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STATISTICAL ANALYSIS OF WIND SPEED FOR ELECTRICAL POWER GENERATION IN SOME SELECTED SITES IN NORTHERN NIGERIA

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ABSTRACT

In this paper, statistical analysis is carried out to determine the accurate frequency distribution that fits wind speed data. The frequency distributions used include Weibull, Rayleigh and Gamma distribution functions. The performances of the probability distributions are based on the error evaluations between the predicted and the theoretical wind power densities of the site. The Results show that Weibull distribution modelled the wind speed better compared to other distribution functions. According to the European Wind Energy Association, most of the sites are suitable for the generation of electrical energy. Also, the results have shown that Jos, Kano and Minna fall in class 4 and therefore suitable for both off grid and grid connected modes. In addition, the effects of c and k parameters on the probability distribution functions have been presented.

Keywords: *Wind speed - probability - density function – wind energy conversion system- statistical analyses*

1. INTRODUCTION

In order to predict and model the potential of any site, either historical records of the renewable energy potentials or statistical methods are employed. Site potential analysis is considered the first step in the design of any system of renewable energy sources. In order to use historical records from the site, it is recommended that data for at least 3years and above are used. But for areas with sparse or limited data, a year measurement may be adequate to at least describe the seasonal variability of the wind-speed. Some of the drawbacks of the historical approach include data accuracy, time, technical challenges and expense. These may result in unrealistic or inaccurate predictions. Recently, statistical methods have gained much popularity. Some reasons for this are economy, shorter times and the possibility of predicting the behaviour of the system with less error [1]. Therefore, statistical methods are now employed for the analysis of renewable energy resources. Statistical distributions used for the assessment of the renewable energy potential at a site include Weibull, Gamma, Lognormal, Rayleigh and Pearson type three to mention but few.

Much work has been carried out in analysing the renewable energy potential of particular sites. The wind-energy potential of Penjwen region, Iraq has been investigated in [2], the Weibull distribution was found to fit the wind-speed data. Statistical analysis of wind-speed data for Malaysia using lognormal and Weibull distributions are given [3]. In addition, Weibull distribution is proposed to fit the wind speed energy potentials of Tehran [4]. Similarly, the Weibull distribution also fit the wind-speed data of Turkey [5]. At some sites, the Weibull is not suitable, and it was found that Burr, lognormal and gamma distributions performed better than Weibull, Rayleigh or Freshet distributions in Pakistan [6]Another application of statistical analysis of wind-energy potentials includes analysis of wind data in India [7].

Previous works in the wind energy potential of some sites in Nigerian have been reported in [8]-[12] However, while these works reported that the wind speed in Nigeria varies from 2 to 9.5 m/s. The reported figure in the literature could be related to the time, measurement, accuracy of the data used and the method of data analysis. Mean wind speed and power densities of about 30 locations for period of 8 to 30 years were obtained in [8]. Authors in [9] reported the maximum extracted wind power and mean wind speed across the six geopolitical zones in Nigeria. In similar

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way, authors in [10] have fitted Weibul, normal, gamma, and Raleigh distributions for 8 locations in Nigeria. Wind speed analysis in [11], is based on 2-parameter Weibull distribution which may not accurately fit the wind speed data of all the sites. Furthermore in [12] Gumbel and the Weibull probability distributions were used show the economic viability of using wind energy resources at Calabar, Warri and Katsina

In this paper the probability distributions mentioned are employed to fit wind speed data of some selected sites in Northern Nigeria. This is because the design of wind energy conversion systems depends on the correct analysis of the site renewable energy resources [13]. In addition, the statistical judgements are based on the accuracy in fitting the available data at the sites.

1.1 Determination of the Mean Wind Speed

Wind speed is the fundamental factors considered in the development of wind energy conversion systems. The judgements begin with the determination of the mean wind speed, which acts as an important parameter in the wind-power generation system. Therefore, the mean wind speeds, for some sites were obtained from data collected over a period of one year. The data involved are sampling of wind speed and solar radiation at 5 minute intervals. The Quarterly samples of the wind speed data used in the analysis are shown in Figures 1 to 4 for January, April, August and December respectively.

The mean wind speed, v_m of the site is normally obtained using Equation (1). Using this method may lead to underestimation of the site potential [14]. However, the month-to-month wind-speed variation of a particular site can vary between -30% to +30 % of the annual average [15].

$$v_m = \frac{1}{N}\sum_{i}^{N} v_i \qquad (1)$$

where v_i is the wind observed, and N is the data point.

Regardless of the shape and scale parameters, use of mode or the mean wind speed in the power density equation would always introduce a significant error in the energy estimate. It can alter the result by several folds, therefore making the estimate useless. Therefore, for the assessment of the site power density due to the wind speed, root mean cube (RMC) speed is used. The expression for the RMC speed, v_{rmc} is given in Equation (2). Therefore, in this paper RMC speed is used, and always provides a correct estimate [14].

$$v_{rmc} = \sqrt[3]{\frac{1}{N}\sum_{i=1}^{N} {v_i}^3} \qquad (2)$$

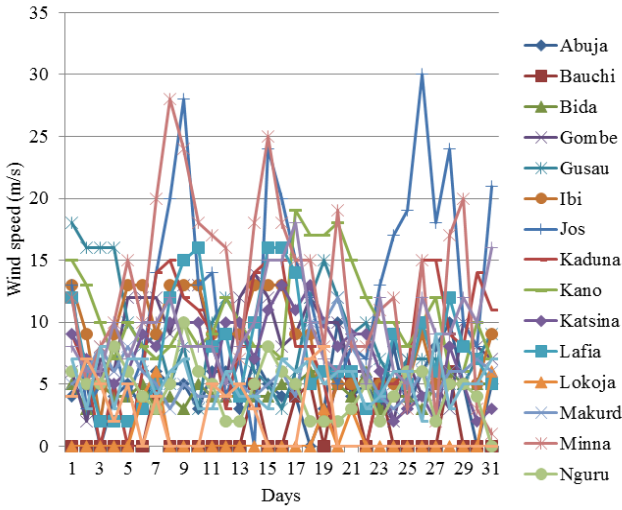

Figure 1: Sites wind speed for the January

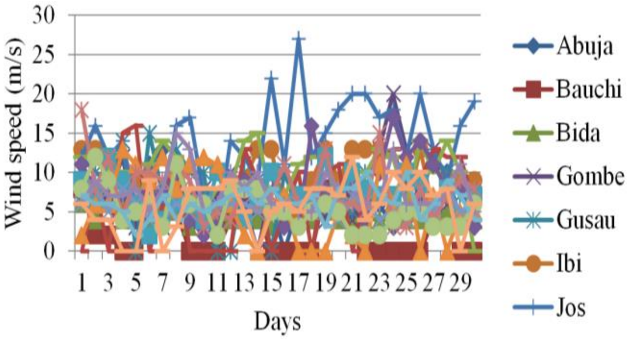

Figure 2: Sites wind speed for the April

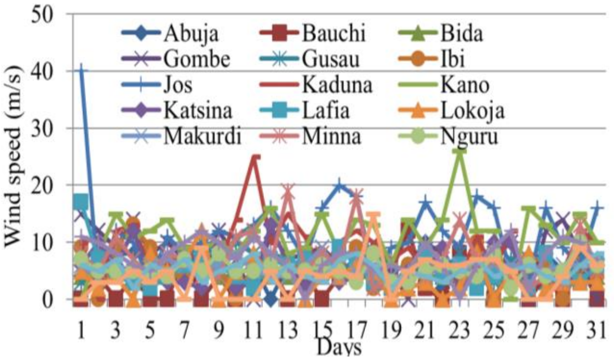

Figure 3: Sites wind speed for the August

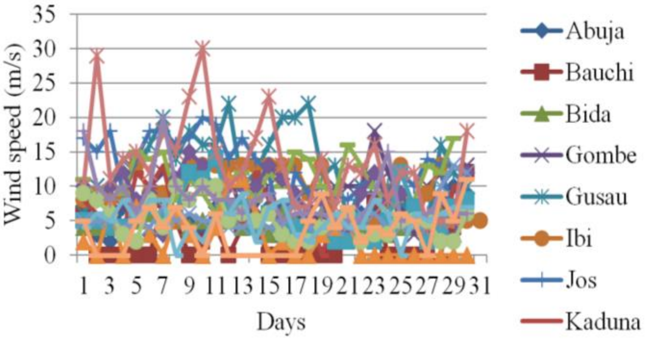

Figure 4: Sites wind speed for the December

1.2 Estimation of the Average Wind-Power Density

The average wind-power density can be defined as the annual average power per unit area. In other words, it can be regarded as the power passing to a site through an area of 1m^2 perpendicular to the wind as defined in Equation (3).

$$P_w = \frac{1}{2}\rho\, v_{rmc}{}^3 \qquad (3)$$

where P_w is the average wind-power density at the given site and ρ is the observed air density. The air density is assumed to be constant due to the absence of this from the measured data, and a value of 1.225 kg/m^3 is used. Average wind-power density is given by [16]

$$\overline{P_w} = {}^1/_2\,\rho \sum_{i=1}^{N} P(V_i) * V_i^3 \qquad (4)$$

Equation (4) gives the actual or true power in the wind speed if the probabilities $P(V)$ are determined from the actual wind-speed data. On the other hand, if a probability density function $f(v)$ is used to model the average power in the wind speed, the average power density is given by

$$\overline{P_w} = {}^1/_2\,\rho \int_0^\infty V^3.f(v).dv \qquad (5)$$

Depending on goodness of fit, if the probability density function fits the actual data, the power predicted by Equations (5) and (3) will be the same. The probability distribution used in the analysis of wind-energy potential includes the Weibull, gamma and Rayleigh distributions [5].

1.3 Weibull Distributions

The Weibull distribution is one of the most widely used probability distributions in wind-speed applications. Many research papers, including [17], have defined the Weibull distribution for wind-energy analyses. The mathematical expression of the Weibull distribution is presented in Equation (6) [17] .

$$f_w = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} e^{\left(-\frac{v}{c}\right)^k} \qquad (6)$$

and the cumulative distribution function is

$$F_W = 1 - e^{\left(-\frac{v}{c}\right)^k} \qquad (7)$$

where c is the scale parameter and k = shape parameter.

The probability of the wind speed prevailing at a given site is obtained by the evaluation of c and k parameters. Therefore, accurate modelling using the Weibull distribution is based on the accuracy of c and k parameters. Several methods exist for the evaluation of these parameters [**18**]. One of these methods is the mean-standard deviation. c and k parameters are evaluated using Equations (8) and (9) [18]..

$$k = \left(\frac{\sigma}{V_m}\right)^{-1.086} \qquad (8)$$

$$c = \frac{V_m}{\Gamma(1+\frac{1}{k})} \qquad (9)$$

where Γ is the gamma function, σ is the standard deviation and V_m is the mean wind velocity of the sites. The results of Equations (8) and (9) are tabulated in Tables 1. Once the shape and scale parameters are known, the site average power densities can be obtained using c and k parameters. In this case, the Weibull average wind-power density is obtained using Equation (10) [**17**].

$$WPD_w = \frac{1}{2}\times\rho\times c^3\Gamma\left(1+\frac{3}{k}\right). \qquad (10)$$

The mean wind speed of the Weibull distribution in terms of c and k parameters is expressed in Equation (11)

$$V_m = c\Gamma\left(1+\frac{1}{k}\right). \qquad (11)$$

1.4 Rayleigh Distribution

The Rayleigh distribution probability density function is defined in [**17**]

$$f(v) = \left(\frac{\pi V}{2V_m}\right)\times e\left(-\frac{\pi}{4}\right)\times\left(\frac{V}{V_m}\right)^2. \qquad (12)$$

where V_m is the mean wind speed, and the cumulative distribution function is given by

$$F(v) = 1 - e\left(-\frac{\pi}{4}\left(\frac{V}{V_m}\right)^2\right) \qquad (13)$$

The variance of this distribution function is obtained using Equation (14)

$$\sigma^2 = \left({}^4/_\pi - 1\right)\times V_m{}^2 \qquad (14)$$

Using a similar approach, the average wind-power density is expressed in Equation (15)

$$WPD = {}^3/_\pi\times\rho\times V_m{}^3 \qquad (15)$$

Rayleigh distribution is special case of Weibull distribution with a value of k =2. Therefore the mean wind speed of this distribution is obtained by

$$V_m = c\sqrt{\frac{\pi}{4}} \qquad (16)$$

Also, the Rayleigh wind-power density is defined as

$$WPD_R = {}^3/_\pi\times\rho\times\left(c\sqrt{\frac{\pi}{4}}\right)^3 \qquad (17)$$

1.5 Gamma Distribution

The gamma probability density function of a data with shape α and scale β parameter is defined by

$$f(x;\ \alpha,\beta) = \frac{x^{\alpha-1}}{\beta^\alpha\Gamma(\alpha)}e\left[-{}^x/_\beta\right], \qquad x > 0, \beta > 0 \ (18)$$

and the cumulative distribution function is defined as

$$F(x) = \frac{\Gamma({}^x/_\beta)\alpha}{\Gamma(\alpha)}. \qquad (19)$$

where Γ (x) is the gamma function.

In the same way, the expression for wind-power density for a gamma function in terms of c and k parameter is given by:

$$WPD_{Gam} = \frac{1}{2}\rho \times c^3[k(k+1)(k+2)] \tag{20}$$

1.6. Goodness of Fit

Several tests exist for predicting the accuracy of the probability density function of the sites. Some of the methods include root mean square error (RMSE) [19], chi-square test (x^2), correlation coefficient (R), and coefficient of determination (COD) [20]. In this section, the performance of the model in predicting the wind-power densities of the sites is assessed by the value of percentage errors as follows [21]:

$$monthly\ error(\%) = \frac{P_x - P_A}{P_A} \times 100\%,\quad x = W, R, G \tag{21}$$

Similarly, the annual mean error of the power density is defined in Equation (22).

$$annual\ mean\ error(\%) = \frac{1}{12}\sum_{i=1}^{12}\frac{P_x - P_A}{P_A} \times 100\%,\quad x = W, R, G \tag{22}$$

where P_x is the Weibull, Rayleigh and gamma distributions power density and P_A is the actual power density of the site determined from the actual wind speed. The comparison is obtained by quantifying the errors evaluated in Equations (21) and (22). The closer the error is to 0%, the more accurate is the model in predicting the wind-power density of the site.

1.7. Application of the Procedure

The proposed procedure is tested on data for some sites shown Figure 5. The results of the analyses are presented in Tables 1. The result presented Weibull, Rayleigh and gamma function fitting parameters for the sites under consideration. In Table 1, a lower value of $k < 2$ shows a greater deviation about the mean wind speed. On the other hand, a higher value of $k > 2$ indicates a small variation about the mean wind speed.

The annual average power densities and Monthly percentage errors (%) of the sites are presented in Table 2. The result shows that the average wind-energy density predicted is 489.412, 820.235 and 480 W/ m^2 for Weibull, Rayleigh and gamma distributions respectively. Critical observation shows that in all the frequency distributions considered, the wind-energy densities of most sites are different.

In the same way, the annual average errors of wind-speed data are 0.10435, 0.70871and 0.07722 pu for Weibull, Rayleigh and gamma respectively. This shows that the gamma distribution fits best followed by Weibull and Rayleigh distributions in the selected sites. The performance of the individual site shows that the Weibull distribution fits the recorded data better in most cases compared to both Rayleigh and gamma distributions. The whole analysis shows that the Weibull distribution fits best in all the sites, followed by gamma distribution on a site basis. In addition it is observed that, wind speed distribution varies with state in northern Nigeria.

Table 1: Scale and shape parameters of different distribution for selected sites

PDF		Weibull Dist.		Rayleigh Dist.		Gamma Dist.	
Sites	Geographical Location(Long., Lat.)	Parameter					
		k	c	k	c	k	c
Abuja	9^{0}5’N, 7^{0}32’E	2.6897	6.2820	2	6.3119	6.3727	0.9874
Bida	9^{0}5’N, 6^{0}1’E	5.7177	4.6225	2	4.8215	25.1773	0.1830
Gombe	10^{0}17’N,11^{0}10’E	2.5222	9.0399	2	9.0738	5.6372	1.5752
Gusau	12^{0}09’N, 6^{0}40’E	2.6411	9.1233	2	9.1626	6.1768	1.5386
Ibi	8^{0}19’N, 9^{0}51’E	2.9795	8.7252	2	8.8082	8.2765	1.3167
Jos	9^{0}55’N, 8^{0}54’E	3.1175	14.8710	2	15.0481	8.5111	2.0144
Kaduna	10^{0}31’N, 7^{0}26’E	1.5549	7.4513	2	7.7204	2.3962	3.5757
Kano	11^{0}59’N, 8^{0}31’E	2.9506	11.3675	2	11.4551	7.5428	1.4877
Katsina	12^{0}59’N,7^{0}35’E	2.1497	7.4536	2	7.4868	4.2579	1.7006
Lafia	8^{0}29’N, 8^{0}31’E	2.8148	6.2528	2	6.3022	7.0073	0.9935
Lokoja	7^{0}48’N, 6^{0}44’E	1.0454	3.6520	2	4.0832	1.1572	3.5205
Makurdi	7^{0}44’N, 8^{0}32’E	4.8286	6.0020	2	6.1904	19.4048	0.4129
Minna	9^{0}36’N, 6^{0}33’E	2.1513	9.2655	2	9.2998	4.1739	2.2241
Nguru	12^{0}52’N,10^{0}27’E	2.3615	5.9476	2	5.9750	5.0640	1.2444
Sokoto	13^{0}3’N, 5^{0}13’E	3.0813	8.9300	2	9.0292	8.2995	1.1865
Yelwa	10^{0}17’N, 9^{0}47E	3.0409	6.2692	2	6.3394	8.0434	0.8331
Yola	9^{0}12’N, 12^{0}29’E	1.4621	4.7351	2	4.9154	2.1438	2.3529
Annual Average		2.6543	7.3143	2	7.4721	7.2300	1.7767

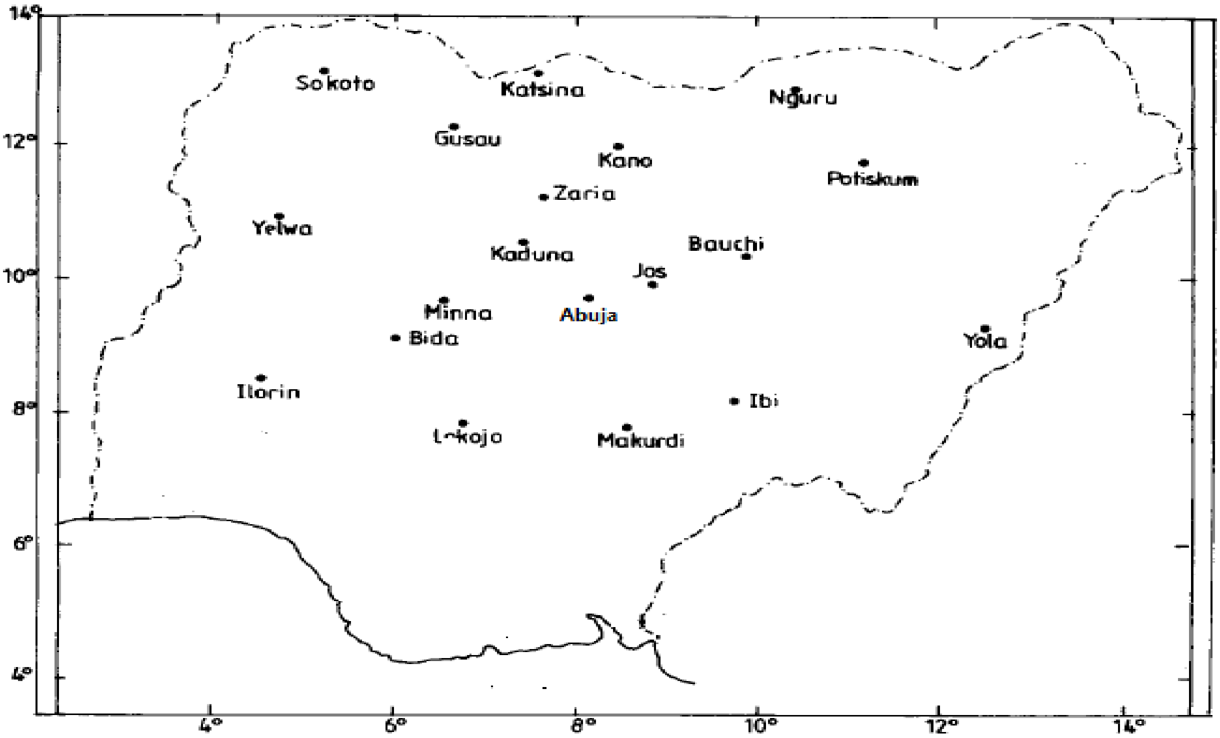

Figure 5: Map of Nigeria showing the sites used in the analysis

Table 2: Annual average wind-power densities and mean error.

PDF	Weibull Dist.		Rayleigh Dist.		Gamma Dist.	
Sites	Parameter					
	WPD (W/m^2)	Error (pu)	WPD (W/m^2)	Error (pu)	WPD (W/m^2)	Error (pu)
Abuja	174	0.0298	306	0.8417	179	0.0585
Bida	55	-0.0014	133	1.4323	55	0.0025
Gombe	538	0.022	918	0.7468	554	0.0533
Gusau	666	0.0338	1132	0.8194	687	0.0632
Ibi	484	0.0299	895	0.8712	496	0.0574
Jos	2147	0.0034	4013	0.9276	2198	0.025
Kaduna	616	0.1452	591	0.1233	627	0.1737
Kano	948	0.0185	1799	0.9328	968	0.0413
Katsina	358	0.0132	573	0.5069	371	0.0535
Lafia	194	-0.0068	334	0.8124	200	0.0187
Lokoja	193	1.1891	102	-0.3274	181	0.3445
Makurdi	126	-0.0004	280	1.269	127	0.0091
Minna	855	-0.0015	1233	0.5097	889	0.0366
Nguru	173	0.0282	269	0.6498	180	0.0632
Sokoto	468	-0.0127	888	0.9027	478	0.0083
Yelwa	161	0.0197	308	0.9431	164	0.042
Yola	164	0.264	170	0.0867	169	0.262
Annual Average	489.41	0.10435	820.24	0.70871	501.35	0.07722

Therefore, the assumption of uniform probability distribution could lead to underestimation or overestimation of wind power density of some sites.

1.8. Effects of c and K Parameters on the Probability Distribution Function

In order to show the effects of c and k parameters on the probability distribution functions, data for the month of January is used. The analysis in section 1.7 has shown that Weibull best fits the wind speed data of the sates. In the same way, Jos has the highest wind energy density compared to other site; the result presented in this section is also sample of the sites. Figure 6 shows a fitting of Weibull distribution in the wind speed data of Jos for a representative month. Therefore, the analysis in this section is based on Weibull distribution function by considering different levels of c and k.The results are shown in Figures 7 to

8. It can be observed that increase in the *k* level by 25% and 50% has a significant effect on the probability distribution shown in figures 7 and 8 by nearly the same factor. In the same way, increase in the *c* by the same factor is shown in Figures 9 and 10. Sharp decrease in the probability distribution is observed compared to the site wind speed. Therefore, the error of prediction becomes more pronounced compared to the original wind speed data.

1.9. Wind Power Classification

According to the European Wind Energy Association (EWEA) classification shown in Table 3, it can be observed that the classes of sites differ. In northern Nigeria, only Bida falls in class 1 and therefore is not suitable for wind-energy development. Abuja, Makurdi, Lafia, Lokoja, Nguru, Yelwa and Yola, are class 2. Those in class 3 include Gombe, Gusau, Ibi, Kaduna, Katsina and Sokoto while Jos, Kano and Minna fall in class 4. Class 2 are usually suitable if tall towers are used, therefore is considered marginal. In addition, Classes 3 and 4 are referred to very good and exceptionally good respectively for wind energy generation [22]. Most of the sites considered are suitable for wind-power generation from off-grid to grid-connected modes.

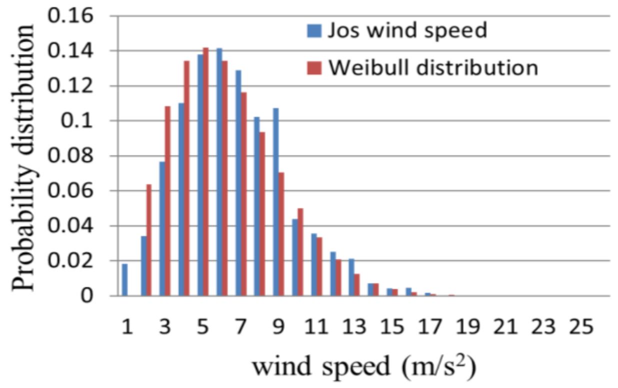

Figure 6: Comparing wind speed and Weibull distribution.

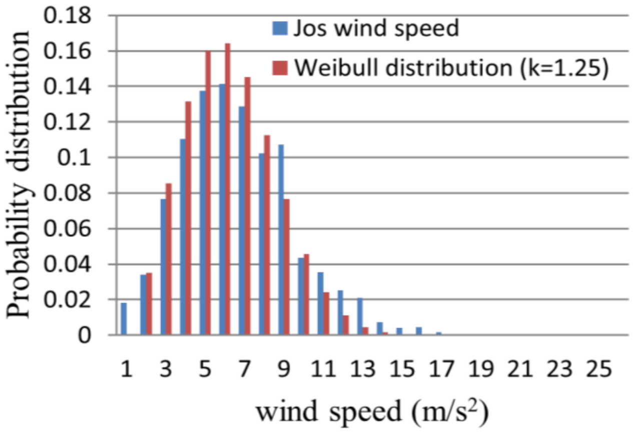

Figure 7: Comparing wind speed and Weibull distribution (25 % increase in k).

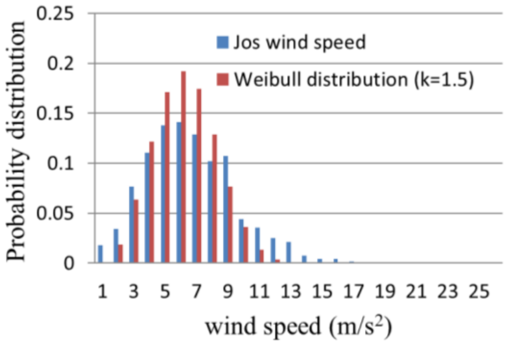

Figure 8: Comparing wind speed and Weibull distribution (50 % increase in k).

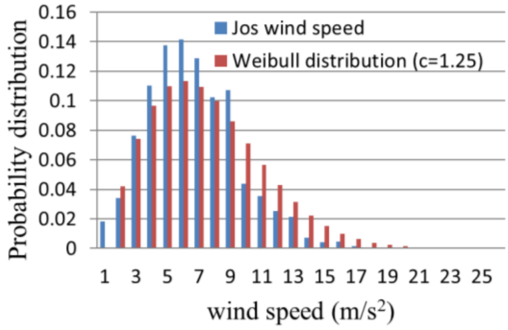

Figure 9: Comparing wind speed and Weibull distribution (25 % increase in c).

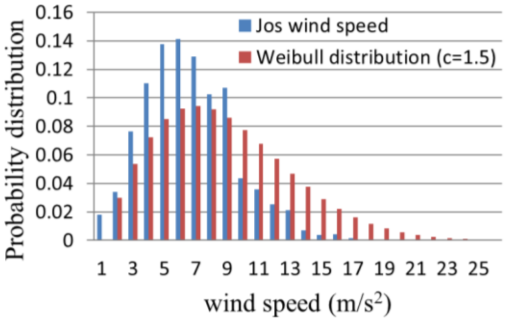

Figure 10: Comparing wind speed and Weibull distribution (50 % increase in c).

Table 3: Wind-energy power classification [23]- [24].

Category	Power (W/m²)	Class
Poor	$P < 100$	1
Fairly good	$100 \leq P < 300$	2
Good	$300 \leq P < 700$	3
Very good	$P \geq 800$	4

1.10. Maximum and Probable Wind Speed

In the analysis of wind-speed data, wind speed carrying the maximum energy (V_{emax}) and the most probable wind speed (V_{mp}) are of exclusive interest to the system planner. Wind speed carrying the maximum energy is used to estimate the rated wind speed. On the other hand, the most probable wind speed is the one which represents the peak of the probability density function [25]. Since the Weibull distribution accurately fits the wind-speed data, these two wind speeds are defined in the Equations (23) and (24) for V_{emax} and V_{mp} respectively [**26**].

$$V_{emax} = c\left(\frac{k+2}{k}\right)^{\frac{1}{k}}. \quad (23)$$

$$V_{mp} = c\left(\frac{k-1}{k}\right)^{\frac{1}{k}}. \quad (24)$$

In order to determine these wind speeds, the simulation is carried out for all the sites under consideration. The results are as shown in Figures 11 and 12. It can be seen that Lokoja and Kaduna have the highest maximum energy carrying wind speed and the most probable wind speed.

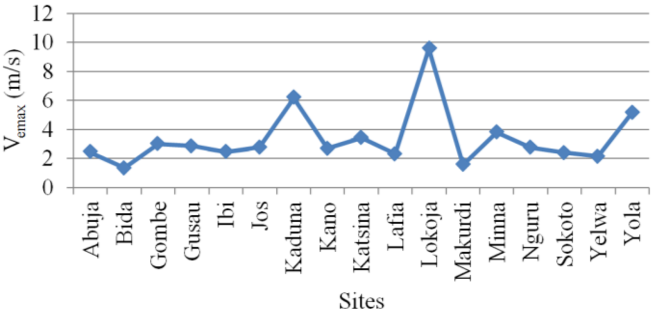

Figure 11: Comparing the maximum energy carrying wind speeds.

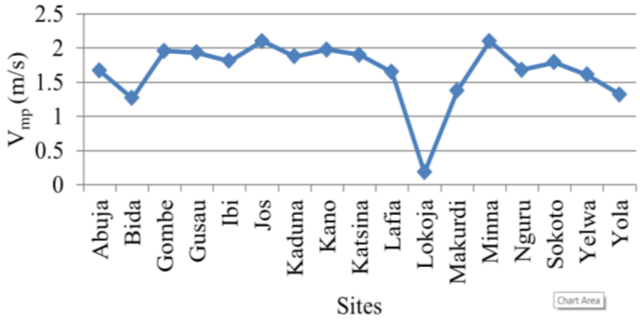

Figure 12: Comparing the most probable wind speeds.

1.11. Electrical Output Power from a Real Wind Turbine

Installing a wind turbine in any site is capital intensive; therefore, it is important to match the site parameters with available wind turbine generators. This will make it possible to estimate the electrical power that could be obtained from the available wind turbine models. Many models are available for simulating the electrical power of a wind turbine generator. The magnitude of the power that can be produced by a practical wind turbine generator is simulated using [27].

$$P_e = \begin{cases} P_r \cdot \dfrac{V_i - V_{ci}}{V_r - V_{ci}} & V_{ci} < V < V_r \\ P_R & V_r \le V < V_{co} \\ 0 & V \le V_{ci} \; or \; V \ge V_{co} \end{cases} \quad (25)$$

where P_r is the rated electrical power, V_{ci} is the cut-in-speed, V_r is the rated wind speed, V_{co} is the cut-off wind speed. The capacity factor of each wind turbine generator is obtained by using equation (26). Table 4 shows the technical parameters of the available wind turbine generators [26].

$$CF = \frac{P_{eav}}{P_R} \quad (26)$$

where P_{eav} = average electrical power.

Table 5 shows the system annual output power for different wind turbine generators. Careful examination of the result shows that wind-energy production over the period is in the range of 2241 kW to 3182 kW for SWT-3.6-107 wind turbine. In the same vain, the annual averages for all wind turbines used in the simulations are 2877, 2137, 2097, 1137 and 1124 kW for SWT-3.6-107, V90, AV928, GE1.5sle and GExle respectively. Comparing the GE 1.5 sle and GE 1.5 xle shows that the rated speed is one of the determinant factors that influenced the output power of a practical wind turbine generator. The trend is the same for all the wind turbine generators analysed. This presentation makes it possible to analyse seasonal variations in wind turbine output power. It is clear that the sequence of wind-energy production in each month of the year varies with time and location. Similarly, the sequence in Jos is November, May, September, June, February, December, March, April, October, July, August and January in that order. This means the system output power is sensitive to both location and the seasonal variation. It can be observed that in both locations, AV 928 has the highest capacity factor, followed by GE 1.5 xle, SWT-3-107 AD, GE 1.5 sle and V90 respectively.

Table 4: Turbine technical parameters.

S/No.	Wind turbine	P_R (kW)	Wind speed (m/s)			Rotor diameter (m)
			v_{ci}	v_R	v_{co}	
1	GE 1.5 sle	1500	3.5	14	25	77
2	GE1.5 xle	1500	3.5	11.5	20	82.5
3	AV 928	2500	3	11.6	25	93.2
4	V90	3000	4	15	25	90
5	SWT-3.6-107	3600	3	13	25	107

Table 5: Comparing monthly output power of Jos

Wind turbine	GE 1.5sle	GE 1.5xle	AV 928	V 90	SWT-3.6-107
January	878	714	1622	1636	2241
February	1153	1183	2155	2144	2942
March	1141	1125	2124	2139	2903
April	1136	1034	2059	2155	2845
May	1254	1280	2297	2369	3161
June	1202	919	2130	2309	3000
July	1071	1074	1960	2006	2717
August	1012	1095	1922	1891	2590
September	1243	1263	2277	2336	3120
October	1136	1222	2132	2129	2903
November	1270	1349	2331	2393	3182
December	1151	1226	2149	2140	2922
Annual Average	1137	1124	2097	2137	2877

Table 6: Different capacity factors for different wind turbines.

Wind turbine generator	GE 1.5sle	GE 1.5xle	AV 928	V 90	SWT-3.6-107
January	0.5714	0.4917	0.6372	0.5303	0.6100
February	0.7863	0.7660	0.8730	0.7366	0.8308
March	0.7158	0.7344	0.8052	0.6676	0.7625
April	0.8187	0.7339	0.8957	0.7771	0.8548
May	0.8525	0.7782	0.9107	0.8182	0.8839
June	0.7098	0.6113	0.7747	0.6676	0.7531
July	0.7158	0.7754	0.8096	0.6648	0.7625
August	0.7515	0.7852	0.8227	0.7131	0.7844
September	0.8095	0.8286	0.8965	0.7625	0.8516
October	0.7573	0.8206	0.8582	0.7038	0.8065
November	0.7576	0.7479	0.8380	0.7121	0.7987
December	0.7143	0.9375	0.9302	0.6364	0.8000
Annual Average	0.7467	0.7509	0.8376	0.6992	0.7916

2. CONCLUSION

This paper is aimed at comparing different probability distribution function models for fitting the wind-speed data. The probability distribution functions used includes the Weibull, Rayleigh, gamma distributions. The goodness of fit for wind-speed data was judged based on the percentage error between the predicted and the actual power densities. In this paper, the following conclusions can be drawn, as follows:

1. Throughout the study, the Weibull distribution performed best, followed by the gamma, with Rayleigh ranked lowest in predicting the average wind-power densities of selected sites in northern Nigeria.
2. The system output power is sensitive to location, type of wind turbine generator and the seasonal variation.

4 All the sites are suitable for the development of a renewable energy system consisting of wind sources.

5 The capacity factor depends on the location and the seasonal variations in the wind speed of site.

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