Evaluation of Wind Potential for the Generation of Electricity in Aliero, Kebbi State

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Authors' contributions

This work was carried out in collaboration among all authors. Authors AAY and IMB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NM and IM managed the corrections, protocols and analyses of the study. Author MIM managed the literature searches and references. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJR2P/2020/v3i130110

ABSTRACT

One of the major developments in the technology today is the wind turbine that generates electricity and feed it directly to the grid which is used in many part of the world. The main purpose of this work is to determine the wind potential for electricity generation in Aliero, Kebbi state. Five years data (2014-2018) was collected from the metrological weather station (Campbell Scientific Model), the equipment installed at Kebbi State University of Science And Technology Aliero The data was converted to monthly and annual averages, and compared with the threshold average wind speed values that can only generate electricity in both vertical and horizontal wind turbines. The highest average wind speed 2.81 m/s was obtained in the month of January and the minimum average wind speed of 1.20 m/s in the month of October. Mean annual wind speed measured in the study

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area shows that there has been an increase in the wind speed from 2014 which peaked in 2015 and followed by sudden decrease to a minimum seasonal value in the year 2016. The highest wind direction is obtained from the North North-East (NNE) direction. From the results of wind power density it shows that we have highest wind power density in month of January and December with 0.8635 w/ m² and 0.8295 w/ m² respectively, while lowest wind power density in the month of October and September with 0.6780 w/ m² and 0.6575 w/ m² respectively. Result of the type Wind Turbine to be selected in the study area shows that the site is not viable for power generation using a horizontal wind turbine but the vertical wind turbine will be suitable for the generation of electricity.

Keywords: Wind; turbines; metrological; threshold; wind speed; electricity; potential.

1. INTRODUCTION

Wind as a source of energy is a clean renewable source, free and in exhaustible source of energy, from all various source of energy wind has come to be abundant in supply and environmentally source of energy, its availability has been of a means used from the ancient days for propelling ships and driving wind to turbine to be grind grain and pump water, recently wind energy is gaining worldwide attention USA, China, Denmark, Germany, Spain and India are among the leading countries efficiently utilizing the source of energy [1].

The interest in the wind energy has lagged due to interest in cheap and plentiful petroleum product which has place in an economic disadvantageous state, though the days of this cheap and plentiful petroleum products are gradually drawing to an end. It is also believed that the cost of maintenance and implementation of wind energy technology is expensive but technology have improved in recent times to see that the utilization of this energy source is less expensive making it clear that the wind energy will be acceptable technology in the world energy sector [2]. Energy majorly affects each part of our financial life. It assumes a crucial part in the economic social and political improvement of our country. Inspire of the wealth of energy resources in Nigeria, the nation is still hard to come by of electrical power. Just around 40% of the countries more than 140 million approaches electrical power. Indeed, even the power supply to the consumers that are associated with the network is flightly. These are accordingly the need to tackle sustainable power source potential (for example wind and sun oriented etc.) for dependable power supply in this nation. Additionally, the worry about a worldwide temperature alteration and proceeded with misgivings about atomic power far and wide should drive us into solid interest for wind power generation [3].

Wind being atmospheric air in motion can be said to take it origin from the fact that the earth atmosphere extracted energy from solar radiation (the sun) and release to the space at low temperature through convention, [4]. During the process work is done on the gases in the atmosphere and upon the earth-atmosphere boundary. This difference in air pressure cause atmospheric gases or wind to flow from the region of higher pressure to that of lower pressure through diffusion [5]. Human have been using wind energy for their daily work for some 4,000 years for propelling ship which no longer had to make to do with muscle power. As early as 5,000 B.C wind propelled boats along the Nile River [1]. In 1700 B.C King Hammurabi of Babylon used wind powered scoop to irrigate Mesopotamia, by 200 B.C simple wind mills in china were pumping water while wind mills are used to grain in Persia and Middle East, [4]. The major and significant innovation is the wind turbine that generate electricity and feed it directly to the grid which start from the used of synthetics to make rotor blades. Development in the field of atmospheric physics aerodynamics, mechanical /electrical engineering, control engineering and electronics provide the technical basics of wind turbines used today [6]. Recent wind turbines for electricity generation usually have two or three rotor blades while horizontal axis, a nacelle with a rotor hub gear and a generator all which can be turn in and out of the wind [6].

Wind turbine design is the process of defining the forms and specification of a wind turbine to extract energy from the wind. For installing a wind turbine, necessary systems are needed to capture the wind’s energy, point the turbine to the wind, and convert the mechanical rotation to electrical power and control systems to start, stop and control the turbine [7]. The operation of wind turbine is based on two well-known processes. The first one is the conversion of kinetic energy of the air to mechanical energy
while the second process is the electromechanical energy conversion through a generator that is transmitted to the electrical grid [8]. The speed of the wind is responsible for rotating the wind turbine and the amount of power generated by the wind turbine is proportional to the cube of the wind speed. Before a wind speed will start producing energy. The wind speed must have overcome a threshold speed which is known as the cut-in speed, it is well expressed in Fig. 1. The cut-in speed is the speed where turbine first starts to rotate and produces energy and it is typical between 2.5 m/s to 3.5 m/s [9]. As the wind speed rises above the cut-in speed, the energy produces increase rapidly. At a certain wind speed, equilibrium is observed as increase in wind speed will lead to an equilibrium effect on the energy produce which indicates the generator output limit and called rate power-output and the wind speed at this limit is known as rated output wind speed. According to Albert Betz, who postulate a law called Betz's law, he indicates that the maximum power that can be extracted from the wind, independent of the design of a wind turbine in open flow, cannot be more than 16/27 (59.3%) of the kinetic energy in wind [10].

The aim of this work is to determine the wind potential for electricity generation in Aliero Local Government Kebbi State. With objectives of determining the wind speed for the generation of electricity in Aliero Local Government, Kebbi State, to Study the wind potential characteristics. Also to determine wind direction and the type of wind turbine suitable for the installation in the study area.

2. MATERIALS AND METHODS

The data used for this research was obtained from Kebbi State University of Science and Technology Aliero meteorological station (latitude 12.306°N and longitude 4.492°E). The data spans January, 2014 to December 2018. The parameters used for the research are wind speed and wind direction. The monthly annual averages of both parameters were calculated using the formula.

$$\text{Average} = \frac{1}{N} \sum x_i$$

Where: $X$ is the parameter, $X_i$ are the data points and $N$ is the number of data points.

Compell Scientific Model, C R 10 X (Weather Station) installed in Kebbi State University of Science And Technology Aliero stores data in hourly basis.

The wind power density which is measured in watts per square meter was evaluated using equation (2) to estimate the wind resource available at the potential site.

$$\frac{P}{A} = \frac{1}{2} \rho V^3$$

Where $P$ is the wind power in watts, $\rho$ is the air density in Kgm$^{-3}$ ($1.225$ kg/m$^3$), $A$ is the rotor area of the blade in m$^2$, $V$ is the speed of the wind in m/s.
3. RESULTS AND DISCUSSION

3.1 Average Monthly Wind Speed

Fig. 3 is the bar chart for average monthly wind speed against the month of the year. The red horizontal line indicates the level of the threshold speed which can generate electricity. Observation from the figure shows that the wind speed exhibits double maxima along the months of the year. The wind speed increases from the month of March and first maximum is observed in June, it then decreases consistently until October when the minimum wind speed is attained. The second maximum starts from November of one year and attained the peak gust in January of the following year. It is likely that the wind speed decreases with increase in the amount of rainfall because the period covered by decreased wind speed is well known rainfall period for the study area. Similarly the hamattan period could be a determinant for high wind speed since the higher values of wind speed are recorded more frequently in Hamattan. This implies that the site is only capable of generating electricity during the month of January and slightly in December. Wind speed wise, the potential of the place is lower than the threshold condition given by Youm, [9].

3.2 Mean Annual Wind Speed of the Study Area

Fig. 4 gives the plot for average wind speed in Aliero. Seasonal changes do contribute to variation in wind speed; the climate of the study area is equatorial with a raining season starting from June, July and with a peak point between August to late September [11]. For the five years available data Fig. 4 shows that there has been an increase in the wind speed from 2014 which peaked in 2015 and followed by sudden decrease to a minimum seasonal value in the year 2016. The parameter shows a gradual increase from 2016 up to 2018, this increase may probably last until another peak gust is reached for the next cycle. The sudden decrease in the wind speed could be attributed to the reduction in driving force and increase in the drag force [12]. Other works like [13,14] have attributed the changes in wind speed to the changes in observational instruments e.g. location of the observation site and height of the anemometer. Changes in these factors cause large discontinuity and are inevitable in a long term record.
Fig. 4. Mean annual wind speed measured in the study area

Fig. 5. Illustration of observable wind direction of the study area

Fig. 6. Wind power density of the study area
3.3 Wind Direction of the Study Area

Observation from Fig. 5 shows that the wind direction is frequently observed in the North-North-East (NNE) direction having at 27.45% of the total wind direction while the direction of South-East (SE) experience no record of wind. This indicates that the turbines installed in the NNE direction are more likely to produce electricity than any other orientation.

3.4 Wind Power Density of the Study Area

The power density is a useful way to evaluate the wind resource available at a potential site as it indicates how much energy is available at the site for conversion by a wind turbine. Fig. 6 in comparison with Fig. 3, shows that the wind power density energy produce is directly proportional to the wind speed i.e., the higher the wind speed the higher the energy to be produce. The highest wind power density is obtained in the month of January and December as 0.8635 W/m² and 0.8295 W/m² respectively, while having lowest wind power density in October and September as 0.6780 W/m² and 0.6575 W/m² respectively.

4. CONCLUSION

The focal point of this research is to draw attention to wind potential for electricity generation in Aliero, Kebbi state. Five years Data (2014-2018) was collected from the metrological weather station (Campell Scientific Model), the equipment installed at Kebbi State University of Science And Technology Aliero. The data was converted to monthly and annual averages, and compared with the threshold average wind speed values that can only generate electricity in both vertical and horizontal wind turbines.

The graphical representation of the result was obtained for better understanding and interpretation of the result obtained over period of years available. The following conclusions are deduced with regards to this research work:

- The minimum monthly average wind speed that was recorded in the month of October as 1.24 m/s while the maximum that was recorded in January as 2.8 m/s.
- From the result of mean annual wind speed for the five years available data it shows that there has been an increase in the wind speed from 2014 which peaked in 2015 and followed by sudden decrease to a minimum seasonal value in the year 2016. The parameter shows a gradual increase from 2016 up to 2018, this increase may probably last until another peak gust is reached for the next cycle.
  - The lowest power density is obtained in the month of October as 0.6575 W/m² while the highest power density is obtained in the month of January as 0.8635 W/m².
  - The data shows that the prospect of wind energy in the study area is low for horizontal axis wind turbine due to relatively low wind speed, therefore, the site is not viable for power generation using a horizontal wind turbine but for the vertical wind turbine will be suitable for electricity generation.
  - From the result of wind direction it shows that for power generation, the turbine will suitably be install in a location favoring North North-East (NNE) direction of the wind speed.

ACKNOWLEDGEMENT

The Authors wish to acknowledge the Kebbi State University of Science and Technology Aliero Meteorological Station for making the data available for the research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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