VOL. 17, NO. 1, 2018, 21-27
www.elektrika.utm.my
ISSN 0128-4428

ELEKTRIKA
Journal of Electrical Engineering

Wind and Solar Radiation Potential Assessment in Kano, Nigeria Using Weibull and Samani Models

Mustapha Mudasiru*, Mohd Wazir Mustafa

Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.

*Corresponding author: mustapha0604@yahoo.com

Abstract: A clean, source free, environmentally friendly and renewable source of energy such as wind and solar energy can be used for providing sustainable power supply to remedy an epileptic and unreliable power supply systems. For decades, electric power supply situation in Kano, Nigeria has been a major source of serious concern. The epileptic power supply has hindered the socio-economic growth industrialization and, subsequently, increase air pollution due to individual stand-alone diesel generators. Various government incentives and policies have little or no effect to improve the availability and reliability of the electric power. The aviation industries especially the Navigation and communication equipment required, apart from availability, a reliable power sources because of their sensitivity to reliable and safe Aircraft navigation. The need for an alternate renewable energy system (RES) of power supply away from the National grid and diesel generator is inevitable at Kano. This paper proposes an assessment of wind and solar energy potentialities at Kano in Nigeria using Weibull distribution methods and the Samani model to determine the wind features and estimate global solar radiation potentials respectively for power supply generation. A six years (2009-2014) monthly mean wind speed data measured at 10 *m* height was collected and extrapolated to 50 *m* height level for statistical analysis, while 22 years monthly solar radiation, temperature amplitude and relative humidity of the location were obtained from NASA web to calibrate, validate and evaluate the Samani model, ten years (2003-2012) maximum and minimum temperature were then used to predict the global solar radiation on horizontal surface of the location. The minimum Weibull average wind speed was found to be 8.60 *m/s* and the maximum average wind speed was 11.24 *m/s* while the minimum power density was 440.03 W/m^2 and the highest was 947.26 W/m^2 at the 10 *m* height level. The lowest average global solar radiation on the horizontal surface was 17.96 $MJ/m^2/d$ and highest average global solar radiation on the horizontal surface was 26.38 $MJ/m^2/d$. The site has been found to have great potentials for wind and solar utility power generation capacity.

Keywords: Air temperature amplitude, global solar radiation, power density, Samani model, wind speed data.

Article History: received 1 November 2017; accepted 21 March 2018; published 16 April 2018.

1. INTRODUCTION

Development and advancement of any nation depend on the accessibility of reliable electric power energy. However, the task of maintaining, upgrading of the existing power system as well as introducing new energy systems in correlation with the increasing energy demand due to population explosion and industrialization has been an important trend worldwide [1]. For decades, electric power supply situation in Nigeria has been a major source of serious concern. The epileptic power supply throughout the nation has hindered the socio-economic growth and, subsequently, increase air pollution due to individual stand-alone diesel generators and hindered industrialization of the country. Various government incentives and policies have little or no effect to improve the availability and reliability of the electric power supply [2]. The aviation industries especially the Navigation and communication equipment required, apart from availability, reliable power sources because of their sensitivity to reliable and safe Aircraft navigation. The need for an alternate renewable energy system (RES) of power supply away from the National grid and diesel generator is inevitable. Solar energy is the main source from which all fossil and renewable energy types are derived. Various ancient technologies have been used for harnessing the solar and other renewable energy types since human early civilizations for water irrigations and wind power have been used for milling and navigation purposes [3]. RES technology such as wind turbine (WT) though stochastic in nature and solar photovoltaic (PV) are popular RES for electricity generation because these are source free and inexhaustible in nature. Wind and solar energy are most preferable renewable energy resources being utilized around the globe because of their sustainability and green nature as well as their integrative equipment for proper sizing and configurations [4].

Both in the past and presently many research works have been carrying out to look into wind speed potentials in terms of power generation using such tools and models as artificial neural network (ANN), autoregressive integrated moving average, autoregressive moving average, Monte Carlo simulations, Weibull and Rayleigh distribution methods in various nations around the world [5-11]. In

Nigeria, several studies have been carried out in various locations on the assessment of wind speed variability and its energy potentialities [2, 12, 13] using various analytical model tools such as Weibull and Rayleigh distribution parameter methods, ANN , amongst other several analytical methods however none of these literature has considered Kano despite its economical viabilities. Different locations vary in meteorological weather data hence methods of solar radiation estimates differ and need to be adapted for that particular location. In Nigeria the most frequently investigated weather parameters are the sunshine hour duration, wind speed, relative humidity, cloud cover, rainfall and air temperature. Globally, scientists have derived various empirical equations to relate solar radiation with various meteorological parameters [14-20]. Many researchers in Nigeria have modeled global solar radiation using sunshine-based models. [1, 16, 21-25] used Angstrom model while [26] used Hargreaves-Samani model to estimate solar radiation for various locations and cities across Nigeria. [27-29] used Hargreaves-Samani models to calibrate and calculate the solar radiation using temperature parameters only, while [30] employed Angstrom, temperature, relative humidity and precipitation models. Temperature based models utilize air temperature amplitude as a modification of the cloud cover amount in Angstrom and Bristow-Campbell models and thereby measure the state of the sky [3]

The aim and objective of the current study is to carry out the analysis of wind and solar renewable energy potential assessment for possible wind and solar power generation for Kano, Nigeria based on Weibull parameters models to analyze meteorological monthly average wind speed data measured over a period of six years while calibrated Samani model will be utilized to estimate global solar radiation on horizontal surface of the location using air temperature amplitude method.

2. MATERIALS AND METHODS

Kano, Nigeria is located at Latitude 12.046° N and Longitude 8.522° E and at 476m above the sea level is the site under considerations for this study. In this paper six years (2009 - 2014) monthly mean speeds wind data measured at a height of 10m for wind energy assessment and ten years (2003-2012) air temperature data for global solar radiation estimation were obtained from the Nigerian Metrological Agency (NIMET) Kano Airport. The global solar radiation on horizontal surfaces, air temperature, relative humidity and atmospheric pressure for a period of 22 years were obtained from the archives of National Aeronautics and Space Administration (NASA) [31] to calibrate, validate and evaluate Samani air temperature-based model. The Samani model is to estimate global solar radiation potentialities at the Kano using air temperature as the sole parameter as the input because of its easiness in availability and accessibility, R programming will be used for all analysis.

3. WIND ENERGY POTENTIAL ASSESSMENT

Weibull parameters models are used to analyze and investigate the wind potentials for the location under investigation and the models are enumerated bellow.

3.1. Mean wind speed and standard deviation

Mean monthly wind speed V_m and standard deviation σ were obtained from the wind speed data using equations (1) and (2) respectively [32]

$$V_m = \frac{1}{N}\left(\sum_{i=1}^{N} V_i\right) \tag{1}$$

$$\sigma = \left[\frac{1}{N-1}\sum_{i=1}^{N}(V_i - V_m)^2\right]^{1/2} \tag{2}$$

Where V_m is the mean wind speed in *m/s*; σ is the standard deviation of the observed data in *m/s*; V_i is the monthly wind speed in *m/s*; N is the number of measured monthly wind speed data.

3.2. Weibull parameters computation of the wind speed.

In statistical methods, wind speed variation is described by the Weibull distribution function [33]. Two parameters (shape parameter k and scale parameter c) functions are popularly used for studies. The probability density function of the Weibull distribution is given by the expressions in equation (3) [34].

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

Where v is the average wind speed in *m/s*, *c (m/s)* is the scale parameter and k (dimensionless) is the shape parameter.

From the mean and variance of the wind speed the Weibull's probability distribution parameters can be determined using equations (1) and (2) [34] as follows:

$$k = \left(\frac{\sigma}{v}\right)^{-1.086}, \quad (1 \le k \le 10) \tag{4}$$

$$c = \frac{\mathrm{v}}{\Gamma\left(1+\frac{1}{\mathrm{k}}\right)} \quad \frac{m}{s} \tag{5}$$

Where *Γ(x)* is the gamma function of *x* and mathematically expressed thus as:

$$\Gamma(\mathrm{x}) = \int_{0}^{\infty} \mathrm{t}^{\mathrm{x}-1}\exp(-\mathrm{t})\mathrm{dt} \tag{6}$$

From equation (3) above the mean wind speed on the basis of Weibull parameters could be defined [35] as

$$v_a = c\Gamma\left(1 + \frac{1}{k}\right) \quad \frac{m}{s} \tag{7}$$

To evaluate the performance criteria of the Weibull distribution model for the wind speed estimation with respect to the meteorological data obtained, an analysis on the basis of root mean square error (RMSE) equation is shown in equation (8).

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(y_i - x_j\right)^2} \tag{8}$$

y_i is the i^{th} wind speed data and x_j is the j^{th} Weibull estimated value and N is the observed wind data number.

3.3. Wind speed vertical height extrapolation.

Wind speed varies as a function of the height above ground up to an optimum altitude. It is, therefore, necessary to determine the wind speed at the height of the wind turbine's hub in terms of the measured wind speed. The equation for variations in wind speed with hub height is a power law expressed in equation (9) as follows: [4], [36].

$$v_2 = \left(\frac{h_2}{h_1}\right)^{\alpha} v_1 \qquad \left(\frac{m}{s}\right) \tag{9}$$

Where v_1 is the measured wind speed at a known height h_1 while v_2 is extrapolated wind speed at practical height h_2. The exponent, α, is the surface roughness coefficient or wind shear factor and dependent on height, time of the day, season of the year, nature of the terrain, wind speed and temperature and could be determined by equation (10). [37]

$$\alpha = \frac{[0.37 - 0.088 ln v_1]}{1 - 0.088 ln\left(\frac{h_1}{10}\right)} \tag{10}$$

3.4. Wind power density estimation

The wind power available at a given site is assessed by calculating the mean wind speed V_m passing through the rotor blade sweep area A of a wind turbine is a function of the cube of the velocity and is as shown in equation (11). [33].

$$P(v) = \frac{1}{2}\rho A V_m^3 \quad W \tag{11}$$

Where ρ (kg/m^3) is the standard air density and is taken as 1.225 kg/m^3 for this work, thus it is a function of altitude, air pressure, and temperature. A (m^2) is the swept area. The wind power density (wind power per unit area) based on the Weibull probability density function (PDF) can be calculated by the formula given in equation (12). [36]

$$P(v) = \frac{P(v)}{A} = \frac{1}{2}\rho c^3 \Gamma\left(1 + \frac{3}{k}\right) \tag{12}$$

4. SOLAR ENERGY POTENTIAL ASSESSMENT

Air temperature-based model type is investigated in this work. The inputs variables into the model are air temperature amplitude, extraterrestrial solar radiation, declination angle, solar hour angle, latitude and day of the year which except the air temperature defined the extraterrestrial solar radiation parameters. The daily average extraterrestrial global solar radiation *(H_O)* is given [30] as:

$$H_O = \frac{24}{\pi} I_{SC}(A) \times (B) \tag{13}$$

$$A = \left(1 + 0.033\cos\left(\frac{360N}{365}\right)\right) \tag{14}$$

$$B = \left(\cos\emptyset\cos\delta\sin\omega + \frac{2\pi}{360}\sin\emptyset\sin\delta\right) \tag{15}$$

Where I_{sc} is the solar constant and the value is given as 1.367kW/m^2; ϕ is the latitude of the location (in degrees); δ is the solar declination angle in degrees; ω is the sunset hour angle and N is day of the year, starting with *1* for January *1st* and *365* for December *31st* . The solar declination angle can be determined from equations *(14) - (17)* [30, 38];

$$\delta = -23.45 \times \cos\left[\frac{360}{365}(N + 10)\right] \tag{16}$$

$$\alpha = \frac{2\pi \times (N - 1)}{365} \tag{17}$$

Where α is the day angle (in radians)
The sunset hour angle is given by equation *(18)*:

$$\omega = \cos^{-1}[-\tan\delta\tan\emptyset] \tag{18}$$

$$K_T = \frac{H_m}{H_o} \tag{19}$$

The ratio of average horizontal surface radiation H_m to the average extraterrestrial radiation H_o measures the clearness index at that particular surface, the temperature-based model relates the temperature amplitude to K_T in equation *(19)*.

4.1 Samani Air Temperature Amplitude Based Model

Samani [39] was able to provide further improvement in the empirical coefficient K_r of equation *(19)* by analyzing one year average monthly data which reduced the estimated global solar radiation errors. The improved Kr is given in equation *(20):*

$$K_r = A(T_{max} - T_{min})^2 + B(T_{max} - T_{min}) + C \tag{20}$$

The coefficients $A = 0.00185\ ^oC^{-2}$, $B = -0.04330\ ^oC^{-1}$ *while* $C = 0.40230$.

The overall steps of the potential power assessment flow chart are shown in Figure 1.

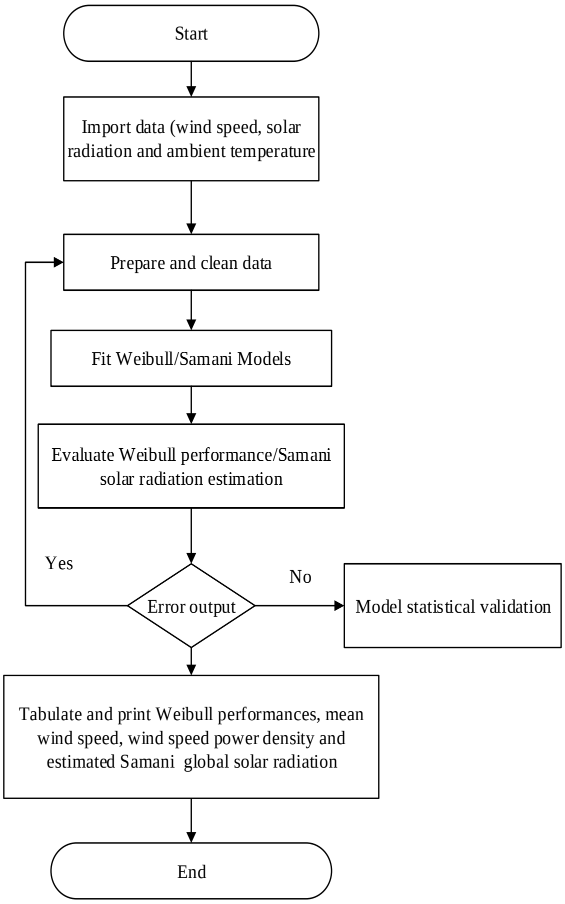

Figure 1. Flow chart of the methodology used.

5. RESULTS AND DISCUSSION

5.1. Mean Wind Speed Variation

The months of February and October as shown in *Figure 2* and *Table 1* had the lowest mean wind speed values of 8.60 *m/s* and 8.76 *m/s* respectively These are due to the transitions between the Harmattan - Hot season in February and Rainy - Dry season transition periods in October while the Months of March and July had the peak mean wind speed values of 11.14 *m/s* and 11.24 *m/s* respectively and are due to Hot season climate in March and high warm humidity in July, in between these periods the mean wind speed is relatively moderate.

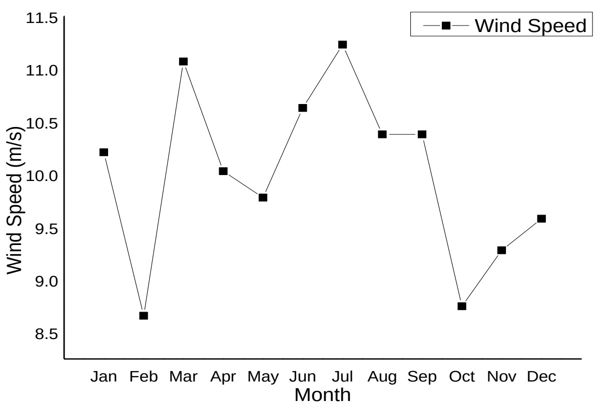

Figure 2. Monthly Weibull mean wind speed at 10 *m* height

Table 1. Monthly Weibull and Performance Parameters at 10 *m* height.

Month	*V_m m/s*	*C m/s*	*K*	*P W/m^2*	*RMSE*
Jan	10.21	11.07	5.41	738.44	0.004
Feb	8.60	9.32	5.50	440.03	0.062
Mar	11.14	11.64	11.78	874.32	0.075
Apr	10.05	10.64	8.60	657.53	0.025
May	9.75	10.32	8.45	600.08	0.028
Jun	10.59	11.40	6.13	804.67	0.040
Jul	11.24	12.04	6.83	947.26	0.019
Aug	10.38	11.27	5.37	780.23	0.017
Sep	10.34	11.11	6.40	744.92	0.032
Oct	8.76	9.67	3.92	511.65	0.014
Nov	9.30	9.77	10.30	512.97	0.029
Dec	9.56	10.56	3.94	664.32	0.015

5.2 Weibull Parameters Performances and Probability Distribution

The Weibull scale parameter *c*, shape parameter *k*, power density *P*, mean wind speed and the model validation parameter *RMSE* at 10 *m* height level are shown in *Table 1*. Weibull scale parameter *c* varies between 9.32 *m/s* and 12.04 *m/s* thus were found to be generally higher than the shape parameter *k* which varies between 3.92 and 11.78. The monthly power density has 440.03 W/m^2 as the minimum value and 947.26 W/m^2 as its highest value.

Weibull probability density distribution for wind speed data at 10 *m* height is shown in *Figure 3* and the wind speed distribution for the six years data could be seen to have a good fit of between 10 *m/s* to 15 *m/s*. *Figure 4* shows the cumulative wind speed when is equal to or lower than the wind speed *v m/s*, at a particular value between 10 *m/s* and 15 *m/s*.

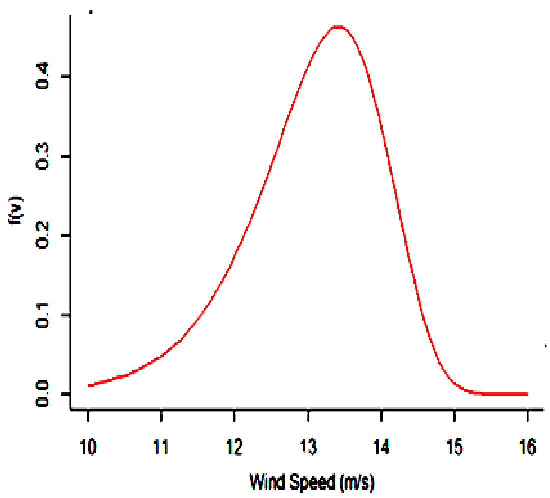

Figure 3. Weibull wind probability density distribution

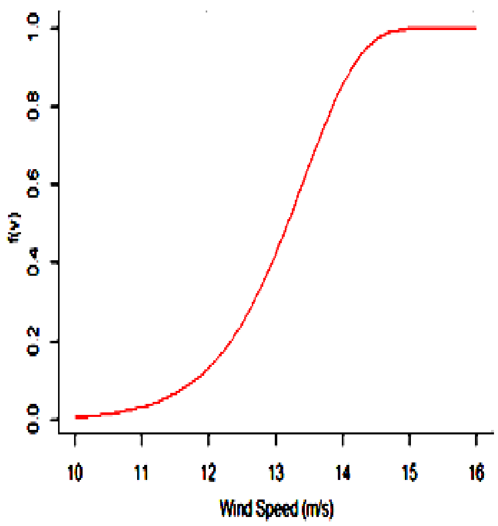

Figure 4. Weibull wind speed cumulated probability distribution.

5.3. Wind speed power density

The wind speed data based on the annual average depicting the monthly wind speed power density is shown in *Figure 5* at both 10 *m* and 50 *m* height levels.

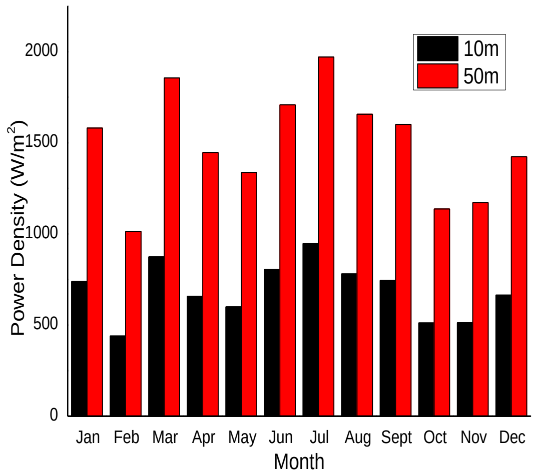

Figure 5. Monthly wind power density variation at heights 10 *m* and 50 *m* height levels.

At both levels the months of February, October, and November had the minimum values of 440.03 W/m^2, 511.65W/m^2 and 512.97 W/m^2 respectively for the 10 *m* height and the values of 1014.10 W/m^2, 1137.21 W/m^2 and 1172.33 W/m^2 respectively at the height of 50 *m*. The highest power density were observed in the months of March and July with values of 874.32 W/m^2 and 947.26 W/m^2 at the height of 10 *m* while the values were 1855.46 W/m^2 and 1970.61 W/m^2 at 50 *m* level for the same period, the remaining months for the year fall within these range of values. It could be observed that the value of the power density at 50 *m* height level is more than twice the power density values at 10 *m* height level. Based on the National Renewable Energy Laboratory (NREL) wind data classifications, Kano falls under areas designated above class 3 and therefore suitable for most utility-scale wind turbine applications. [40]

Figure 6 shows the temperature amplitude plot for the year 2003 to 2013, MAXT is the mean monthly maximum temperature, MINT is the mean monthly minimum temperature while DFT is the mean monthly difference between the MAXT and MINT. The high temperature in the Month of April is due to clear sky hot climate season while the low temperature in the Month of August is due to yearly heavy August rain with cloud cover. The DFT has the highest temperature in the Months of December and January during the Harmattan period while the lowest temperature is in the Month of August. *Figure 7* is the global solar radiation on horizontal surface plot of the location under study and it follows the same pattern as DFT with the lowest average global solar radiation on the horizontal surface of *17.96* $MJ/m^2/d$ in the month of September and highest average global solar radiation on the horizontal surface of *26.38* $MJ/m^2/d$ in month of March. The Samani model statistical validation indicated correlation coefficient R^2 value of *0.0977*, *RMSE* of *3.2121*, *MBE* value of *0.1518* while *CRM* value is *-0.0070*.

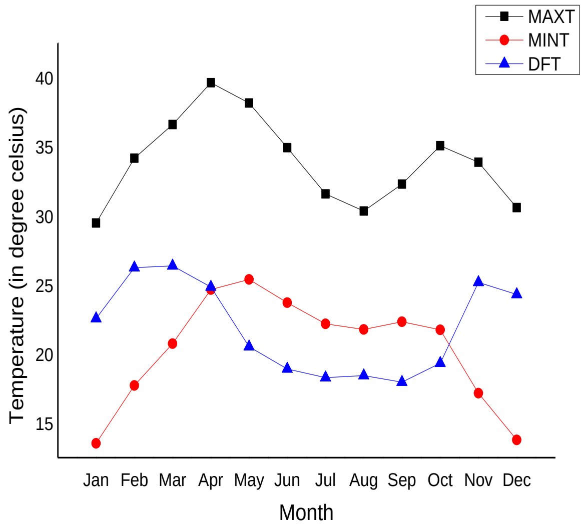

Figure 6. Temperature amplitudes of the collected data

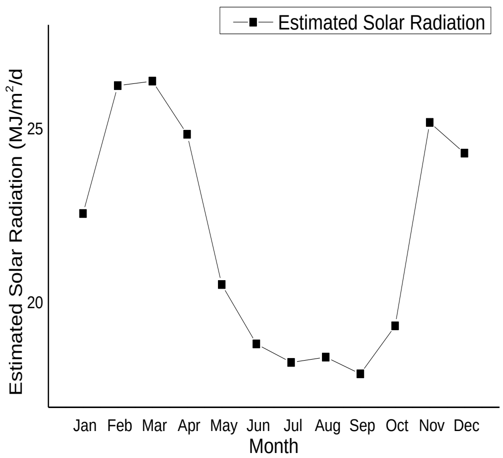

Figure 7. Estimated monthly average daily global solar radiation

6. CONCLUSION

Wind and solar renewable energy potentials at Kano, Nigeria were analyzed in this work. Air temperature, relative humidity, solar radiation data were taken from National Aeronautics and Space Administration (NASA) website while wind speed and air temperature were as well taken from Nigerian Metrological Agency (NIMET) and these data were analyzed statistically using R programming. The Weibull analyzed average monthly wind speed measured at height of 10 *m* level for the six-year period data was moderately high throughout the year as could be seen from both minimum value of 8.66 *m/s* and the maximum value of 11.23 *m/s* of the annual mean wind speed for the site. The site wind data under the period of study were analyzed using Weibull parameter model. The average wind speed value was found increasing with increase in vertical height level. The Weibull scale *(c m/s)* parameter was however found to be higher than the Weibull shape *(k)* parameter both at 10 *m* height level and at 50 *m* height level. The Weibull probability density distribution for wind speed data at 10 *m* height for the period of years under analysis shows that the wind speed distribution for the purpose of this study is quite fit in between 10 *m/s* and 15 *m/s*. The Samani model estimated global solar radiation on the horizontal surface of the site under considerations varies between the values of $17.96\ MJ/m^2/d$ and $26.38\ MJ/m^2/d$. The power density of the wind speed data and the global solar radiation on horizontal surface values show that the site under study is fit for the intended application of wind and solar power generation both for the intended application and at commercial power generation.

REFERENCE

[1] O. Ajayi, O. Ohijeagbon, C. Nwadialo, and O. Olasope, "New model to estimate daily global solar radiation over Nigeria," Sustainable Energy Technologies and Assessments, vol. 5, pp. 28-36, 2014.

[2] J. O. Okeniyi, O. S. Ohunakin, and E. T. Okeniyi, "Assessments of Wind-Energy Potential in Selected Sites from Three Geopolitical Zones in Nigeria: Implications for Renewable/Sustainable Rural Electrification," The Scientific World Journal, vol. 2015, 2015.

[3] M. Paulescu, E. Paulescu, P. Gravila, and V. Badescu, Weather modeling and forecasting of PV systems operation: Springer Science & Business Media, 2012.

[4] W. K. Cheruiyot, J. K. Tonui, and S. C. Limo, "Assessment Of Wind Energy Potential At Kesses Region-Kenya Based On Weibull Parameters," International Journal of Advanced Research, vol. 4, pp. 641-648, 2016Int. J. of Adv. Res.

[5] A. Belhamadia, M. Mansor, and M. A. Younis, "Assessment of wind and solar energy potentials in Malaysia," in Clean Energy and Technology (CEAT), 2013 IEEE Conference on, 2013, pp. 152-157.

[6] E. Dokur and M. Kurban, "Wind Speed Potential Analysis Based on Weibull Distribution," A. Pre-processing Pre-processing are quite important to obtain the most accurate result from the data. At this stage, first data cleaning, next data integration processes were carried out. In the final stage, data conversion process was performed., vol. 1, p. 2, 2015.

[7] S. Ahmed and H. Mahammed, "A statistical analysis of wind power density based on the Weibull and Rayleigh models of "Penjwen Region" Sulaimani/Iraq," Jordan Journal of Mechanical and Industrial Engineering, vol. 6, pp. 135-140, 2012.

[8] T. Unchai, A. Janyalertadun, and A. E. Holdø, "Wind energy potential assessment as power generation source in Ubonratchathani Province, Thailand," Wind Engineering, vol. 36, pp. 131-143, 2012.

[9] A. Abdulkarim, S. M. Abdelkader, and D. J. Morrow, "Statistical Analyses of Wind and Solar Energy Resources for the Development of Hybrid Microgrid," in 2nd International Congress on Energy Efficiency and Energy-Related Materials (ENEFM2014), 2015, pp. 9-14.

[10] D. Kidmo, R. Danwe, S. Doka, and N. Djongyang, "Statistical analysis of wind speed distribution based on six Weibull Methods for wind power evaluation in Garoua, Cameroon," Revue des Energies Renouvelables, vol. 18, pp. 105-125, 2015.

[11] D. H. Didane, A. Ab Wahab, S. Shamsudin, and N. Sand Rosly, "Wind as a sustainable alternative energy source in Malaysia-a review," ARPN Journal of Engineering and Applied Sciences, vol. 11, p. 18, 2016.

[12] D. Fadare, "A statistical analysis of wind energy potential in Ibadan, Nigeria, based on Weibull distribution function," The pacific journal of science and technology, vol. 9, pp. 110-119, 2008.

[13] R. Fagbenle, J. Katende, O. Ajayi, and J. Okeniyi, "Assessment of wind energy potential of two sites in North-East, Nigeria," Renewable Energy, vol. 36, pp. 1277-1283, 2011.

[14] K. Mehmet, "Estimation of global solar radiation on horizontal surface in Erzincan, Turkey," International Journal of Physical Sciences, vol. 7, pp. 5273-5280, 2012.

[15] F. Meza and E. Varas, "Estimation of mean monthly solar global radiation as a function of temperature," Agricultural and Forest Meteorology, vol. 100, pp. 231-241, 2000.

[16] C. Augustine and M. Nnabuchi, "Relationship between global solar radiation and sunshine hours for Calabar, Port Harcourt and Enugu, Nigeria," International Journal of Physical Sciences, vol. 4, pp. 182-188, 2009.

[17] K. Bakirci, "Correlations for estimation of daily global solar radiation with hours of bright sunshine in Turkey," Energy, vol. 34, pp. 485-501, 2009.

[18] M. Iqbal, "A study of Canadian diffuse and total solar radiation data—I Monthly average daily horizontal radiation," Solar Energy, vol. 22, pp. 81-86, 1979.

[19] F. Newland, "A study of solar radiation models for the coastal region of South China," Solar Energy,

vol. 43, pp. 227-235, 1989.

[20] A. Ugwu and J. Ugwuanyi, "Performance assessment of Hargreaves model in estimating solar radiation in Abuja using minimum climatological data," International Journal of the Physical Sciences, vol. 6, pp. 7285-7290, 2011.

[21] M. D. Umoh, S. O. Udo, and Y.-O. N. Udoakah, "Estimating global solar radiation on horizontal surface from sunshine hours over Port Harcourt, Nigeria," Journal of Electrical and Electronics Engineering Research, vol. 6, pp. 1-5, 2014.

[22] N. Gana and D. Akpootu, "Angstrom type empirical correlation for estimating global solar radiation in north-eastern Nigeria," The International Journal Of Engineering And Science, vol. 2, pp. 58-78, 2013.

[23] A. Sambo, "Solar radiation in Kano: A correlation with meteorological data," Nigerian Journal of Solar Energy, vol. 4, pp. 59-64, 1985.

[24] E. Arinze and S. Obi, "Solar energy availability and prediction in Northern Nigeria," Nig. J. Solar Energy, vol. 3, pp. 3-10, 1983.

[25] R. L. Fagbenle, "Estimation of total solar radiation in Nigeria using meteorological data," Nigerian Journal of Renewable Energy, vol. 1, pp. 1-10, 1990.

[26] Ohunakin, M. Adaramola, O. Oyewola, and R. Fagbenle, "Correlations for estimating solar radiation using sunshine hours and temperature measurement in Osogbo, Osun State, Nigeria," Frontiers in Energy, vol. 7, pp. 214-222, 2013.

[27] A. O. Olalekan, "Estimation Of Global Solar Radiation Of Portharcourt, Nigeria And How It Is Influenced By Daily Temperature Range."

[28] I. Hassan and M. Onimisi, "Assessment of the Global Solar Energy Potential at Nigerian Defence Academy (NDA) 2 Permanent Site Afaka Kaduna, Nigeria. 3," Methodology, vol. 49, p. 50.

[29] J. F. Wansah, A. E. Udounwa, A. U. Mee, and J. B. Emah, "Analysis of temperature based radiation models for Nsukka."

[30] M. S. Adaramola, "Estimating global solar radiation using common meteorological data in Akure, Nigeria," Renewable Energy, vol. 47, pp. 38-44, 2012.

[31] Available: http://eosweb.larc..nasa.gov/sse/

[32] C. Justus, W. Hargraves, A. Mikhail, and D. Graber, "Methods for estimating wind speed frequency distributions," Journal of applied meteorology, vol. 17, pp. 350-353, 1978.

[33] G. M. Masters, Renewable and efficient electric power systems: John Wiley & Sons, 2013.

[34] O. S. Ohunakin, "Wind characteristics and wind energy potential assessment in Uyo, Nigeria," Journal of Engineering and Applied Sciences, vol. 6, pp. 141-146, 2011.

[35] X. Li, Green energy: Springer, 2011.

[36] E. Akpinar and S. Akpinar, "Statistical analysis of wind energy potential on the basis of the Weibull and Rayleigh distributions for Agin-Elazig, Turkey," Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, vol. 218, pp. 557-565, 2004.

[37] S. O. Oyedepo, M. S. Adaramola, and S. S. Paul, "Analysis of wind speed data and wind energy potential in three selected locations in south-east Nigeria," International Journal of Energy and Environmental Engineering, vol. 3, p. 7, 2012.

[38] J. Almorox, M. Bocco, and E. Willington, "Estimation of daily global solar radiation from measured temperatures at Cañada de Luque, Córdoba, Argentina," Renewable Energy, vol. 60, pp. 382-387, 2013.

[39] Z. Samani, "Estimating solar radiation and evapotranspiration using minimum climatological data," Journal of Irrigation and Drainage Engineering, vol. 126, pp. 265-267, 2000.

[40] (2017, 5th May 2017). Wind Data Details. Available: http://www.nrel.gov/gis/wind_detail. html