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Assessment of Wind Energy Potential in Maiduguri, Nigeria

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Abstract— **This paper present an evaluation of wind power potential of Maiduguri in North Eastern part of Nigeria based on the Weibull and Rayleigh models using 15 years monthly wind speed covering period of 1998 to 2012 obtained from Nigeria Metrological Agency. Its monthly variation recorded for the speed is maximum 12.98m/s in the year 2006 while the minimum with a value of 1.12m/s in the year 2012. It is observed that Maiduguri and its environs have wind regime between 2.2 and 6.4m/s and still confirms that it falls into moderate wind regime. The annual mean power density ranges from 6.3 to 160.9 W/m2.These results indicate that wind speed has the viable potential for wind-to-electricity at height of 10 m.**

Index Terms— **Wind power, Moderate wind, Power density, Viable potential.**

I. Introduction

Wind can be defined simply as air in motion. It is an abundant resource available in nature that could be utilized by mechanically converting wind power using wind turbines for generation of electricity, grinding grain, pumping water in rural areas and draining of water from lowland areas (Medugu and Markus, 2011). The wind power has to be integrated for economic purpose which means all of the available output (resources) have to be taken into consideration (Suleiman, 2010).

Nigeria is a well-endowed country with abundant wind energy resources but its utilization is practically minimal and relatively insignificant (Iheonu et al, 2002). The wind energy resources can be used to generate electricity but there is persistent electricity supply deficit, which may be attributed to under utilization of these potentials. Though turbines have been used as wind pumps still have not been made popular due to high installation and maintenance cost (ECN-UNDP, 2005). Various policy issues have been generated with the government demonstrating the intention to generate electricity from wind (Ajayi, 2013). The United Nation Development Programme (UNDP) in 1984 proposed major feasibility studies on windmills with specific interest in small scale irrigation, domestic water pumping, livestock water supply and electric power generation but ended up as mere desktop study. It is concluded that there is insufficient information about the wind's quantity, quality, distribution, and utilization that could possibly be used to determine its commercial viability for utility scale power generation (ECN-UNDP, 2005).

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Several studies on wind resource assessment have been done in Nigeria (Ajayi, 2011; Asiegbu, and Iwuoha, 2007; Fadare, 2008; Ogbonnaya, et al, 2007; Ngala, et al, 2007; ECN-UNDP, 2005; Fadare,2010; Fagbenle, et al 2011). Each one of these reports considered different sites and presented analyses to justify their results. Due to the varying topography and roughness of the nation, it has been reported that large differences in wind distribution within the same locality exist (ECN-UNDP 2005). This is corroborated by the fact that wind resources are site specific and despite reports summarizing for the country, a site-by-site assessment is necessary in order to have proper wind classification for the nation. The objective of this study is therefore to assess and investigate the quality of wind energy Potential in Maiduguri and proposes the way forward with particular emphasis on Nigeria.

II. Materials and Method

2.1 Description of the Study Area

Maiduguri is the capital of Borno State in Nigeria. The city lies on latitude 11°51' and longitude 13°09' and within the semi – arid zone of Northeastern Nigeria. The study area is illustrated in the map shown in Fig 1.

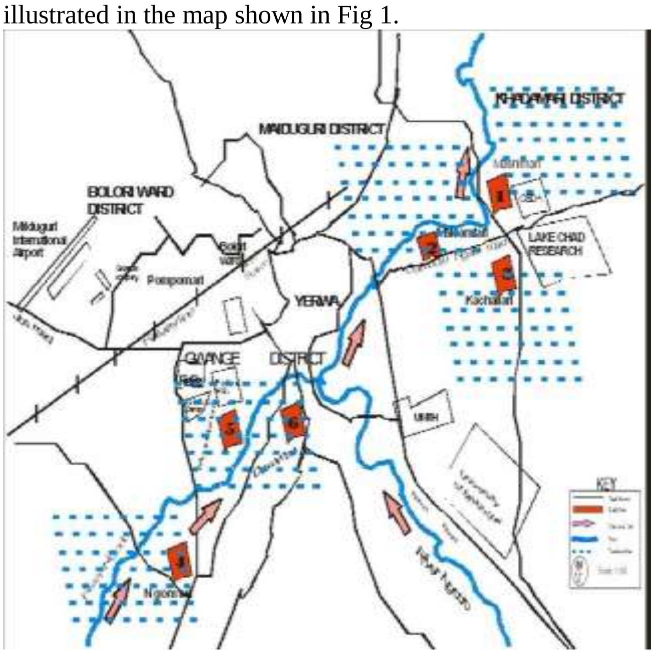

Fig 1: Map of the Study Area (Maiduguri and its Environs)

2.2 Data Source

The records of wind speeds (measured in knots) used in this study at a height of 10 m with its station coordinates are obtained from Nigeria Metrological Agency. The monthly average of the wind speed data were taken over a period of fifteen years (1979-2012).

2.3 Data Analysis

Wind speed for a given location can be characterized by several probability density functions. For wind data analysis, the Weibull and Rayleigh probability density functions are commonly used and widely adopted (Celik, 2003; Chang, et al, 2003; Weisser, 2003; Lu, et al, 2002; Mathew,et al, 2002; Persaud, 1990)

The Probability Density Function *f* (*v*) and the corresponding Cumulative Density Function *F* (*v*) associated with the 2-parameter Weibull distribution are given by Equations (1) and (2) respectively (Fagbenle, et al, 2011):

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

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

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

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

where *f* (*v*) = the Weibull probability of observing wind speed *v* , *k* = the dimensionless Weibull shape parameter, *c* (m/s) = the Weibull scale parameter and *F* (*v*) = Rayleigh probability density 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 parameters as (Fagbenle, et al, 2011):

$$p(v) = \frac{1}{2}\rho C^3\left(1 + \frac{3}{k}\right) = \frac{1}{2}\rho\bar{v}^3 \qquad 3$$

An approximation widely accepted for the values of *k* and *c* for the 2-parameter Weibull distribution is given (Justus, et al, 1976; Balouktisis, et al, 2002) by:

$$k = \left(\frac{\sigma}{\bar{v}}\right)^{-1.086} \qquad 4$$

$$c = \bar{v}\frac{k^{2.6674}}{0.184 + 0.816k^{2.73859}} \qquad 5$$

where σ is the standard deviation of the wind speed for the site.

III. Results and Discussion

Table 1: Extrapolated wind speed data.

Years	$\bar{v}$ (m/s)	σ	F(v)	f(v)	p(v) W/m^2	k	c (m/s)
1998	5.288	19.275	0.000610	0.006341	90.5690	0.252	0.6340
1999	5.429	20.817	0.000490	0.001843	98.0090	0.346	0.4820
2000	5.608	22.283	0.000655	0.001147	108.026	0.218	0.6670
2001	6.405	23.986	0.000675	0.002009	160.940	0.238	0.7420
2002	5.075	18.500	0.000534	0.001756	80.0598	0.229	13.183
2003	4.061	15.579	0.005014	0.002645	41.0209	0.233	10.569
2004	5.686	19.828	0.003690	0.001849	112.597	0.289	14.039
2005	4.556	17.170	0.004570	0.003688	57.9238	0.239	11.836
2006	5.944	22.039	0.003680	0.002188	128.630	0.241	15.317
2007	5.896	20.778	0.003550	0.001438	125.539	0.768	1.9340
2008	4.414	16.606	0.004270	0.002621	52.6748	0.238	0.4850
2009	3.559	13.311	0.005640	0.005004	27.6115	0.238	0.3890
2010	2.522	8.5630	0.010390	0.002304	9.82520	0.251	0.2320
2011	2.949	11.005	0.008310	0.006858	15.7083	0.239	0.3190
2012	2.178	8.1280	0.008060	0.002184	6.32819	0.219	0.2220

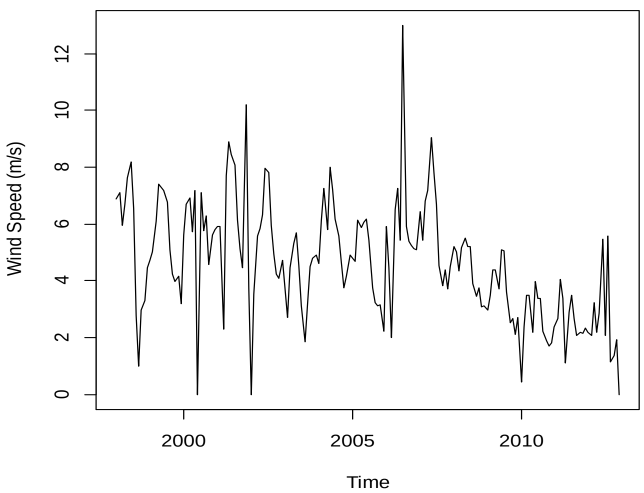

Fig 1: Mean wind speed for 1998 – 2012.

Extrapolated wind speed data and wind speed profile for year 1998 – 2012, is shown in Table 1 and Fig.1 respectively. Its monthly variation recorded for the speed is maximum 12.98m/s in the year 2006 while the minimum with a value of 1.12m/s in the year 2012. The maximum value occurred in July while minimum occurs in September. Observing the profile carefully it is noticed that there is gradual increase from the 1998 to 2002, then from 2005 to 2007. Then a gradual decrease is observed from 2009 to 2012. This entire short in variation occurs due to diurnal differential heating of the earth's surface during the daily radiation cycles. From the observation it shows that wind speed is maximum during the dry season than in the wet season. It is observed that Maiduguri and its environs have wind regime between 2.2 and 6.4m/s, and still confirms that it falls into moderate wind regime. Maiduguri and its environs are potential wind farm areas because most wind turbines start generating electricity at wind speeds of around 3-4m/s. The study also shows that Maiduguri has highest annual power density of 160.940 W/m^2, corresponding to power class (1) since the density value is above 100W/m^2. This show that it is ideal for grid connection and application.

IV. Conclusion

In this study, the assessment of the potential of wind power generation in Maiduguri, the Northeastern part of Nigeria was carried out. Fifteen years of monthly mean wind data at 10 m height from the Nigeria Metrological Agency Nigeria were assessed and subjected to Weibull two-parameter and Raleigh model of probability distribution. It was discovered that its monthly variation recorded for the speed is maximum 12.98m/s in the year 2006 while the minimum with a value of 1.12m/s in the year 2012. The maximum value occurred in July while minimum occurs in September. It is also observed that Maiduguri and its environs have wind regime between 2.2 and 6.4m/s, and still confirms that it falls into moderate wind regime and are potential wind farm areas because most wind turbines start generating electricity at wind speeds of around 3-4m/s. The study also shows that Maiduguri has annual power density corresponding to power class (1) since the density value is above 100W/m^2 indicating that it is ideal for grid connection and application.

References

[1] Ajayi, O.O. (2013). Nigeria's energy policy: Inferences, analysis and legal ethics towards RE development, *Energy Policy*, *60*, 61–67.

[2] Ajayi, O.O. (2013). Sustainable energy development and environmental protection: The case of five West African Countries, *Renew. Sustain. Energy Rev.*, *26*, 532–539.

[3] Ajayi, O.O. (2011). Development of Wind Energy Models and Maps for Nigeria. Ph.D. Thesis, Covenant University, Ota, Nigeria.

[4] Asiegbu, A.D.; Iwuoha, G.S. (2007). Studies of wind resources in Umudike, South East Nigeria—An assessment of economic viability, *J. Eng. Appl. Sci.*, *2*, 1539–1541.

[5] Balouktisis, A. Chassapis D. and Karapantsios, T. D. (2002). A nomogram method for estimating the energy produced by wind potential generators, *Solar Energy*, 72(3) , 251- 259.

[6] Celik, A.N. (2003). Assessing the Suitability of Wind Energy Speed Probability Distribution

[7] Functions Based on Wind Power Density, *Renewable Energy*, 28, 1563 - 1574.

[8] Chang, T.J. Wu, Y.T. Hsu, H.Y. , Chu C.R and Liao, C.M. 2003. Assessment of Wind

[9] Characteristics and Wind Turbine Characteristics in Taiwan, *Renewable Energy*, 28, 851 - 871.

[10] ECN-UNDP (Energy Commission of Nigeria-United Nations Development of Nigeria) (2005). Renewable energy master plan: Final draft report, Available online: http://www.iceednigeria.org/ REMP%20Final%20Report.pdf (accessed on 12 August, 2017).

[11] Fadare, D.A. (2008). Statistical analysis of wind energy potential in Ibadan, Nigeria, based on weibull distribution function, *Pac. J. Sci. Technol*, *9*, 110–119.

[12] Fadare, D.A. (2010). The application of artificial neural networks to mapping of wind speed profile for energy application in Nigeria, *Appl. Energy*, *87*, 934–942.

[13] Fagbenle, R.O.; Katende, J.; Ajayi, O.O.; Okeniyi, J.O. (2011). Assessment of wind energy potential of two sites in North East, Nigeria. *Renew, Energy*, *36*, 1277–1283.

[14] Fagbenle, R.O., Katende, J., Ajayi, O.O. and Okeniyi, J.O. (2011) Assessment of Wind Energy Potential of Two Sites in North-East, Nigeria, *Renewable Energy*, 36, 1277-1283.

[15] Iheonu, E. E. Akingbade F. O. A. and Ocholi, M. (2002). Wind resource variations over selected site in the West African sub –region, *Nigerian Journal of Renewable Energy*, 10(1&2), 43-47.

[16] Justus, W. R. Harngraves W. R. and Yalcin, A. (1976). Nationwide assessment of output from wind power generators, *Journal of Applied Meteorology*, 15, 673-678.

[17] Lu, L. Yang H. and Burnett, J. (2002). Investigation on Wind Power Potential on Hong Kong

[18] Islands - An Analysis of Wind Power and Wind Turbine Characteristics, *Renewable Energy*, Vol. 27, 1 - 12.

[19] Medugu, D.W. and Markus, A, (2011). Wind as a Viable Source of Energy for Fluctuation of Electric power in Yola, *Ozean Journal of Applied Sciences* 4(1), 41 – 50.

[20] Mathew, S. Pandey K.P. and Anil K. V., (2002). Analysis of Wind Regimes for Energy Estimation, *Renewable Energy*, 25, 281 - 399.

[21] Ngala, G.M.; Alkali, B.; Aji, M.A. (2007). Viability of wind energy as a power generation source in Maiduguri, Borno state, Nigeria, *Renew, Energy*, *32*, 2242–2246.

[22] Ogbonnaya, I.O.; Chikuni, E.; Govender, P. (2007). Prospect of wind energy in Nigeria. Available online: http://active.cput.ac.za/energy/web/due/papers/2007/023O_Okoro.pdf (accessed on 20 July 2017).

[23] Persaud, S. Flynn D. and Fox, B. (1999). Potential for Wind Generation on Guyana Coastlands, *Renewable Energy*, 18, 175 - 189.

[24] Suleman, L. N., (2010). Thesis of Vaasan ammattikorkeakoulu. University of Appied science, *Renewable Energy as a Solution of Nigeria Energy Crisis*.

[25] Weisser, D. (2003). A Wind Energy Analysis of Grenada - an Estimation using the 'Weibull'

[26] Density Function, *Renewable Energy*, 28, 1803 - 1812.