, interest for cleaner energy resources, and government subsidizing motivations, wind turbines have turned out to be suitable innovation for power generation, because the use of wind energy has been expanding around the world at an accelerating pace [4] Literature evident that few urban cities are connected to the grids with limited electricity access for domestic household and industrial power demand [5], [6, 7]. The Nigeria power demand supply gap is estimated to be more than 76% as of the year 2016**.**

Nigeria is a well-endowed country with abundant wind energy resources which can be used to generate electricity [8]. However, despite the abundance of these energy resources, there is persistent electricity supply deficit, which may be attributed to underutilization of these potentials. Other major barriers to the deployment of wind energy technology in the country include high initial cost of wind power generation, systemic issues governing reliable transmission and system integration, social acceptance of technology and energy market structure [9]. The non-proper coordination of activities in the energy sector largely because of lack of concrete policy and energy plan is also worth mentioning. Wind energy has been widely used in Nigeria to power water supply for many decades now. In recent times efforts are largely geared towards its use for electricity generation, for example, the Federal Government of Nigeria is currently constructing 10 MW Wind Farm at Katsina and work has reached advanced stage of completion, although there are some issues with grid integration. In Nigeria, typical wind pattern occurs mostly from the east for inland areas and from the west over the coastal areas. During the Harmattan period (December – March) strong winds appear covering the country especially in the northern parts where the main wind direction shifts to west/south western directions. A study on the wind energy potentials for a number of Nigerian cities shows high wind speeds in the Sokoto region, Jos, Gembu and Kano / Funtua. Nigeria depends on thermal. The stations at Maiduguri, Lagos and Enugu also indicated relatively strong wind speeds, sufficient for energy generation by wind farms. Apart from these sites, other promising regions with usable wind potentials are located at the Nigeria's shoreline. The proper utilization of these wind energy potentials will ensure promotion of socioeconomic development as well as quality of life of the citizenry. Expanding the use of renewable resources such as wind will reduce carbon-dioxide emissions which contribute to global warming and lower long-term overdependence on fossil fuels and hydropower for electricity supply which has over the years proved inadequate [10, 19].

2. STUDY AREA

Zamfara state with it administrative Headquarters at Gusau, lies in the Northwestern part of Nigeria, on the latitude of 12.6°N and longitude 6.17°E at an elevation of 451m above sea level air density of 1.204kg/m^3 occupying a total landmass of 3,364km (2090mi)^2.

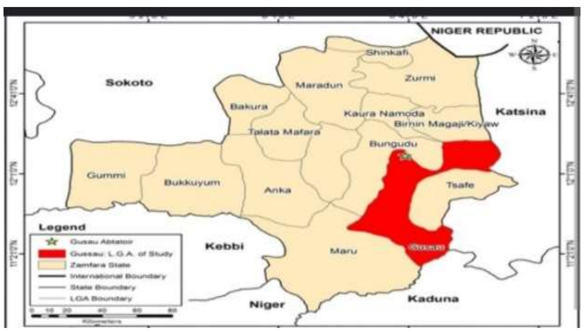

Fig. 1. Map of Zamfara State Showing the Study Area

3. MATERIAL AND METHOD

3.1. Materials

The data used in this work were obtained from the Nigeria Meteorological Agency (NiMet Abuja) a central database for all meteorological record nationwide via Gusau Branch office, which includes average wind speeds and direction per day of the selected location, measured at the anemometer height of 10 m over a period of 11 years and calculated different parameters using Weibull distribution.

3.2. Methodology

3.2.1. Statistical Distribution Analysis of Wind-Speed Data

The potentials in wind becomes more sensible when the wind power is determined using the available wind speed (preferably mean speed) at the height of interest to see if it has meet the required demand to rotate a turbine to a useful output rotation speed and torque requirement. Several mathematical models can be used for wind data analysis. However, the statistical model used in this research is Weibull and Rayleigh distribution models. Simply because it gives a better fit for measured monthly probability density distributions than other statistical functions. In addition, the Weibull parameters at known height can be used to estimate wind parameters at another height [11]. The parameters needed for this analysis can be calculated as shown in the equations below;

3.2.2. The Weibull Probability Density Function

f(v) is a function of a continuous random variable whose integral across an interval gives the probability that the variable lies within the same interval, it is given as:

$$F(v) = \frac{k}{c}\left(\frac{V}{c}\right)^{k-1}\exp^{\left[-\left(\frac{V}{c}\right)^{k}\right]} \quad (1)$$

Where; k= Dimensionless shape parameter, C= weibull scale parameter (m/s) V= monthly wind velocity (m/s).

3.2.3. Cumulative Distribution F(V)

Is function whose value is the probability that a corresponding continuous random variable has a value less than or equal to the argument of the function. According to [12]. It is simply the integral of the probability density function expressed as;

$$F(v)=1-e^{-\left(\frac{V}{c}\right)^{k}} \quad (2)$$

3.2.4. Method Used for Finding Weibull Parameters

The methods by which Weibull shape factor ‘k’ and scale factor ‘c’ can be determined in this work, is the method of moments (MOM); The Method Of Moments (MOM) is one of the common techniques used in the field of parameter estimation. According to the work of [13] as reported by [14], if v_m is represent the mean wind speed data the value of k and c can be easily determined by

$$K= \left(\frac{\sigma}{Vm}\right)^{-1.086} \quad (3)$$

Where Vm= mean wind speed and σ is the standard deviation.

The Weibull scale parameter (C) measured in meter per second is given by the 2005 report on Nigerian Wind Power mapping project as:

$$C=\frac{V_m k^{2.6674}}{0.184+0.816k^{2.74}} \quad (4)$$

3.2.5. Monthly Variation of the Wind Speed.

The monthly variation of this speed characteristics which include mean power density and mean energy density as well as the annual values of these parameters at a height of 10m have been determined using the work of [14,16,17] as reported by [18].

$$V_f = C\left(\frac{k-1}{k}\right)^{\frac{1}{k}} \quad (5)$$

$$V_E = C\left(\frac{k+2}{k}\right)^{\frac{1}{k}} \quad (6)$$

Where; V_f = Most probable wind speed, V_E = Wind speed carrying maximum energy

3.2.6. Mean Power Density

The mean power density which is measured in watts per square meter indicates how much energy is available at a site for conversion by wind turbine.

Thus, it is a very useful way to evaluate the wind resource available at a potential site. It can be estimated by using the equation:

$$P_D = \frac{1}{2}\rho V_m^3 \quad (7)$$

Where; $\rho = Density\ of\ air\ (kg/m^3)$

3.2.7. Energy Density (E_D)

The mean energy density (E_D) over a period of time is the product of the mean power density and the time (T), according to [15], it is expressed as:

$$E_D = \frac{1}{2}\rho C^3 \gamma (1-\frac{3}{k}) \quad (8)$$

Where; ρ= air density, C = the Weibull scale parameter (m/s), γ =Design tip.

4. RESULT AND DISCUSSION

4.1. Results

Results of statistical energy analysis of wind data, annual density plot, annual Weibull shape parameter plot model for 2011 to 2021 analysis of probability distribution function, cumulative distribution function and monthly energy analysis of wind data were presented as shown on table 1, and Figures 2 – 5 respectively.

Table 1. Energy Analysis Using 2011 to 2021

YEARS	V_M (m/s)	K	C (m/s)	V_F (m/s)	V_E (m/s)	P_D (W/m²)	E_D (KWh/m²)
2011	4.1	5.06	4.45	4.26	4.75	41.49	363.45
2012	3.9	6.56	4.16	4.06	4.33	35.71	312.8196
2013	3.9	7.24	4.14	4.06	4.28	35.71	312.8196
2014	4.2	5.86	4.53	4.36	4.73	44.6	390.696
2015	4.0	4.91	4.35	4.15	4.66	38.53	337.5228
2016	4.2	5.46	4.54	4.37	4.81	44.6	390.696
2017	4.1	7.04	4.36	4.27	4.52	41.49	363.45
2018	4.1	5.38	4.44	4.27	4.71	41.49	363.45
2019	3.8	5.09	4.13	3.96	4.41	33.03	289.3428
2020	4.2	5.2	4.56	4.38	4.85	44.6	390.696
2021	3.9	4.48	4.27	4.04	4.64	35.71	312.8196
TOTAL	**44.4**	**62.28**	**47.93**	**46.18**	**50.69**	**436.96**	**3827.762**

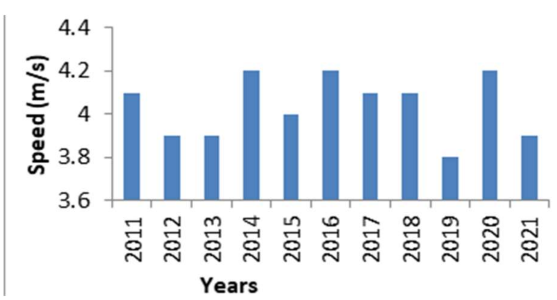

Fig. 2. Annual Mean Wind Speed Plot Model

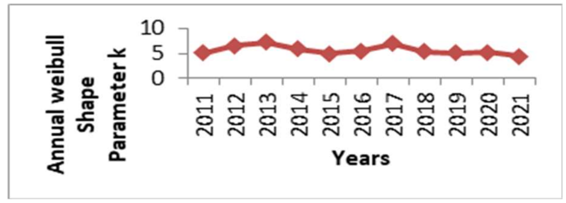

Fig.3. Annual Weibull Shape Parameter Plot Model

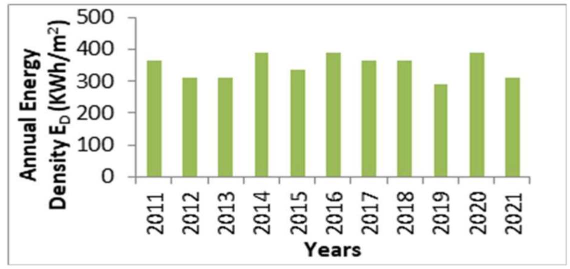

Fig. 4. Annual Energy Density Plot Model.

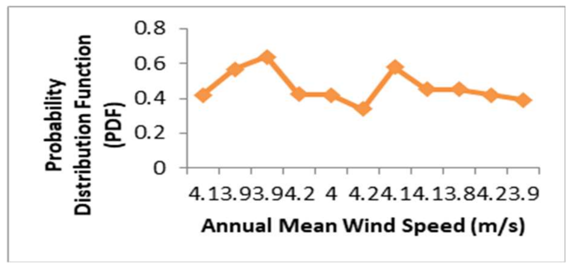

Fig. 5. Probability Density Function Against Annual Mean Wind Speed.

4.2. Discussion

The mean wind speed experienced at the site reach a monthly mean speed of 4.9 m/s in the month of January and December with a maximum wind speed of 5.17 m/s and 5.29 m/s at an instant during the months. The least annual value of Weibull scale parameter "C" is obtained as 4.13 m/s in the year 2019 and the highest value is 4.56 m/s in the year 2020. This result implies that the year 2020 has more peaking wind and narrower variation than the rest of the years under study.

The least annual value of Weibull shape parameter "k" for the site is 4.48 in the year 2021 and reached the highest value of 7.24 in the year 2013. Therefore, the wind speed is most uniform in the year 2013, while it is least uniform in 2021.

The minimum and maximum values of the annual wind speed are 3.8 m/s in the year 2019 and 4.2 m/s in the year 2014, 2016 and 2020 respectively. For a modern wind turbine, the cut-in wind required to start generating electricity is generally between 3.0 m/s to 5.0 m/s. Depending on the size of the turbine, the peak power output can be attained when the wind speed is in the range of 10 m/s to 15 m/s.

5. CONCLUSION

The study was carried out to assess the potential of wind energy resources for power generation in the study area. Daily mean wind speed data for the study were obtained from the Nigerian meteorological agency, Abuja, Nigeria for the selected location and subjected to the Weibull statistical distribution to determine the potential of the sites' wind resources for power generation. It was found that the Weibull 2-parameter statistical distribution was adequate at characterizing the wind profiles of the sites. The range of the monthly and annual Weibull k and C parameters for the sites were each found to be greater than two, indicating that the data spread exhibited good uniformity with relatively small scatter and also the Weibull predicted results were accurate at explaining the wind profile situation of the sites.

6. RECOMMENDATION

Nigeria is yet to have utilizes 30 per cent of it abundant wind sources as a form of energy generation for it rapidly growing population, rather battling with hydro means generating about 4000MW inadequate to meet the power needs of it citizenry. To mitigate the above challenges and for the attainment of SDG by 2030 and preparation towards carbon neutrality by target 2060 moving away from fossil fuel ravaging our environment, climate change, global warming and to reduce or eradicate greenhouse gases emissions, following recommendation has been made:

- The stakeholders in wind energy development should emphasize the importance deploying wind energy system in terms of economics benefits as well as reducing emission rate to the government.
- The government should improve funding and awareness to – a- just transitions by adopting renewable energy sources for better farm yields, electricity generation using biomass, wind and solar.
- Government should adopt the strategic measures employ by other country that have reaches a remarkable progress to scale up massive rural electrification projects.
- It is very important to know that the wind speed generally increase with high above ground, its recommends another study at different anemometer height 20, 30, 40 50 60 etc to comparatively assesses the potentiality of this parameter.

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