Assessment Of Wind Energy Potential For Electricity Generation In Sokoto,Nigeria

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ABSTRACT

Nigeria depends on thermal and hydropower for electricity supply which has over the years proved inadequate, especially in the rural areas where about 70% of citizens live. This is despite governments efforts at meeting the energy needs of the teeming population. The electricity generation is dominated by fossil fuels with attendant consequences of environmental pollution, contribution to global warming and the source being finite. On the other hand, it has been discovered that the country possesses large amount of renewable energy sources which can be harnessed to supplement the energy supply capacity. The area under consideration is found to be suitable for many renewable energy investments. Wind energy, being part of renewable energy is abundant in this part of the country. This paper considered wind data recorded for the site obtained from the National Meteorological Agency, (NIMET), for one year and calculated different parameters using Weibull distribution function and concluded that wind energy if properly utilized can provide a cost effective energy source in the long run. The average annual wind speed for the year 2010 was 5.15m/s which is sufficient for electricity generation. The maximum monthly mean wind speed was found in January with a value of 6.22m/s and the annual extractable energy for year was calculated as 608.1144kWh/year.

Key Words: Wind power, Renewableenergy, Electricity generation,Weibull distribution,

Paper presented at 1st international conference on renewable energy by SOLARAFRICA at UsmanuDanfodioUniversity,Sokoto,Nigeria from 12-15 December,2012

Introduction

Nigeria depends on thermal and hydropower for electricity supply which has over the years proved inadequate. As a matter of fact, energy has been a major challenge in the country. Despite governments efforts at meeting the energy needs of the populace, the total generation in 2007 was put at a total installed capacity of 7876MW (75.9%thermal and 24.1%hydro), available capacity of 4914MW (67.8% thermal and 32.2% hydro) and an operational capacity of 3149MW (68.2%thermal and 31.8% hydro)(Ohunakin,2011).This shows that for a nation with a population of over 150 million people, this production level is very insufficient. In addition, the electricity generation is largely dominated by fossil fuel sources. Fossil fuel generators produce emissions that are toxic and as such degrade the environment. It has been estimated that only about 40% of the population have access to grid electricity and at the rural areas ,where about 70% of the population lives, the availability of electricity drops to 15%.Furthermore, it was shown in Ohunakin,2011, that the projected energy demand form 2005-2030 showed an increasing trend on the four adopted scenarios.

Thus, it becomes imperative to fully exploit renewable energy sources vastly available in the country so to supplement conventional sources, avoid energy crisis and improve access to electricity to achieve sustainable national development. The federal government has embarked on series of reforms since 2001 with the preparation of National Electric Power policy leading to theliberalization of the power sector in 2005 through the passage of the Electric Power Sector Reform Act (EPSR) and establishment of the Nigerian Electricity Regulatory Commission and the Rural Electrification Agency (REA). This is aimed at breaking the monopolistic framework in the power sector to allow private operators to apply and obtain a license to build and operate power plants with aggregate capacity above 1MW and fully incorporate renewable energy in the energy options. The contribution of hydro power to the total electricity generation though substantial, has been observed to be decreasingbecause as reported by Ohunakin, 2011, water inflow into the Kainji Lake that feeds Kainji and Jebba power plants has dropped as a result of climate change and the power dam initiated by Niger republic on the Niger river. Renewable energy sources such as wind, if thoroughly investigated, could be used to reduce the dependence on fossil fuels for electricity generation.

According to Sambo, 2005, the projected electricity supply by fuel-mix by the Energy Commission of Nigeria reflected a good contribution from wind energy among renewable energy sources. However, despite the potential of wind as a source of energy in the country, its contribution to the total energy consumption has been very insignificant.

Although wind energy is one of the most efficient energy sources, it is very variable compared to other sources of energy. It is also more sensitive to variations with topography and weather patterns compared to solar energy. Wind energy can be harvested at an economical level if the wind turbine issited in windy area and a careful choice of the type of wind turbine that matches the wind pattern of the site is made. Thorough knowledge of the wind speed characteristics at a site of interest is very important in planning to harvest wind energy.

The attempts so far made at harnessing the wind energy potentials in the country have not made much impact as there is no wind power plant connected to the national grid anywhere in Nigeria. The few existing ones are pilot wind electricity schemes which include the 5kWp Sayya, Gidan Gada, 2kWp at Danjawa Renewable energy model village,both in Sokoto and 1kwp at Energy Research Centre, Benin. But the most ambitious project to date is the 10MW wind farm under construction in Katsina State. Hence the progress in tapping the resource has been rather slow despite the fact that records show that wind pumps for rural water supply were established in some parts of the north like Katsina,Bauchi and Sokoto since 1960s(Idris et al,2012).

Studies on the vast potentials of renewable energies in Nigeria have been conducted by various writers and scholars such as Sambo,2005 &2007, Mnse&Ojo,2009,Ohunakin,2011,Adaramola et al,2011,Idris et al,2012 and Saddik etal ,2012 among others. These studies revealed some parts of the country endowed with strong conditions like the coastal areas and the offshore states such as Lagos,Ondo,Delta, Rivers,Bayelsa,AkwaIbom,the inland hilly regions of the north like Sokoto, Kano ,Katsina,Kaduna,the mountain terrains in the middle belt like Plateau and the northern part of the country(Saddik et al,2012). Consequently, several papers were published to determine wind characteristics and electricity generation cost.

The Site

Sokoto town lies in the northwestern part of Nigeria, with latitude 12.28 ˚N and longitude 04.13˚E as well as an elevation of 220.0m .According to Adaramola and Oyewola,2011,the monthly mean wind speed range for the northwest region is 1.9m/s- 3.9m/s and the corresponding mean wind speed range is 2.39m/s-3.59m/s.

Analysis of wind speed data

To evaluate the wind power potential for a particular location, parameters such as wind speed and direction are measured usually using instruments like anemometers and wind sensors.Thereafter, the recorded data is interpolated and extrapolated with measured data in order to obtain a general profile of the wind resource potential for the chosen site.However,long term data study and analysis usually gives a better picture of wind resources since both calm and windy periods can be adequately captured.Nonetheless,one year study can give an illustration of available wind energy that can be harvested in an area as well as serve as a basis for future studies, projects and research.

Monthly mean wind speed is used to study seasonal change in wind speed and as reported in Adaramola and Oyewola,2011,it facilitates wind data analysis. Wind speed data for this paper are collected at 10m height, but for any particular wind energy conversion system, it is important that the wind speed be estimated at the respective turbine hub height.

$$\frac{v}{v_o} = \left(\frac{h}{h_o}\right)^{\alpha} \quad \ldots\ldots (1)$$

Where v is the wind speed at the required height, $v_\circ$ is wind speed at reference height $h_\circ$ and α is the surface roughness coefficient, which in this paper is taken as 0.143 (i.e. 1/7)

Evaluation of electric power and energy from wind speed

The available power, p (W/m^2) from the given wind speed,v can be obtained from this relation;

$$P=0.5\times\rho\times v^3 \quad \ldots\ldots (2)$$

Where ρ is the average air density (assumed in this paper as 1.22),Adaramola &Oyewola,2011

The available energy in aspecified period is given by the product of the power and the number of hours in a year and further converted to standard units of electricity (i.e. kWh) by multiplying the available energy by a factor of 0.001

Mathematical model

In the analysis of the data, the two parameter Weibull distribution function is employed as given in Ohunakin,2011. The probability density function and the cumulative distribution functions of the Weibull are given as equations (3) &(4) respectively;

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k.1} \exp\left[-\left(\frac{v}{c}\right)^{k}\right], \text{(K>0, V>0, C >1)} \quad \ldots(3)$$

$$F(v)=1-\exp -(v/k)^{k} \quad \ldots(4)$$

Where k=Weibull shape parameter and c=Weibull scale parameter

For evaluating k and c, the submission of Adaramola and Oyewola,2011,using standard deviation methods is used in this paper as

$$k = (\sigma/Vm)^{-1.086} \; (1 \leq k \leq 10) \quad \ldots(5)$$

$$c = \frac{v}{\Gamma\left(1-\frac{1}{k}\right)} \quad \ldots(6)$$

Where Γ= gamma function which is defined as;

$$\Gamma = \int_{-v}^{\infty} e^{-u} U^{x-1} du \quad \ldots(7)$$

Another approach is given by Lysen in Pam et al,2008 as

$$\frac{c}{v} = (0.568+0.433)^{-\frac{1}{k}} \quad \ldots(8)$$

For wind energy estimation, the two significant wind speeds are the most probable (V_{mp}) and wind speed carrying maximum energy (V_{maxE}).These are calculated as given in Ohunakin, et at 2011;

$V_{mp} = C\left(1-\frac{1}{K}\right)^{1/K}$ m/s ………………………………………………………………….. (9)

$V_{maxE} = C\left(1-\frac{2}{K}\right)^{1/K}$ m/s …………………………………………..(10)

It is essential that for a wind turbine to operate at maximum efficiency the rated wind speed and the maximum energy wind speed should be as close as possible.

Estimation of Wind Energy

The extractable mean daily, monthly energy and annual energy are defined by following relationship (Ohunakin, et al, 2011) as;

$$\bar{E}_j = 24\times10^{-3}\bar{P}_T \left(kWh/m^2\right) \quad (11)$$

$$\bar{E}_{jm} = 24\times10^{-3} d\, \bar{p}_T \left(kWh/m^2\right) \quad (12)$$

$$\bar{E}_a = \sum_{n=1}^{n=12} \bar{E}_{jm} \left(kWh/m^2\right) \quad (13)$$

Where $\bar{P}_T = P_{(V)}$ in (W/m^2) and d is the number of days in the month considered.

RESULTS AND DISCUSSION

Wind Speed Patterns

The average mean wind speed during this period was 5.15m/swhile the monthly mean wind speed at Sokoto was above the annual average from the month of January to June (table 1) .From the month ofAugust; it was about 4.88m/s to 4.62m/s in December and was fairly steady (fig.1). The period of high wind speed coincides with dry season when the northern part of the country was usually dry and the use of wind energy for electricity generation would help alleviate the shortage of hydroelectricity that results from the low level of water in the Niger River.

Table 1: Monthly mean wind speed (m/s)

Location	Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sokoto	2010	6.22	5.30	5.64	5.54	5.33	5.21	5.06	4.88	4.72	4.63	4.65	4.62

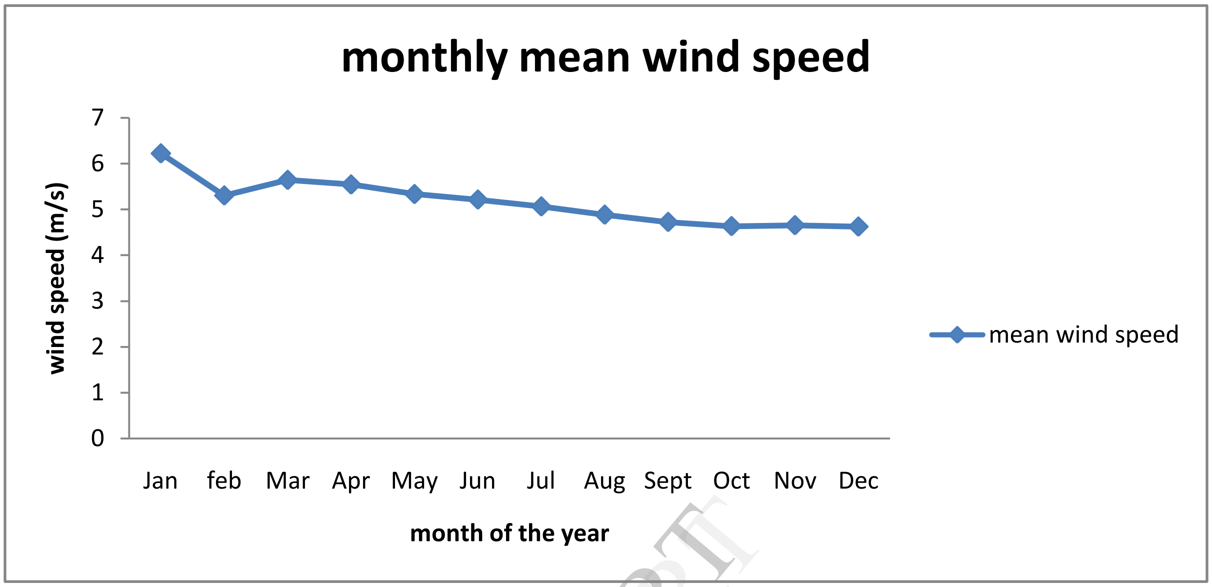

Figure 1: Monthly mean wind speed

The period of low wind speed is also mainly the wet season in the area when there is usually sufficient water in the rivers to run the hydroelectric plants. Similarly, the wind speeds in this period falls in the class 4 range which is strong enough for electricity generation (Ohunakin,2011).

The measurement of the data was done at 10m height but was extrapolated to 50m, which is the standard height for most wind turbines, using the power law equation (table 2).

Table 2: Extrapolated wind speed

Month	V10(m/s)	V50(m/s)
January	6.22	7.83
February	5.30	6.67
March	5.64	7.10
April	5.54	6.97
May	5.33	6.71
June	5.21	6.56
July	5.06	6.37
August	4.88	6.14
September	4.72	5.94
October	4.63	5.83

ISSN: 2278-0181
Vol. 2 Issue 6, June - 2013

November	4.65	5.85
December	4.62	5.81

It can be observed that the extrapolated values of the wind speed gives a fairly higher range thereby suggesting that a wind turbine with a 50m hub height is appropriate for harnessing wind energy for electricity generation.

Wind Power

According to Dahmouni et al cited in Ohunakin (2011), wind power density of a location is the most important parameter to be considered in citing a wind energy conversion system (WECS) as it takes into consideration the wind speed, wind speed distribution and air density. The figure below gives the mean power density for the site in the period under study.

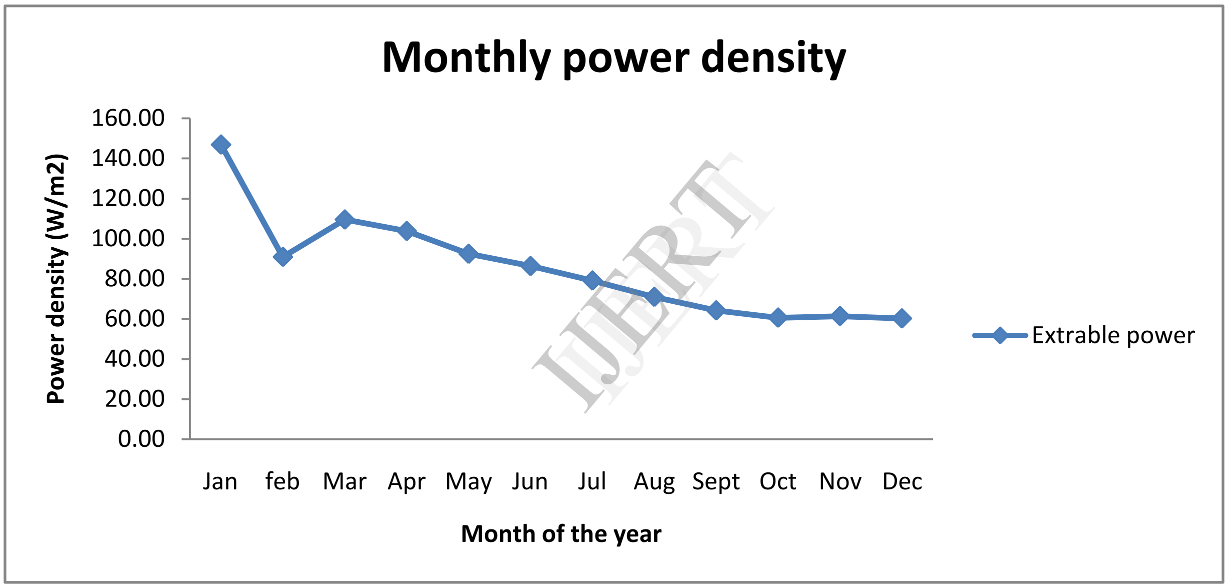

Figure 2: Monthly power density

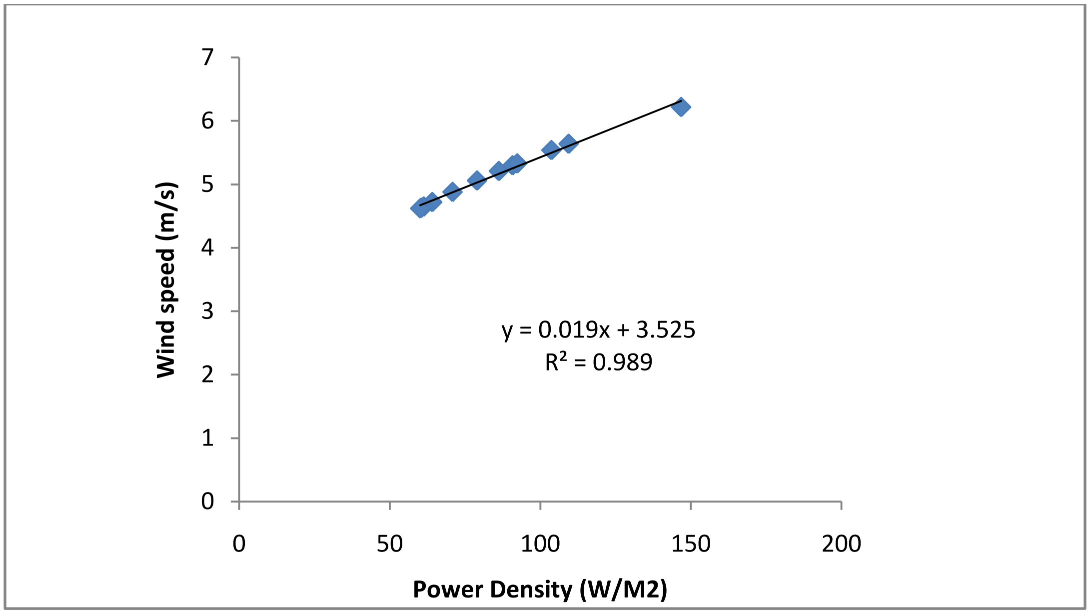

Figure 3: Relationship between wind speed and power density of the location using Linear regression coefficient

The average annual extractable energy density was calculated from equation (2),using the annual average wind speed of 5.15m/s and it was found to be 608.11kwh/year. Similarly, the most probable wind speed was calculated and the maximum was found in the month of September as 0.932 m/s and the wind speed carrying maximum energy was highest in November with the value of 1.054m/s.

Month	Vmp	VmaxE	
January	0.071	0.085	
February	0.063	0.073	
March	0.068	0.079	
April	0.728	0.074	
May	0.866	1.028	
June	0.891	1.029	
July	0.833	1.038	
August	0.830	1.039	
September	0.932	1.042	
October	0.850	1.031	
November	0.803	1.054	
December	0.901	1.031	

Table 3: Measured Vmp and VmaxE for Sokoto in 2010

The results obtained in the preceding paragraphs were in agreement with many of the available literature on the area. The Weibull parameters were also calculated and can be used to assess the particular type of WECS suitable for the site.

Month	Power density	k-value	c- value
January	146.79	3.93	0.077
February	90.81	4.42	0.067
March	109.43	4.24	0.072
April	103.72	4.39	0.068
May	92.37	4.02	0.930
June	86.26	4.40	0.945
July	79.03	3.54	0.915
August	70.89	3.50	0.913
September	64.14	5.01	0.975
October	60.54	3.78	0.922
November	61.33	3.19	0.905
December	60.15	4.57	0.952
Annual	1025.488	49.00	7.740

Table 3: Monthly and annual variation of Weibull parameters (k and c) for the site

The table above shows the monthly and annual variation of Weibull parameters at 10m height at the selected location. It can be observed that the lowest value of Weibull shape parameter(k),was 3.19 in the month of November and the highest value of 4.57 was recorded in December. However, despite slight variation in January, the shape parameter,(c) was generally constant from December to May within the range of 4.0 – 4.5, which indicates that the wind speed is fairly uniform in this period. The monthly scale parameter has the highest value of 0.975m/s in September and the lowest value of 0.066m/s in February at the site.

Conclusion

The wind energy potential of was analyzed based on the wind data for 2010 using two parameter Weibull distribution. The results can be concluded as follows:

-The minimum monthly mean wind speed is recorded in the month of December as 4.62m/sand the maximum was6.22m/s in January

-Weibull shape parameter varies from 3.19 to 5.21 while the scale parameter is between 0.67 and 0.952m/s

-The relationship between mean power density and mean wind speed is expressed in the form of linear regression coefficient,R^2= 0.9899

-The lowest average power density and energy are obtained in the month of December as 60.153 and35.671 respectively. The months of September and November have the highest values for

Vmp and VmaxE with 0.932 and1.054m/s respectively, while the lowest values are available in the month of February as 0.063 and 0.073 respectively.

=The annual extractable energy for the year was calculated as 608.2244kWh/year.

Evidently the amount of electricity that can be generated from wind energy in this location can be said to be fairly reasonable compared to other parts of the country. Because as reported in Ohunakin, (2011) and further reaffirmed in this paper, the site conveniently falls in class 4 category in the classification of wind energy resource potentials which makes it a very good location at height of 10m for wind energy development. Therefore if proper wind turbines that can harness wind energy at an optimum level are installed at this site, electricity can be produced to complement the persistent shortfall in the supply from the national grid as well as forsmall application like water pumping among others, especially in the rural areas.

Recommendations

Rural electrification is now and will remain an essential element for rural development in Nigeria. Wind power scheme can provide an economical and environmentally sustainable option for meeting energy needs of the rural populace of the country. This can be achieved through deliberate and strong measures and policies such as:

The building of institutional framework to support wind energy development; for instance establishment of Renewable Energy Commission of Nigeria

The adoption of incentive based actions to spur renewable energydevelopment; like provision of special grants for research in renewable energy, subsidy on renewable energy equipment and sponsors for studies on renewable energy.

The implementation of market transformation strategies to encourage renewable energy development; such as low tax on importation of renewable energy equipment, encouraging local manufacturing and fabrications as well as patronizing renewable energy programs and projects.

The enhancement of international cooperation to promote wind energy technologies; in the form of encouraging foreign direct investment on renewable energy projects, sourcinginternational scholarships for renewable energy programs and projects and promoting participation and cooperation in global renewable energy activities.

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