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Wind Energy toward Electric Current Generation in Borno State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author UMM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors UMM and JM managed the analyses of the study. Authors UMM and JM managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

This research focused on evaluating the prospect of wind energy for electric power generation in Borno State, Nigeria was carried out. Sixteen years of monthly mean wind data at 10 m height of anemometer from the ministry of aviation Maiduguri (Maiduguri meteorological center) Nigeria were assessed and snubbed to Weibull two parameter and Rayleigh model of probability distribution. It was found that its monthly and annual variation recorded for the maximum speed were 6.97 m/s in 1997 and 5.23 m/s in 2001 respectively and the minimum wind speed was 1.00m/s and occur in the year 2012. The maximum mean wind speed occurs in March, June, July and August while the minimum value occurs in September. Maiduguri is a potential wind farm area; the moderate wind falls within the consistent values for wind power generation to operate wind turbine for electric power conversion. The study also displays that Maiduguri has annual power density approximately to power class (2) which is 87.98 W/m^2 showing that it is perfect for grid connection and application.

Keywords: Wind speed; density; wind power; power density; viable potential.

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1. INTRODUCTION

Wind is termed simply as air in motion. It is an abundant resource available in nature that could be harnessed by mechanically converting wind power using wind turbine for generation of electricity, grinding grains, pumping water in rural areas and draining of water from lowland areas [1]. The wind power has to be integrated for economic purpose which means all of their available output (resources) have to be taken into consideration [2].

The first windmill used for the production of electric power was built in Scotland in July 1887 by Prof. James Blyth of Anderson's college, Glasgow (the precursor of Strathclyde University). Blyth's 10 m high, cloth – sailed wind turbine was installed in the garden of his holiday cottage of Mary Kirk in kincardine shire and was used to charge accumulators developed by the Frenchman Canille Alphonse Faure, to power the lighting in the cottage [3].

Wind power is the use of air flow through wind turbines to mechanically power generators for electric power generation. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, consumes no water, and uses little land [4-5]. The net effects on the environment are far less problematic than those of renewable power sources [4-5].

Nigeria is a well-endowed country with abundant wind energy resources but its utilization is practically minimal and relatively irrelevant [6]. The wind energy resources can be used to generate electricity but there is persistent electricity deficit which may be attributed to underutilization of these potentials.

Though turbines have been used as wind pumps still have not been made popular due to high installation and maintenance cost [7]. Various policy issues have been generated by the government demonstrating the intention to generate electricity from wind [8-24].

A wind power class of 3 or above (equivalent to a wind power density of 150 to 200 watts per square meter, or mean wind speed of 5.1 to 5.6 meter per second) is suitable for utility-scale wind power, although some suitable sites may also be found in areas of classes 1 and 2 having mean wind speed of apparently 3.1 and 4.6 respectively. In the United States there are substantial wind resources in the Great plain region as well as in some offshore region/ locations. As of 2010 the largest wind farm in the world was Roscoe wind farm in Texas, which produces 781.5 megawatss. By comparison, a typical new coal-fired generating plant produce averages about 550 m egawatss [9].

In Nigeria a research obtained from different meteorological stations on wind speed ranges from 2.0 to 9.5 m/s based on the recent report and the trend shows that wind speed are low in the south and gradually increases to relatively high in the north. Due to the recent development in wind energy converters mostly in developed countries (especially in Europe) with desire to reduce the environmental impact of the conventional energy resources, there is a general growing interest in the wind energy devices development in Nigeria. The global cumulative capacity of wind power gradually increases from 6100 MW in 1996 to 158,505 MW in 2009 [10].

Several studies on wind resource assessment have been carried on in Nigeria [7-15]. Each one of this report considered sites and presented analysis to justify their results. Due to varying topography and roughness of the nation, it has been reported that large differences in wind distribution within locality exist [7-24]. This corroborated by the fact that when resources are site specific and despite report summarizing for the country, a site by site assessment is necessary in order to have proper wind classification for the nation [7-24].

Hence, the objective of this research is to probe and investigate the quality of wind energy potential in Maiduguri and proposes an appropriate methodology with particular emphases on Nigeria [7-24].

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Study area

Maiduguri is a city found in Borno, Nigeria. It is located 11.85 latitude and 13.16 longitudes and is situated at elevation 325 meters above sea level and within the semi-arid zone of North eastern Nigeria.

It has a wind speed of 3.4 m/s North-Eastern cloudiness of 61.7% and 16.1% humidity and atmospheric pressure of 1010.6hpa and annual rainfall of 225.7 mm per year, (Mapsstreetview.com). The study area is illustrated in the map shown in Fig. 1.

2.2 Methods

2.2.1 Data source

The records of wind speeds used in this research at a height of 10 m which is the standard for typical meteorological stations to measure wind speed.

These records of wind speed were obtained from Maiduguri meteorological agency. The monthly average of wind speed data were taken over a period of sixteen years (1997-2012).

2.2.2 Data analysis

Wind speed for a particular area can be attributed or characterized by several probability density functions. For wind data analysis, the Weibull and Rayleigh probability density functions are commonly employed and acknowledged, and adopted [16-20,24].

According to [15-20], the probability density function f (v) and the corresponding Cumulative Density Function F (v) associated with the 2-parameter (factor) Weibull distribution are given by Equation (1) and (2) respectively:

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

$$v \geq 0; k, c > 0$$

$$\int_0^v f(v)dv = F(v) \quad (2)$$

$$F(v) = 1 - exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (3)$$

$$v \geq 0 and F(v: k, c) = 0 for v < 0$$

Where $f(v)$ = the Weibull probability of observing wind speed v, k = the dimensionlessWeibull shape factor and c(m/s) = The Weibull scale parameter and F(v) = Weibull cumulative distribution function.

The wind power density (W/m^2) which is the quantitative measure of the wind energy available at any location can be estimated from the Weibull factors as [15-20].

$$p(v) = \frac{1}{2}pc^3(1 + \frac{3}{k}) = \frac{1}{2}p\,\bar{v}^3 \quad (4)$$

An approximation widely accepted for the values of k and c for the 2- parameter Weibull distribution is given according to [21-24] by:

$$k = \left(\frac{\sigma}{\bar{v}}\right)^{-1.086} \quad (5)$$

$$c = \bar{v}\ \frac{k^{2.6674}}{0.184 + 0.816k^{2.73859}} \quad (6)$$

Where σσis the standard deviation of the wind speed for the site.

3. RESULTS AND DISCUSSION

Extrapolated wind speed data and wind speed profile for year 1997 – 2012, is displayed in Table 1 and Fig. 1 respectively. Its monthly variation

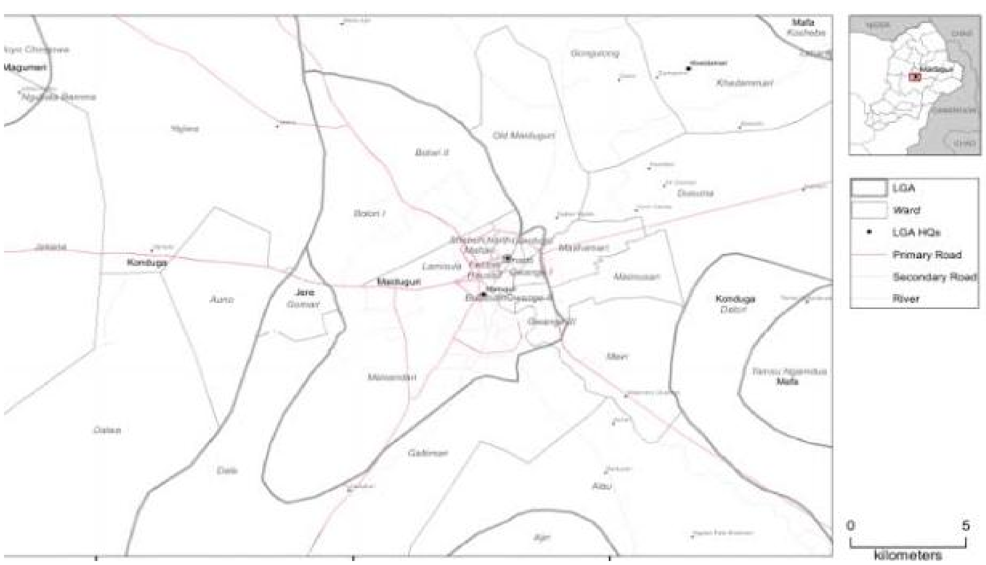

Fig. 1. Map of the study area (Maiduguri and its Environs)

Table 1. Extrapolated wind speed data

Years	V(m/s)	σ	F(v)	f(v)	P(v) W/m^2	k	c(m/s)
1997	4.556	15.785	0.8144	0.0538	58.16	0.260	0.6133
1998	4.242	14.694	0.8145	0.058	46.945	0.2595	0.5677
1999	4.186	14.5	0.8145	0.059	44.93	0.2594	0.5604
2000	4.502	14.237	0.8106	0.0201	55.9	0.2864	0.7613
2001	5.23	18.117	0.8145	0.0471	87.98	0.2594	0.7001
2002	4.186	15.6	0.8165	0.0661	45.11	0.2396	0.4624
2003	3.38	11.709	0.8145	0.0728	23.75	0.2594	0.4524
2004	4.143	14.35	0.8145	0.0593	43.734	0.2596	0.5556
2005	3.847	13.325	0.81451	0.0641	35.014	0.2595	0.5154
2006	4.397	15.231	0.81452	0.0561	52.281	0.2594	0.5886
2007	4.424	15.326	0.81452	0.0183	53.25	0.2594	0.5922
2008	3.353	11.613	0.81451	0.0734	23.183	0.2595	0.4492
2009	2.673	9.252	0.81436	0.0918	11.75	0.2597	0.359
2010	1.93	6.689	0.81458	0.1274	4.43	0.2594	0.2586
2011	2.228	7.7163	0.8162	0.1109	6.802	0.2594	0.2983
2012	2.198	7.7612	0.8152	0.1157	6.531	0.2537	0.2789

recorded for the speed is maximum 6.97 m/s in the year 1997 while the minimum value is recorded with a value of 1.00 m/s in the year 2012. Mostly the maximum wind data is occurred in the month of February, March (5.59 m/s), April (5.36 m/s), May, June, and July while the minimum wind speed is in the month of September, October. By looking at the profile carefully you notice that a bit raise and fall in the wind speed data for instance from 1997 to 2000 while from 2001 to 2008 there is a gradual decrease in the wind data and from 2008 to 2012 the wind speed decrease. This overall short in variation happens as a result of diurnal differential heating of the earth's surface during daily radiation cycles. By this data it is noticed that maximum wind speed occurred in the dry season than in the wet season. Maiduguri and its environs have an average wind speed of 3.4 m/s and by this data it affirms that it falls in the moderate wind regime. Maiduguri and its environs are potential wind farm areas because most wind turbines start generating electric current at a wind speed of 3-4 m/s.

These results indicate this region has high potential for wind energy and it is ideal for grid implementation and applications.

4. CONCLUSION

In this study, the assessment of wind energy potential in generating electric current in Maiduguri, the northeastern Nigeria was conducted. Sixteen years of monthly mean wind data at 10 m height of anemometer from meteorological agency Maiduguri was evaluated and subjected to Weibull two-parameter and Rayleigh probability distribution. It was found and recorded that the maximum mean speed is 6.97 m/s and it has power density of 87.98 W/m^2. The maximum value of wind data occurred in July while the minimum value occurred in September. It is also observed that Maiduguri and it's environ have monthly average of 3.4 m/s which is within the range to establish a wind power plant.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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