Assessment of Wind Energy Potential In Minna, Niger State, Nigeria

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Abstract

This study assesses the wind energy resources in Minna, Niger State, Nigeria by reviewing the existing literature on the subject matter and also evaluating the wind potential in Minna. Five years (2012–2016) wind speed data obtained from the Federal University of Technology Minna, Physics department weather monitoring station at Bosso campus, were used in the study. Weibull two-parameter statistical model was employed in the analysis. Assessment of the wind-energy resources in the study location reveals that wind speed in Minna is from 0.49ms^{-1} to 1.61ms^{-1} at 4m above ground level, while wind energy potential in Minna has wind power density which varies from 0.10Wm^{-2} to 5.27Wm^{-2} at 4m above ground level. Thus, Minna is not suitable of large-scale and small-scale wind power generation for electricity because of the poor wind potential at surface level. However at higher heights of 30m above ground level, having wind power density of 160 Wm^{-2} will be suitable for pumping water using wind power.

Keywords: *Weibull Distribution Function; Wind Speed; Wind Power Density.*

Introduction

The energy demand for electricity and agricultural purposes is grossly inadequate and this poses a serious challenge to the nation. The conventional fossil energy is fast diminishing from the oil reserves and the environmental pollution by emission of carbon monoxide and the general health hazard of fossil fuel is of concern to the world (Ohunakin, 2011).
The available power as at 2007 was 4914MW, while presently approximately 6000MW is being supplied, which is still grossly inadequate for the teaming population of Nigeria (Maiyama *et al.,*2013; Nigeria Electricity Hub, 2017).

About 60 million Nigerians spend 1.6 trillion naira on generators annually. Companies and Businesses have relocated from Nigeria to neighbouring countries due to the inability of the national electricity power supply to meet their demand, while homes across the nation are forced to adapt to the epileptic power supply, or in some cases, total blackout (Olaoye *et al.,* 2016).

The commonly used source of power generation in Nigeria are hydro and thermal power generation which are burdened with a lot of issues (such as broken down turbines, bunkering of gas pipeline and general infrastructural problem) which have to insufficient and poor power generation.
Nigeria is an energy-rich nation with both non-renewable and renewable energy (Akinbami, 2001). The country is endowed with wind energy resources which have not been exploited to generate

power. Nigeria has a wind farm project at Lambar Rimi in Katsina State, which is at an advance stage of completion and has generation capacity of 10MW.
Wind energy can be harnessed for electricity generation, pumping of water, grinding and irrigation farming. The wind energy application suitable for a specific location, solely depend on the wind energy potential of that location (Olomiyesan, 2018).
This study is aimed at assessing the wind energy potential in Minna, Niger State at 4 m above ground level

MATERIALS AND METHOD

Data collection

Wind speed measured at 4 metres above the groud level was used in this study. The data set span for a period of five years (2012 – 2016) and was collected from the Federal University of Technology Minna, Physics Department weather monitoring station at the Bosso campus.

Statistical analysis of wind data

The analysis of wind distribution in the selected sites was carryout using Weibull distribution function. Weibull probability density function, fw(v), and the corresponding cumulative probability function, Fw(v), can be expressed as

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

$$Fw(v)=1- exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (2)$$

where;
fw(v) =Weibull Probability density function

$F_w(v)$ = Cummulative probability function

k = Shape factor (dimensionless)

c =Scale factor (m/s)

v = wind speed (m/s)
Justus *et al.,*(1978) describes how to determine Weibull parameters k and c as,

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

$$c = \frac{v_m}{\Gamma\left(1+\frac{1}{k}\right)} \quad (4)$$

Also, c can be determined from the expression given by (Justus *et al.*, 1978):

$$c = v_m \left(\frac{k^{2.6674}}{0.184+(0.816k^{2.73859})}\right) \quad (5)$$

$$\sigma = \left[\frac{1}{N-1}\sum_{i=1}^{N}(v_i - v_m)^2\right]^{1/2} \quad (6)$$

where;

σ = standard deviation

v_m = mean wind speed (ms^{-1})

v_i = observed wind speed (ms^{-1})

N = number of months considered and

$\Gamma(x)$ = gamma function expressed as $\Gamma(x) = \int_0^{\infty}(t^{x-1}\, e^{-t}\, dt)$ (7)

Similarly, the wind power density, P(v), can be expressed either in term of the wind speed or in terms of the Weibull shape and scale parameters, k and c, using the correlation given function (Ohunakin *et al.*, 2011) :

$$P(v) = {}^{1}/_{2}\rho\, v^3 \quad (8)$$

$$P(v) = {}^{1}/_{2}\rho c^3\, \Gamma(1+3k) \quad (9)$$

where:

P(v) = Wind Power Density (Wm^{-2})

v=Wind speed (ms^{-1})

c =Weibull scale parameter (ms^{-1})

k =Weibull shape parameter (dimensionless)

ρ =Air density at the site, which can be expressed in the form:

$$\rho = \rho o - 1.194\times10^{-4}\times H_m \quad (10)$$

where ρo is the air density value at sea level usually taken as 1.225 kgm^{-3} and H_m is the site elevation in meters.

Results and discussion

The graphic representation of the monthly mean wind speed recorded for the entire study period of five years presented in Figure 1.

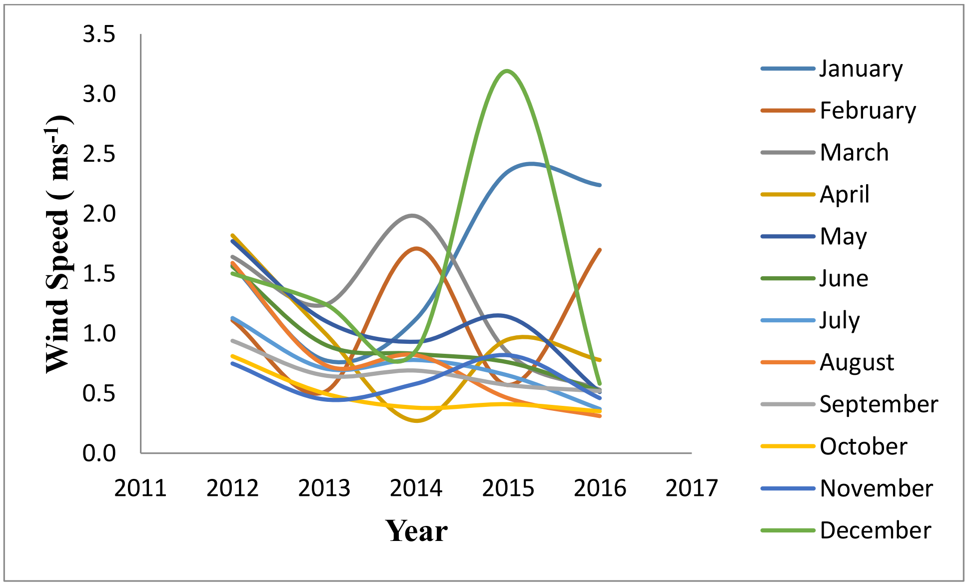

Figure 1: Monthly wind speed for Minna (2012 - 2016).

Figure 1 reveals that wind speeds fluctuate from year to year. During the period under study, the highest monthly mean wind speed recorded was 3.19 ms^{-1} in December, 2015 while the lowest monthly mean wind speed was 0.27 ms^{-1} in April, 2014. The annual mean wind speed recorded for the period of the study was: 0.98 ms^{-1}

Wind speed frequency distribution

The monthly probability density and cumulative distribution derived from the time series data for the whole period are shown in Figures 2 and 3 respectively. The PDF and CDF plots show that all the curves of the monthly wind profiles follow a similar distribution pattern. The variation in shapes of PDF and CDF plots are due to the varying values of the Weilbull parameters c and k. The parameter, c, determines the spread of the distribution, while the shape parameter, k, indicates the peak of the wind distribution.

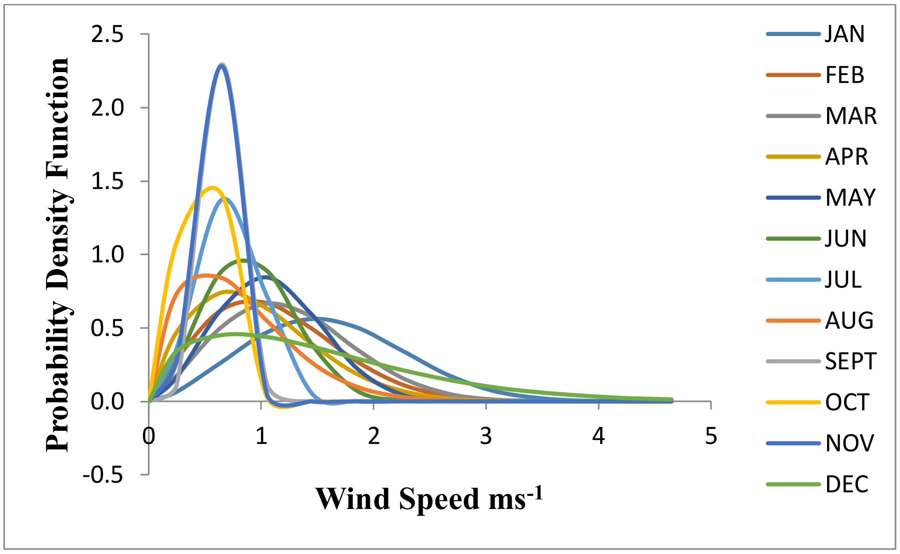

Figure 2: Monthly Wind Distribution for Minna PDF

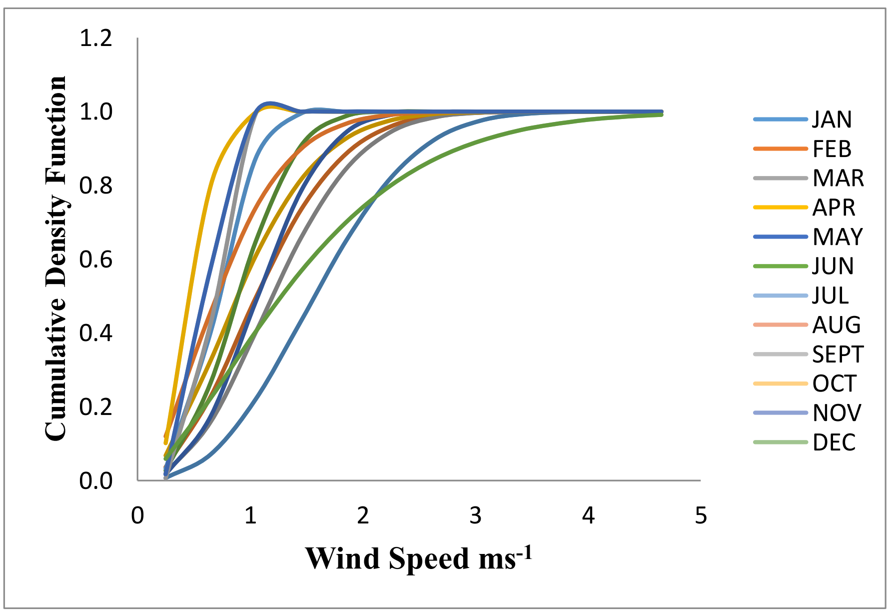

Figure 3: Monthly Wind Distribution for Minna CDF

The plot of the probability density function (PDF) illustrates the fraction of time for which a given wind speed possibly prevails at a location. The peak of the PDF curve indicates the most frequent velocity, whereas the plot of the cumulative distribution function is used for estimating the time for which wind speed is within a certain speed interval. The plots of the monthly PDF shown in Figures 2 and 4 demonstrate that the wind profiles for the study location and months follow the same distribution pattern. It can further be noted that the PDF plot for Minna shows a minimal data.

Similarly, the CDF plots in Figure 3 show that at Minna, most of the data are not in the wind speed range of 0.8 and 2.4 ms^{-1} and others falls below.

The annual probability and cumulative density functions obtained using the Weibull distribution function for Minna are shown in Figures 4 and 5.

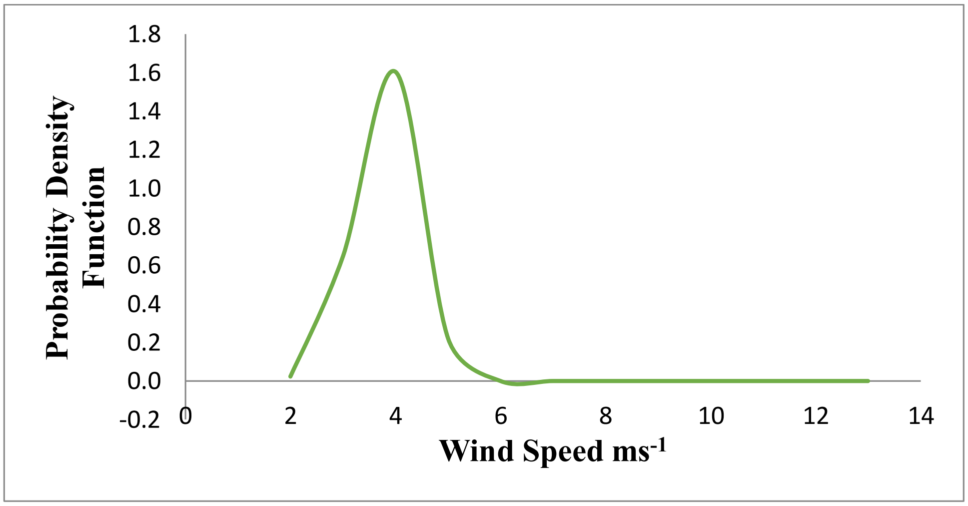

Figure 4: Annual PDF for Minna

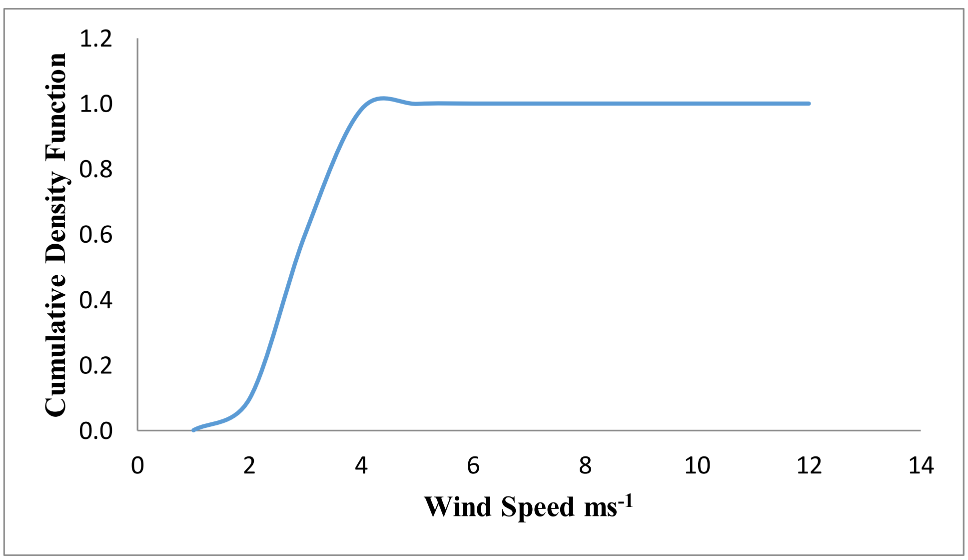

Figure 5: Annual CDF for Minna

From Figure 4, it can be noted that the annual mean and most frequent wind speeds for Minna is about 2.3 ms^{-1}. The cut-in wind speed which contributes to the generation of electricity from wind in most new wind turbine designs is about 2.5 ms^{-1} and above. However, if wind turbines with cut-in wind speed of 3.5 ms^{-1} is selected for use in the site, it can be observed from the CDF curve in Figure 5 shows that, the CDF value is 2.8 ms^{-1} wind speed. Thus, Minna is not viable for wind power generation. This is in agreement with the findings of previous works (Adaramola and Oyewola, 2011).

Wind power density

The result of analysis of monthly and annual variations of the annual mean wind power densities calculated from the measured wind data and those obtained by using Weibull parameters for Minna is shown in Figure 6.

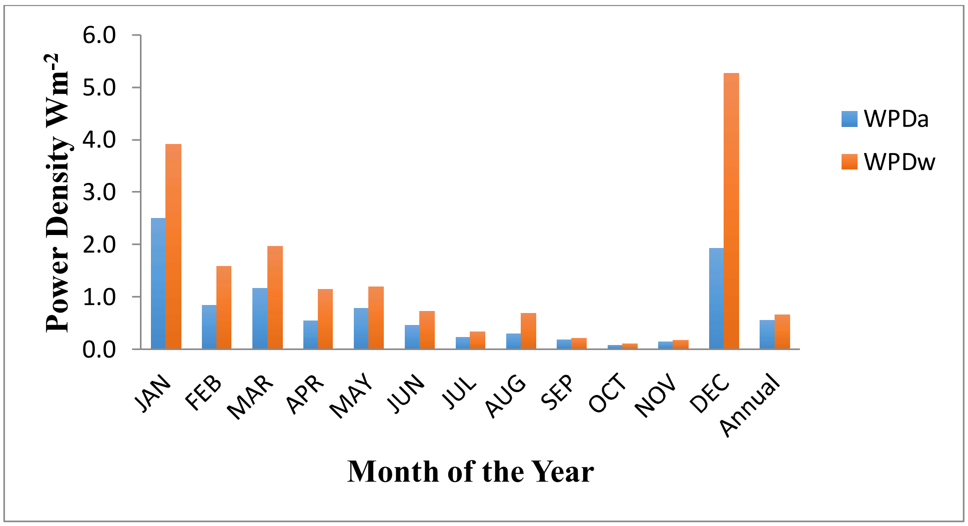

Figure. 6**:** Plot Showing monthly Variations of the Power Density Distributions for Measured and Weibull Values for Minna.
NOTE: WPDa is the actual Wind Power Density; WPDw is the Weilbull Wind Power Density

The monthly variations of the actual and Weibull power densitiy for the Minna in Figure 6 indicates that the estimated Weilbull wind power density are slightly higher than the actual power density for every month of the year and on annual basis. This supports the assertion that, 'Weilbull probability distribution is suitable for analysing and interpreting data of measured wind speed (Olayinka, 2011) and is not discriminative between location with high and low mean wind speeds. For Mjnna the monthly Weibull WPD is in the range of 0.1 – 5.3 Wm^{-2}, which falls into the Wind Classes of 1 of the PNL wind classification (Olomiyesan *et al*., 2017). The estimated annual wind power density for Minna is 0.66 Wm^{-2}. Thus, Minna does not have a good prospect for wind power generation.

Conclusion

In this study, the predictive ability of Weibull distribution function in analyzing wind speed data was assessed in Minna with mean wind speed. The results of the analysis show that the Weibull function is suitable for analyzing measured wind speed data and for predicting the wind-power density in a location. Other relevant findings of this study can be summarised as follows:
i. The annual mean wind speed recorded during the period of the study is: 0.98 ms^{-1}

ii. The annual values of the most probable wind speeds and the maximum energy carrying wind speeds are respectively 0.56 and 0.66 ms^{-1}.
iii. Based on the estimated annual values of the Weibull wind power density, the wind energy resource in Minna can be classified as class 1 in the PNL wind classification. Therefore, does not have a good prospect for wind energy for electricity generation.

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