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Evaluation of Wind Energy Potential of Ikeja, Southwest, Nigeria using Two-Parameter Weibull Distribution Function

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Abstract: The potential of wind energy of Ikeja was investigated using two-parameter Weibull distribution function. The result showed good agreement between the actual data and Weibull prediction. The wind turbulence of the study area was moderate (<0.25) based on the whole year assessment but higher during dry season compare to the raining season. The frequency distribution of the wind speed data indicates that about 90% distribution was within the speed range that is higher than the cut-in speed (3m/s) of most modern wind turbine.The scale parameter (c) and shape parameter (k) ranges between 3.84m/s ≥ c ≤ 5.89m/s and 3.65≥ k ≤4.39 respectively. Mean wind speed at 10m hub height ranges between 1.6m/s≥ v ≤9.7m/s with whole years average of 4.5m/s. Wind power density at 50m hub height ranges between 116.3W/m^2≥ WPD ≤423.3W/m^2 with whole years average of 257.9W/m^2,indicating that the wind energy potential is marginal(power class 2). Seasonally,wind energy potential was fair (power class 3) during raining season and marginal (power class 2) during the dry season. The wind energy potential is therefore sufficient for applications in electricity generation and water pumping.

Keywords: *Ikeja, Turbulence Intensity, Wind Speed, Wind Power Density, Wind Power Class,*

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I. INTRODUCTION

Energy is an important factor for life sustenance on Earth. Every human activity requires one form of energy or the other. Energy has been discovered to be a driving force for the industrialization of any society [1]. The discovery of fossil energy and the subsequent industrial revolution has brought about social and industrial developments, thereby helping civilization. Unfortunately, development and civilization experienced globally as a result of discovery of fossil fuel has evolved at the expense of environmental pollution and degradation, global warming and hence climate change. The adverse effect of fossil energy consumption has made the development experienced so far unsustainable. Sustainable development can only be achieved through the development of renewable energy sector. This is because the unsustainability of present global energy trend necessitates a better balance between energy security, economic development and environmental protection [2].

It is evident that Nigeria is over-dependent on fossil fuel for energy production. Yet, this energy source is tending towards extinction because it is not renewable in nature. Also,the bye-products have constituted serious environmental and health hazards. The sure way out of this global energy challenge is to embark on global sustainable energy development that will mitigate the challenges of climate change, environmental degradation and at the same time provide clean and sustainable energy.The adoption of renewable energy resources for electricity generation and other energy need has become a notable global objective [3].Renewable energy sources actually abound in nature, more than enough to meet human energy demand; they are environmental friendly and cost effective over a reasonable period of time [4].Wind energy is one of the fastest growing renewable sources of energy in both developed and developing countries with total available wind power surrounding the earth being in the order of 10^{11}GW [5]. This is several times more than the current global energy consumption. Wind energy also has the advantage that it can be utilized independently or in network with national grid without constituting environmental hazard.The ability to adequately assess renewable energy resources is an essential prerequisite to integrating renewable energy technologies into the energy supply flow of any community[5].

1.1 Description of the study area

Figure 1: Map of Lagos State with Ikeja (red star) as the capital (Adapted from: NG, 2015 [6]). Inserted is the map of Nigeria that shows the position of Lagos State with red arrow.

Ikeja is the capital city of Lagos state located in the south-western part of Nigeria within approximate coordinate 6.35^0 N and 3.20^0E with average elevation of 39.40m above sea level [7]. The study area has topography that is mostly flat with underlying geology of coastal plain [7]. The seasons in the area is broadly divided into dry and raining seasons under the influence of Inter-tropical Convergence Zone, ITCZ (where easterly trade winds originating from northern and southern hemispheres converge) that migrates along with the position of strongest rainfall [8]. The location normally experience two seasons, the dry season is around October-March while the raining season is between April-September. The raining season is also characterized with two to three weeks break popularly known as August break. Ikeja being a capital city has experienced substantial development in term of structure, commerce and tremendous population growth in the last four decades while the figure is still on the increase [9]. The estimated population of Lagos state has increased from just 1.4 million in 1970 to 21 million in 2014 while the present growth rate of 6% per annum has put the expected population by year 2020 to about 35 million people [10].Lagos is one of the most populated cities in Sub-Saharan Africa and 6^{th} largest in the world [10].The high population density, commercial and industrialization activities as brought about high energy demand in the commercial city of Lagos. One of such energy form in high demand is the electrical energy which is often needed for both domestic and industrial purposes.

The availability of energy being an important factor of production determines the techno-economic advancement of any society.The existing conventional electricity generation systems are not capable of adequately meeting the energy demand of the increasing population. In order to complement the existing conventional system, there is need for development of alternative electricity generation system from renewable energy sources.Land is a very expensive factor of production especially in Lagos metropolis due to its scarcity. The land coverage is just about 3,475 km^2 [7]; however, this size is reduced by Lagoons, rivers, creeks and swamps.Wind as a form of energy has comparative advantage over other renewable energy source like solar energy in Lagos state due to its land requirement.While solar energy requires considerable size of land for installation, wind energy requires minimum land area for its installation and at the same time the land area can also be used for other purposes like farming. Wind turbine can be installed offshore and onshore. Wind power will find good application in Lagos especially in the generation of electricity, grinding in mills, pumping of water for irrigation, industrial and domestic purposes.Prior studies [11-13] have shown that wind energy have viable potential in some locations within the southwestern, Nigeria, especially at hub height above 10m. Therefore, this study is aimed at assessing the potential of wind energy potential at Ikeja using two-parameter Weibull probability distribution function and subsequently classifies Ikeja wind power.

II. MATERIAL AND METHOD

Thirty one years (1980-2010) monthly mean wind speed data for Ikeja was obtained from the Nigeria Meteorological Agency (NIMET), Oshodi, Lagos. The data was recorded continuously using cup-generator anemometer at a height of 10m. The acquired data was measured on hourly basis from which monthly mean wind speed was determined.

2.1 Mathematical analysis

There are many probability distribution functions that describe wind speed distribution in a particular location. However, Weibull distribution has been found to be most accurate and adequate in analyzing and interpreting wind speed data [14]. Therefore, in this study, two-parameter Weibull probability distribution function was used in carrying out the analysis of monthly wind speed data and in the estimation of important related parameters.The two-parameters were estimated using the maximum likelihood method (MLM). Based on the MLM, the Weibull shape parameter k and the scale parameter c were estimated using the following two equations:

$$k = \left\{\frac{\sum_{i=1}^{n} v_i^k \ln v_i}{\sum_i^n v_i^k} - \frac{\sum_{i=1}^{n} \ln v_i}{n}\right\}^{-1} \quad (1)$$

$$c = \left\{\frac{1}{n}\sum_{i=1}^{n} v_i^k\right\}^{\frac{1}{k}} \quad (2)$$

where v_i is the wind speed in time step i and n is the number of nonzero wind speed data points.

The probability density function (PDF) is the most important statistics to be derived from wind speed data set for use in wind resource estimation. This is due to the possibility of calculating the average yearly power production by integrating it with wind turbine power curve [15]. The probabilitydensity function (PDF),f(v),can be estimated using the Weibullshape parameter k and scale parameterc obtained from equations 1 and 2 usingthe expression:

$$f(v) = [(k/c)\,(v/c)\hat{}(k-1)]\, exp[-(\frac{v}{c})^k] \quad (3)$$

where k is the Weibull shape parameter, c is the scale parameter and f(v) is the probability of observing wind speed v(m/s).

The cumulative density function (CDF) corresponding to the PDF is sum of the probability that wind speed takes values within its possible range of values. CDF can likewise be estimated using the expression:

$$F(v) = 1 - exp[-(\frac{v}{c})^k] \quad (4)$$

where F(v) is the cumulative distribution function for observing wind speed v.

The actual mean wind speed can be evaluated from the actual data using the expression:

$$\underline{v} = \frac{1}{n}\left(\sum_{i=1}^{n} v_i\right) \quad (5)$$

while the predicted Weibull mean wind speed (v_m) defined in terms of the Weibull parameters k and c is given according to the expression:

$$v_m = c\Gamma(1 + \frac{1}{k}) \quad (6)$$

where Γ( ) is the gamma function.

2.2Performance evaluation of the Weibull distribution model

The performance of the Weibull distribution model used in the prediction of the mean wind speeds with respect to the actual data values were evaluated using the following statistical test models; Correlation Coefficient (R^2), Chi-Square (χ^2) test, Root Mean Square Error (RMSE) and Coefficient of Efficiency (COE) statistical models. These test models are estimated using the expressions:

$$R^2 = \frac{\sum_{i=1}^{N} (y_i - z_i)^2 - \sum_{i=1}^{N} (y_i - x_i)^2}{\sum_{i=1}^{N} (y_i - z_i)^2} \quad (7)$$

$$\chi^2 = \frac{\sum_{i=1}^{n} (y_i - z_i)^2}{N - n} \quad (8)$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N} (y_i - x_i)^2\right]^{\frac{1}{2}} \quad (9)$$

$$COE = \frac{\sum_{i=1}^{N} (y_i - x_i)^2}{\sum_{i=1}^{N} (y_i - Z)^2} \quad (10)$$

where y_i = ith actual data,
x_i =ith predicted data with Weibull,
z = mean actual data,
N =number of observations and
n = number of constants.

The standard deviation from the mean wind speed can be obtained from the given expression

$$\sigma = [\frac{1}{n-1}\sum_{i=1}^{n} (v_i - \underline{v})^2]]^{0.5} \quad (11)$$

2.3Power law exponent

Wind turbines are designed to operate at different hub heights. Most often the available data used for wind energy potential assessment are those obtained from the Meteorological department. These data sets are usually collected at 10m hub height, thereby necessitating extrapolation of wind speed data for higher hub heights using the power index law. The mean horizontal wind speed is zero at the earth's surface and increases with altitude. The variation of wind speed with elevation above ground has important influence on both the assessment of wind energy resources and the design of wind turbine. The wind speed extrapolation according to power law is given as:

$$v = v_o (\frac{H}{H_o})^{\alpha} \quad (12)$$

where v is the wind speed at the turbine hub height H, v_o is the wind speed at original height H_o and α is the surface roughness coefficient or empirical wind shear exponent. For majority of sites with uniform terrain the values of α is taken as 1/7 or it is called the one-seventh exponent [15]. Since wind speed varies with height, Weibull parameters c and k must be corrected for higher hub heights. This can be determined using Frost equations given as:

$$k = k_r [\frac{1-0.088 \ln(\frac{H_o}{10})}{1-0.088 \ln(\frac{H}{10})}] \quad (13)$$

$$c = c_r (\frac{H}{H_o})^{\alpha} \quad (14)$$

2.4Wind Power Density

The wind power density (WPD) is the amount of wind energy transported across a unit area in unit time. WPD is a truer indication of a particular location's wind energy potential. This important parameter can be estimated from the values of Weibull scale parameter c and shape parameter k using the given expression:

$$WPD = \frac{1}{2}\rho c^3 (1 + \frac{3}{k}) \quad (15)$$

whereρ is the air density in (kg/m^3).Wind resources are usually represented by wind power classes and each class represent a range of annual average wind power densities and equivalent mean wind speed as shown in TABLE 1.

Table 1: Wind power classification at 50m hub height[15]

Wind power class	WPD(W/m^2)	Wind speed (m/s)	Remark
1	≤ 200	≤ 5.6	Poor
2	≤ 300	≤ 6.4	Marginal
3	≤ 400	≤ 7.0	Fair
4	≤ 500	≤ 7.5	Good
5	≤ 600	≤ 8.0	Excellent
6	≤ 800	≤ 8.8	Outstanding
7	≤ 2000	≤ 11.9	Superb

2.5 Wind turbulence intensity

Wind turbulence is the rapid disturbances or irregularities in the wind speed, wind direction and vertical component. It is an important site characteristic, because high turbulence level may decrease power output and cause extreme loading on wind turbine components. The most common indicator of turbulence for sitting purpose is the standard deviation of wind speed. By normalizing standard deviation with the mean speed we get the turbulence intensity (TI) given as:

$$TI = \frac{\sigma}{\underline{v}} \quad (16)$$

Turbulence intensity is a relative indicator of turbulence with low levels indicated by values less than or equal to 0.10, moderate levels up to 0.25 and high levels greater than 0.25 [15]

III. RESULT AND DISCUSSION

The thirty one years (1980-2010) wind speed data obtained from the Department of Meteorology was analyzed using the two-parameter Weibull probability distribution function. The probability density function and the corresponding cumulative distributive function (CDF) were estimated alongside the Weibull shape (k) and scale parameters (c). These parameters were used to estimate the wind power density at different hub heights. The results obtained are presented and discuss in the subsequent sections.

3.1 Weibull Probability Distribution Function

The Weibull probability plot of thirty one year's wind data set is shown in Fig. 2.It could be seen from the plot that the probability of wind blowing with a particular speed increases linearly with wind speed. The linearity observed in the plot is an indication that the data follows Weibull distribution function[16]. Therefore, it is suitable for analyzing and interpreting the situation of measured wind speed.

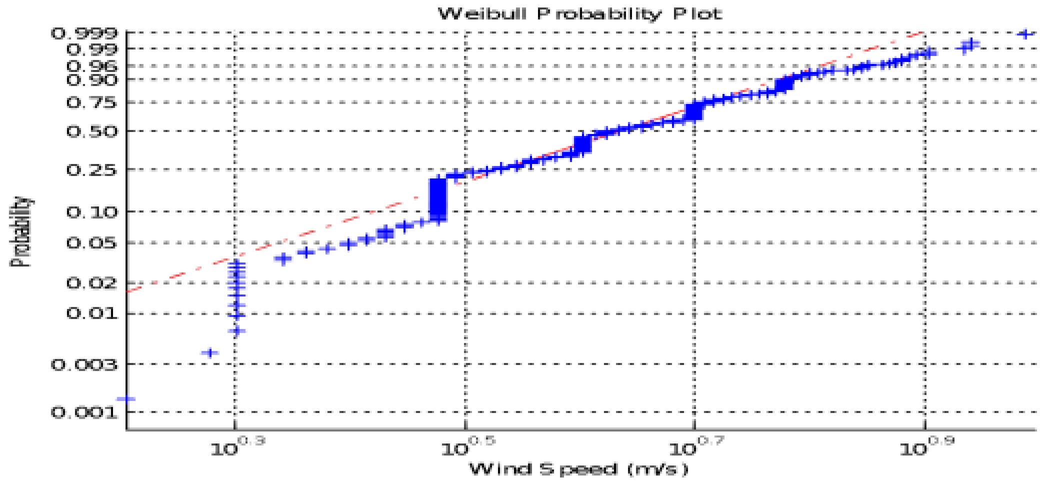

Figure 2: Weibull probability plot for the thirty one yearswind speed data

3.2 Probability Density Function

Probability density function (PDF) is the probability that the wind speed data has values within a certain range. The plot of estimated PDF against wind speed for different months of the year is shown in Fig. 3. It could be observed from the plot that the value of PDF increases gradually for each month of the year until it attains peak value and afterward decreases gradually towards zero. The peak value of PDF for the different months ranges between 0.22 and 0.36,while the corresponding wind speed at the peak PDF value ranges between 3.5m/s and 6.0m/s. This shows that the highest probability density for each month occurs at wind speed that is greater than the cut-in speed (3m/s) of most modern wind turbine. This implies that such wind turbine is capable of generating electricity often within the study area.

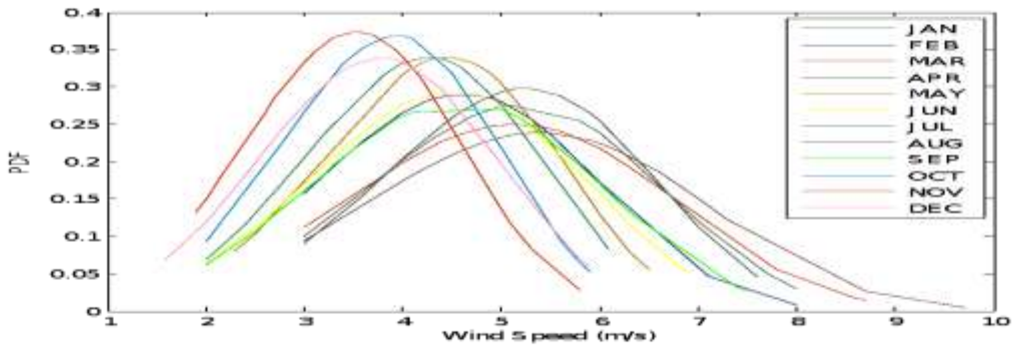

Figure 3: Variation of Weibull probability density function (PDF) against Wind Speed for different months.

3.3Cumulative Density Function

The variation of estimated cumulative density function (CDF) against wind speed is shown in Fig. 4. It could be observed from the plot that the cumulative density function for each month of the year increases gradually with wind speed. The CDF attains maximum value of one with corresponding wind speed ranging between 5.5m/s and 9.5m/s for different months of the year. Lowest value of wind speed was observed at maximum CDF of one in the month of February while highest value of wind speed at maximum CDF of one was observed in the month of August.This observation shows that lowest and highest value of wind speed at maximum CDF occurs during the peak period of dry season and break in raining season respectively.

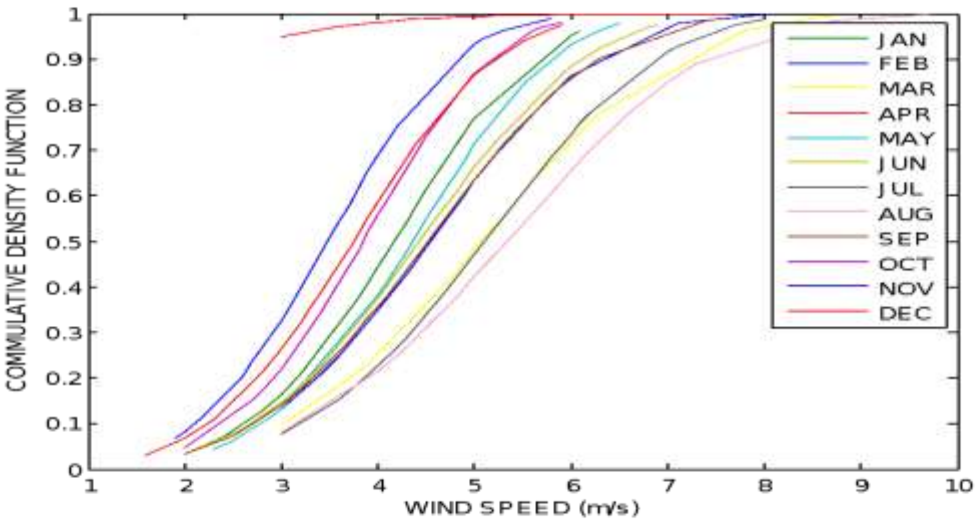

Figure 4: Variation of estimated cumulative density function (CDF) against wind speed for different months

3.4 Time series analysis of monthly mean wind speed

The time series plot of the monthly mean wind speed is shown in Fig. 5. The plot indicates that wind speed pattern is inconsistent but varies with months and seasons of the year. The long term data plot shows significant variability in wind speed monthly and seasonally. The fluctuation in wind speed have several different time periods, but six peaks with value greater than 7m/s are dominant. The first three peaks are approximately 30 months apart while the recurrence of similar pattern was about100 months thereafter. The monthly mean wind speed ranges between minimum value of 1.6m/s and maximum value of 9.7m/s with overall average value of 4.5m/s at 10m hub height. This indicates that the wind speeds has significant variability and belong to wind power class 2. This is because most locations in the tropical latitudes such as Ikeja normally experience pronounced wind variability diurnally and seasonally. This may be partly due to the effect of Inter Tropical Convergence Zone (ITCZ) doldrums wind moving north and south within the tropics following the annual march of the sun and partly due to the effect of monsoons and trade wind.

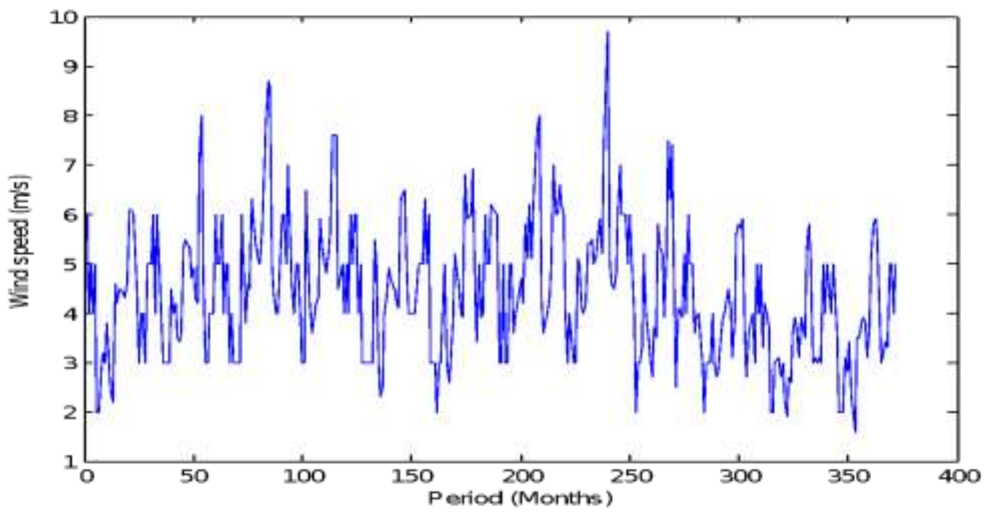

Figure 5: Time series plot of monthly mean wind speed over thirty one years (1980-2010).

3.4.1 Yearly variation of mean wind speed for each month

The yearly variation of mean wind speed for the months within dry season (October, November, December, January, February, March) and raining season (April, May, June, July, August, September) are shown in Fig. 6a and 6b respectively. The mean wind speed for each month was observed to follow increasing trend between 1985 and 2002, and afterward falls to minimum value in year 2003 and again increases gradually between 2003 and 2010. It was observed from the plot that low values of monthly wind speed occurs between October and January during the dry season while higher values of monthly mean wind speed occurs between March and April at onset of the raining season and again between August and September which represent the last two months of the raining season. Analysis of whole data spread for Ikeja location revealed that the site's monthly mean wind speeds ranged between lowest value of 1.6m/s observed in December 1991 and highest value of 9.7m/s observed in August 2002.

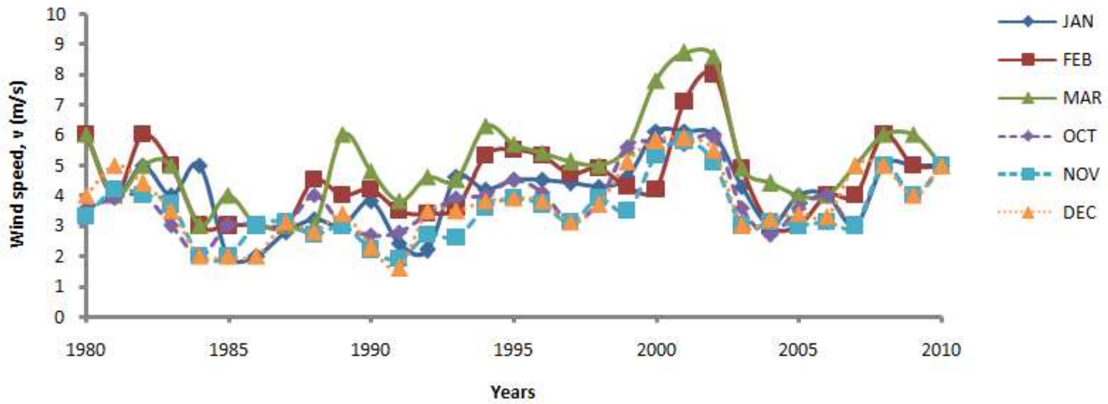

Figure 6a: Variation of annual mean wind speed for months within the dry season (1980-2010)

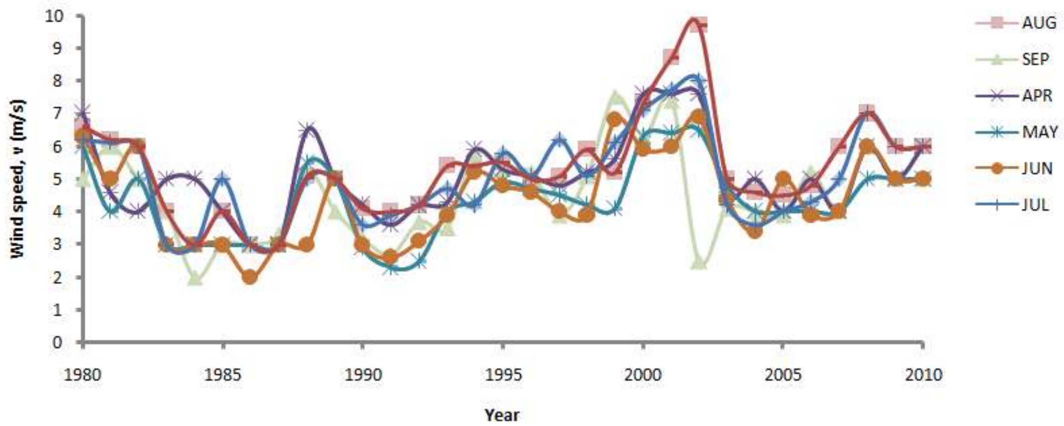

Figure 6b: Variation of annual mean wind speed for months withinthe raining season (1980-2010)

3.4.2 Monthly and seasonal variation of mean wind speed and rainfall at different hub heights

The plot of monthly and seasonal variation of mean wind speed and rainfall at different hub heights is shown in Fig. 7. It could be observed from the plot that the mean wind speed vary with months and seasons of the year while the magnitude of mean wind speed increases with hub heights. At hub height of 10m, mean wind speed higher than 5m/s was observed in the months of March, April, July and August which are mostly months within the period of raining season. The mean wind speed within the range of 4m/s and 4.9m/s was observed in January, February, May, June and September while mean wind speed of value less than 4m/s was observed in October, November and December which are months within the period of dry season. The mean wind speed in most cases is greater than the cut-in speed (3m/s) of most modern wind turbine. This implies that most modern wind turbine is capable of generating electricity regularly at Ikeja location. The potential of wind energy based on the characteristic speed can be describe as fair in the months of March, April, July and August belonging to power class 3, it is marginal in the months of, February, May, June and September belonging to power class 2 and poor in the months of January,October, November and December belonging to power class 1. Seasonally, mean wind speed was observed to be higher during raining season compare to dry season with a whole year average of 4.5m/s. The wind energy potential is remarkably fair during the raining season, poor during the dry season and marginal based on the whole year's assessment.

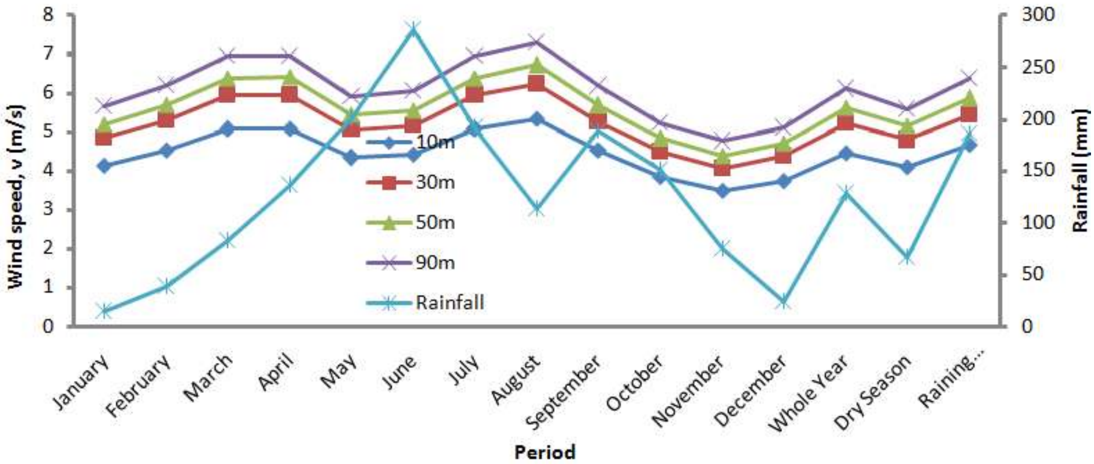

Figure 7: Monthly and seasonal variation of rainfall and mean wind speed at different hub heights

3.5 Monthly and seasonal variation of scale (c) and shape (k) parameters

The monthly and seasonal variation of estimated scale parameter c and shape parameter k is shown in Fig. 8. It is seen in the plot that the value of scale parameter c ranges between minimum value of 3.84m/s and maximum value of 5.89m/s with whole year average of 4.95m/s. The value range exceeded the cut-in speed of most modern wind turbine. It could also be observed from the plot that value of c above 5m/s occurs in the months of March, April, July and August which are mostly months within period of raining season.Scale parameter(c)with value less than 4.6m/s occurs in the months of October, November, December and January which are months within period of dry season.Seasonally, the value of scale parameter was observed to be higher during the raining season compare to the dry season with whole year average of 4.95m/s.The shape parameter k is usually between 1.5 and 3 depending on the variability of wind speed,smaller values ($k<1.5$) corresponding to more variability (more gusty winds)while with $k=2$ for moderately gusty and higher values ($k>3$) correspond to less variability (less gusty winds). The plot of monthly and seasonal variation of k parameter is shown in Fig 8. The value of shape parameter k ranges between the minimum values of 3.65 and maximum of 4.39 with whole average of 3.45. The wind situation could therefore be described as less gusty having less variability. It could be observed from the plot that four maximum points are pronounced. These maximum occur in the months of April, May, July and October which are mostly months within the period of raining season. Seasonally, the value of k parameter is observed to be lowest during dry season and highest during the raining season. The value of k parameter is an indicator of turbulence intensity having inverse relationship,hence, it could be inferred that the wind situation is generally calm or less turbulent.

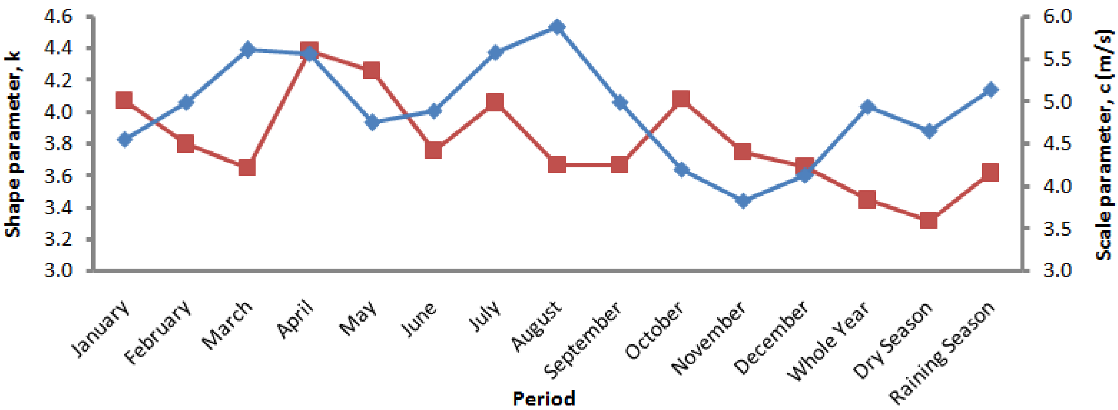

Figure 8: Monthly and seasonal variation of Weibull Shape Parameter (k) and Scale Parameter (c)

3.6Wind speed frequency distribution

Frequency distribution is an important factor in designing and siting of wind turbines since the energy input to a wind turbine can be calculated from the frequency distribution of the wind speed [17]. Wind speed frequency indicates the cumulative time the wind blows at prescribed value or range of values. The plot of wind speed frequency distribution against wind speed range for the thirty-one year data set used in this study is shown in Fig. 9. There are three dominant wind speed ranges with percentage frequency above 20%. These include wind speed ranges 3-3.9, 4-4.9 and 5-5.9m/s. It could be observed from the plot that highest percentage frequency of occurrence of 26.9 %has corresponding mean wind speed within the range 3.0m/s and 3.9m/s. This is followed by wind speed range of 4 to 4.9m/s with corresponding percentage frequency of around 24.7% while wind speed range of 5 to 5.9m/s has percentage frequency of 24.2%.Wind speed range of 6-6.9m/s has corresponding percentage frequency of 11%. It is also observed that wind speed greater than the cut-in speed (3m/s) of the most modern turbine have about 90%percentage frequency. This implies that most modern wind turbine will generate electricity regularly at the study location.

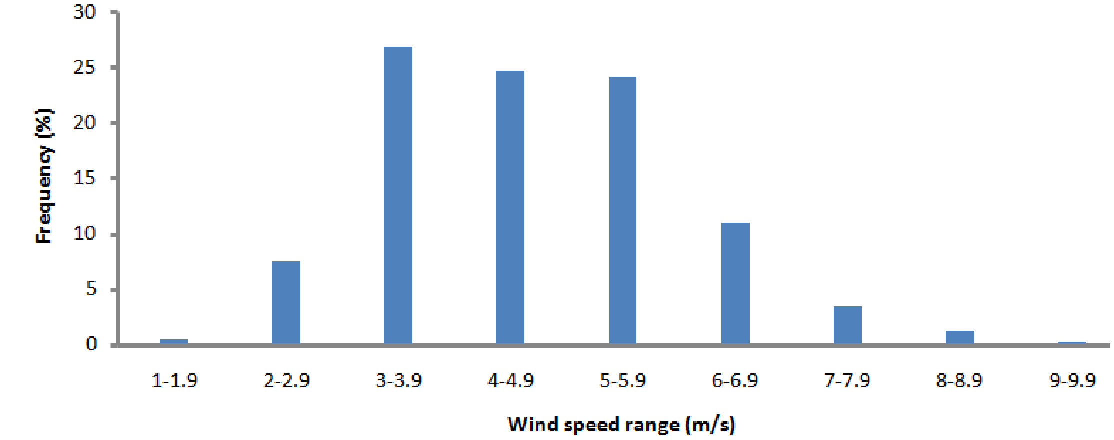

Figure 9: Plot of wind speed frequency distribution

3.7Performance evaluation of Weibull model

The reliability of the weibull model in the prediction of mean wind speed was evaluated.Fig. 10 shows the plot of monthly and seasonal variation of mean wind speed of actual data,weibull predicted mean wind speed and standard deviation. The correlation coefficient between the actual data and weibull predicted data is about 0.99 while the chi-square test estimation gave 1. The root mean square error (RMSE) was estimated to be 0.0268 while the coefficient of efficiency is 0.0026. The performance evaluation shows high level of agreement between the actual data and weibull predicted data with minima error. Therefore, the two-parameter weibull distribution function can adequately and reliably predict the wind situation of Ikeja location.The estimated standard deviation ranges between minimum of 1m/s and maximum of 1.51m/s. It could be observed from the plot that the value of standard deviation have two pronounce maxima occurring in the months of March and August while minimum values were observed in the months of January, May, October, November and December. Seasonally, the value of standard deviation was observed to be higher during the dry season compared to raining season with whole year average of 1.37m/s. Standard deviation is also a relative indicator of turbulence, the observation shows higher level of turbulence during the dry season compare to raining season.

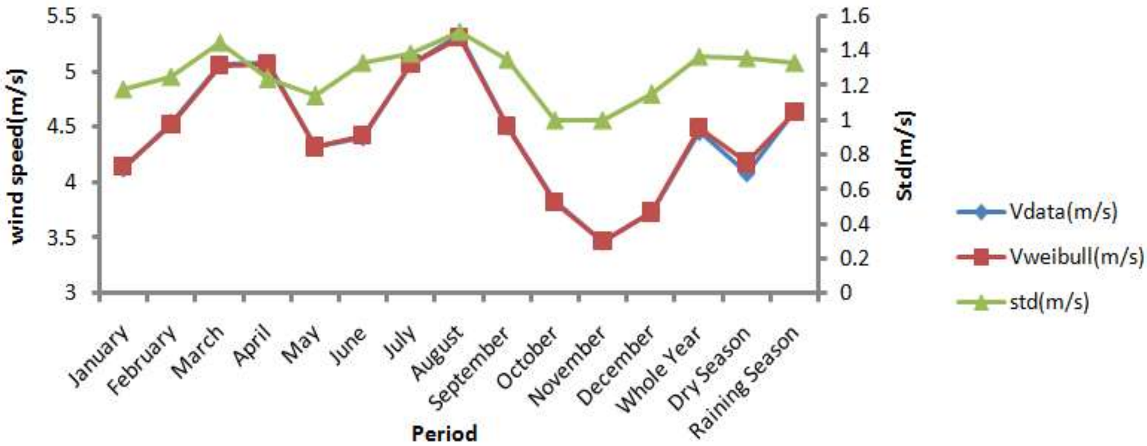

Figure 10: Variation of actual wind speed, Weibull predicted wind speed and standard deviation

3.8Wind Power Density

Wind power density is a truer indicator of a site's wind energy potential than wind speed alone [18]. Fig. 11 shows the monthly and seasonal variation of wind power density estimated at different hub heights.It could be observed that the estimated wind power density increases with hub heights. The variation showed that the wind power density is inconsistent but changes with the months and season of the year. Two maxima points were observed in the months of March and August while minimum value of wind power density was observed in the months of October, November, December, January and May. At hub height of 10m the value of WPD ranges between 62.2W/m^2 and 226.5W/m^2 with whole year average of 138.3W/m^2 and at hub height of 30m the values ranges between 95.3W/m^2 and 347W/m^2 with whole years average value of 211.6W/m^2. The WPDat hub height of 50m ranges between 116.3W/m^2 and 423.3W/m^2 with whole years average of 257.85W/m^2 and at hub height of 90m.the value ranges between 145.9W/m^2 and 530.9W/m^2 with whole years average of 323.1W/m^2.The wind energy potential of the study area can therefore be remarkably described as fair in the months of March, April, July belonging to power class 3 and good in the month of August belonging to power class 4.Wind energy potential was marginal in February, May, June and September belonging to power class 2 and poor in the remaining months of January, October, November and December belonging to power class 1. Base on the whole years assessment,the wind energy potential of Ikeja, can be described as marginal belong to power class 2. Seasonally, the potential of wind energy is higher during the raining season compared to dry session.

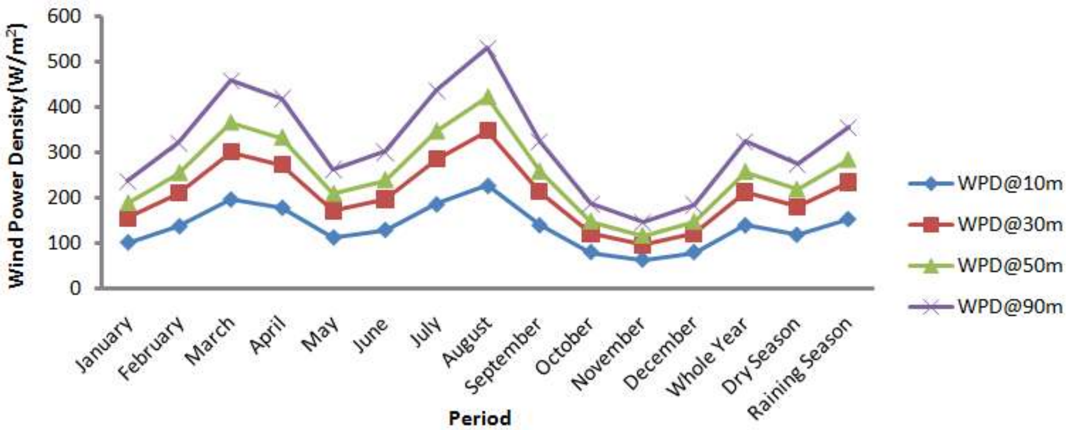

Fig. 11: Monthly and seasonal variation of Wind Power Density (W/m^2) at different hub heights

3.9Wind Turbulence Intensity

Wind turbulence is an important site characteristic;this is because high turbulence level may decrease power output and cause extreme loading on wind turbine component [19]. Fig. 12 shows the plot of yearly variation of estimated turbulence intensity for the thirty one year data set. It could be observed from the plot that the turbulence intensity follows decreasing trend. The value of turbulence intensity ranges between low value of 0.03 and high value of 0.34 with whole year average of0.193. This indicates that the turbulence level of the study area can be described as being moderate (<0.25). High level turbulence (>0.25) was experienced in the years 1985, 1986, 1989 1992, 2002 and 2007, while low level turbulence (<0.1) was observed in the year 1987.

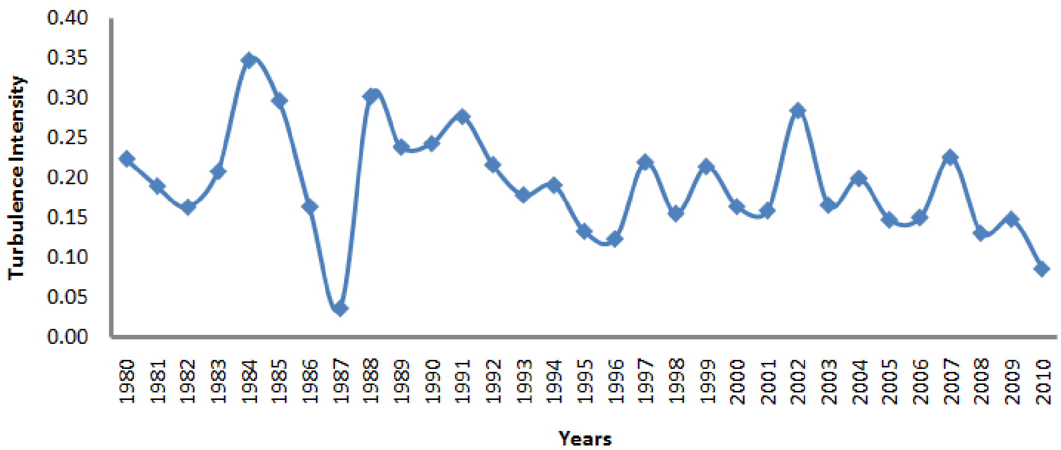

Figure. 12: Yearly variation of estimated wind turbulence intensity for Ikeja (1980-2010)

3.10 Result summary

In this study, the potential of wind energy was assessed using 2-parameter Weibull distribution function. Results revealed that the 31 years data set of the study location varies continuously with months and seasons of the year. The probability distribution of wind data indicated that weibull model is suitable for analyzing and interpreting the wind speed situation of the study location. The values of k parameter range between 3.36 and 4.39, with whole year assessment value of 3.5. This indicated that the wind situation could be described as less gusty having less variability. Seasonally, the value of k parameter is observed to be lowest during the dry season and highest during the raining season.The scale parameter c likewise varies with months and season of the year. Higher value was observed during raining season while minima values were observed during dry season. Performance evaluation of the weibull model shows good agreement between the actual data and weibull prediction having correlation coefficient of about 0. 99 while the chi-square test gave 1, indicating excellent agreement between the actual data and Weibull prediction. The root mean square error and coefficient of efficiency gave 0.0268 and 0.0026 respectively, also indicating minima error. The standard deviation of actual data from the mean value ranges between 1m/s and 1.5m/s while its monthly variation shows higher values in the months of March and August and low values in the months of January, May, October, and November. Seasonal variation indicates that standard deviation is slightly higher during dry season compare to raining season.

The wind turbulence of the study area is moderate (<0.25) based the whole year assessment but the turbulence intensity is higher during dry season compare to raining season. The frequency distribution of the mean wind speed data shows that about 90% distribution was in the speed range above the cut-in speed (3m/s) of most modern wind turbine. Monthly mean wind speed and wind power density shows that the wind energy potential of study location varies with month and season. The wind speed and wind power density is higher during the raining season compare to the dry season.Results obtained also indicated that the wind energy potential of the study location is marginal based on the whole year assessment. Seasonally, wind energy potential is remarkably fair during raining season and marginal in dry season. Considering the potential of wind energy at Ikeja based on the result of this study, the potential is sufficient for electricity generation, water pumping purposes and grinding in mills.

IV. CONCLUSION

In this study, the wind energy potential of Ikeja, southwest, Nigeria was investigated. It can be concluded from the result obtained that:

(i) Weibull model is suitable for analyzing and interpreting wind speed situation of Ikeja and there is good agreement between the actual data and Weibull predicted data.

(ii) The wind turbulence of Ikeja is moderate (<0.25) based on whole years assessment but the turbulence level is higher during dry season compare to raining season.

(iii) Mean wind speed at 10m hub height ranges between 1.6m/s and 9.7m/s with whole year's average of 4.5m/s while about 90% is in the speed ranges greater than the cut-in speed (3m/s) of most modern wind turbine like VENSYS 87.

(iv) Wind power density at 50m hub heights ranges between 116.3W/m^2 and 423W/m^2 with whole year's average of 257 W/m^2.

(v) Wind energy potential was good (power class 4) in August, fair(power class 3) in the months of March, April, July,marginal (power class 2) in the months of February, May, June and September and poor (power class 1) in the remaining months of January, October, November and December. Seasonally, wind energy potential was fair (power class 3) during raining season and marginal (power class 2) during the dry season.

(vi) The wind energy potential of Ikeja is sufficient for application in electricity generation, water pumping and grinding in Mills.

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