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Assessment of Wind Energy Potential for the Generation of Power in Coastal and Sahel Savannah Locations in Nigeria

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Abstract: This study examines the wind power potential for different pressure heights in some Coastal and Sahel savannah stations in Nigeria. A 5-year hourly mean wind speed data at different heights and also at the hour of 00:00 and 12:00 were obtained from ERA Interim reanalysed data set. The data were statistically analyzed using Weibull distribution function. It was found out that Ikeja and Katsina stations have the maximum wind power density of 174.69 W/m^2 and 196.88 W/m^2 for both Coastal and Sahel savannah regions respectively at 100 m height and also at 12:00 hour of the day when there is occurrence of intensive wind speed as observed in the stations considered. Therefore, the analysis demonstrates the economic feasibility of using wind energy as a means of electricity supply at Ikeja in Coastal region and Katsina in Sahel savannah region of Nigeria. Thus, the wind power potential in these areas should be adequately harnessed which could be used to compliment the present power supply and reduce carbon dioxide emissions which contribute to global warming and lower long-term overdependence on fossil fuels in those areas and in Nigeria at large.

Keywords: Global Warming, Wind Power, Weibull, Potential ERA-Interim, Nigeria

1. Introduction

Energy has a major impact on every aspect of our socio-economic life. It plays a vital role in the economic, social and political development of our nation [1]. Despite the abundance of energy resources in Nigeria, the country is still in short supply of electrical power. Over 60% of the Nigerian population does not have power supply, with 40% not on the nation's grid [2]. The Nigerian grid supply of electricity is on average six hours per day rationed among inhabitants of the cities [3]. Almost all rural dwellers in Nigeria have little or no access to electricity. The majority of the electricity supply in Nigeria is generated by Kainji dam which produces about 3.2 x 10^8 W and 9.6 x 10^8 W at its peak [4]. This is due to underperforming hydro dams in the country. Another factor is the high cost of large oil and gas reserve, which compete favourably among the largest reserve in the world, Nigeria is battling with the severe energy crisis. There is therefore the need to harness renewable energy potential (such as wind, solar e.t.c) for reliable power supply in this country. Also the concern about global warming and continued apprehensions about nuclear power around the world should drive us into strong demand for wind generation according to [5]).

Several researchers have studied the prospects of wind energy resources around the world and in Nigeria especially the variation of wind energy potentials for power generation ([6–12]). Each one of these researchers considered different sites and presented analyses to justify their results. It has been reported that due to the frictional drag of the ground, vegetation and building of the nation, large differences in wind distribution within the same locality exist. This is confirmed by the fact that wind resources are site specific and despite reports summarizing for the country, a site-by-site assessment is necessary in order to have proper wind classification for the nation. This paper will assess the wind power potential for different heights in some Coastal and Sahel savannah stations in Nigeria for wind energy generation.

2. Materials and Method

The hourly mean wind speed data for 00:00 and 12:00 hours at different heights ranging from 2006- 2010 period (5 years) were used in the study and were obtained from ERA-Interim reanalysed data set for all the selected stations as shown in Figure 1 over Nigeria. Table 1 presents information about the locations.

3. Data Analysis

Weibull distribution has been found to be most adequate of the various statistical distributions that could be employed for describing and analyzing wind resource data. The wind power density (W/m^2) which is the quantitative measure of the wind energy available at any location was estimated from the equation (1) in terms of Weibull parameter ([13]).

$$p(v) = \frac{1}{2}\rho c^3 \tau \left(1 + \frac{3}{k}\right) \quad (1)$$

where: p (v) = wind power density (W/m^2), ρ = the air density at the site (kg/m^3), = gamma function.

The Weibull parameters (c and k) were estimated by using the Empirical method with mean wind speed and its variance as shown in equation (1) and (2) according to ([14, 15])

$$c = \frac{v_m}{\Gamma\left(1 + \frac{1}{k}\right)} \quad (2)$$

$$k = \left(\frac{\sigma}{v_m}\right)^{-1.086} \quad (3)$$

where: c = the Weibull scale parameter (m/s), k = the dimensionless Weibull shape parameter

σ=standard deviation and v_m = mean wind speed (m/s).

The c and k Weibull parameters account for intensity of wind speed and the stability of the atmosphere In a given area respectively.

Table 1. *Spatial distribution of the Stations used in the study.*

Station	Latitude (°N)	Longitude (°E)	Air Density (kg.m^{-3})	Altitude (m)	Climatic Region
Ikeja	06.35	03.20	1.22	39.40	
Port-harcourt	04.51	07.01	1.23	19.50	Coastal Region
Calabar	04.58	08.21	1.21	61.90	
Maiduguri	11.51	13.05	1.18	358.80	
Katsina	13.01	07.41	1.15	513.00	Sahel savannah Region
Kano	12.03	08.12	1.16	472.50	

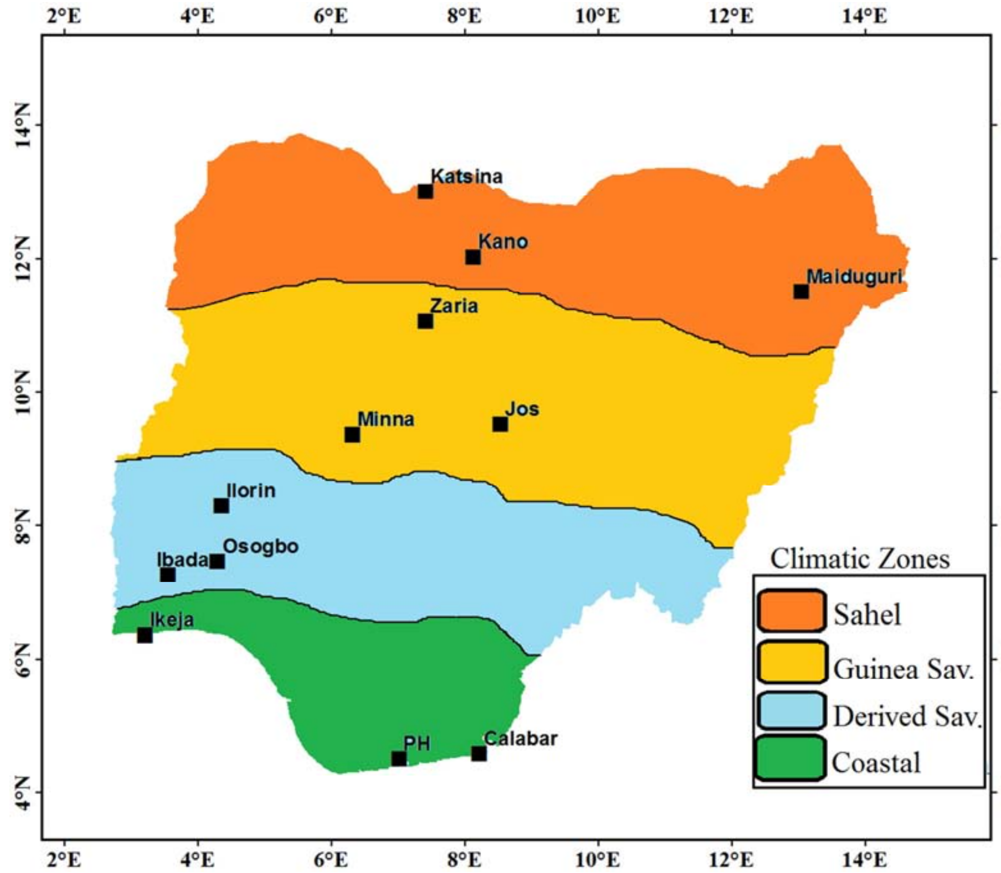

Figure 1. *A map of Nigeria showing the selected stations. (Source: (16)).*

4. Results and Discussion

Figure 2 shows the monthly variation of the wind power density (WPD) at 00:00 hr for 100 m height over all the selected stations in Coastal and Sahel savannah regions. In Coastal stations (Port-Harcourt, Ikeja and Calabar), the maximum WPD was observed in Ikeja with 125.11 W/m^2 in the month of July, while the minimum was in Port-Harcourt with 25.05 W/m^2 in September. The reason may be as a result of the location which is closer to the Atlantic Ocean, thus the sea breeze blows into the city which agrees with ([7]). Sahel Savannah region has its maximum in Katsina with 90.16 W/m^2 in June, while the minimum is in Kano with 27.17 W/m^2 in September. The observation in Guinea and Sahel savannah stations at 00:00 hour of the day could be attributed to convection current ([17]).

Figures 3-5 show the monthly variation of the WPD at 00:00 hrs. for 60 m, 30 m and 10 m heights respectively over all the selected stations in Coastal and Sahel savannah regions. The observation in these Figures (3-5) show the same situation and also follow the same pattern with the observation in Figure 2 as earlier discussed. The only differences observed are the minimum and the maximum values for each station and also the pattern observed in Port-Harcourt at 10 m height (Figure 5) which are not rising. This may be as a result of the obstruction to the wind by vegetation or hills ([18]).

Figure 6 shows the monthly variation of WPD at 12:00 hrs. for 100 m height over all the selected stations in Coastal and Sahel savannah regions. In the Coastal stations which comprises of Port-Harcourt, Ikeja and Calabar, fall in the same region and also characterized with the same climatic factors such as temperature, sunshine etc which could be a determinant to the wind energy generated in the stations [17]. The gradual increase in trend from January to April in all the three stations could be linked to the general rise in solar radiation associated to dry season, while the sudden rise experienced in Ikeja from May to August with a peak of 174.69W/m^2 in August within the rainy period could be attributed to thermal convection resulting from low temperature causing the upper air momentum to be transferred to lower layers ([17]). Though, It may also be as a result of sea breeze ([19]). In Sahel savannah region which is made up of Maiduguri, Katsina and Kano, it was noticed that Katsina has the maximum WPD in the month of December with 196.88 W/m^2 due to high temperature associated with the month and the minimum in Kano with 17.89 W/m^2 in September.

Wind energy potential can be harnessed properly in Coastal region and Sahel savannah regions as supported by ([20]), because anywhere and each time there are differences in atmospheric (air) pressure, there will be a wind. The winds may be even stronger where the difference in the air pressure is greater.

Figures (7-9) show the distribution of the WPD at 12:00 hours for 60 m 30 m, and 10 m heights respectively over all the selected stations in Coastal and Sahel savannah regions. The observation here is the same as that of Figure 6 discussed above. But it was noticed that at each height, wind energy potential was decreasing compared to the observation in Figure 6.

Figure 10 shows the spatial distribution of wind power density for 00:00 and 12:00 hours at different heights over the Coastal and Sahel savannah regions.

It was observed that in each of the synoptic hours considered, Sahel savannah region due to its high temperature, has the highest wind energy potential in all the isobaric heights, then followed by Coastal region. Therefore, wind energy can be harnessed maximally in the Sahel savannah region as supported by ([21]) where he said the northern part of the country is the best region to tap wind energy.

In addition, it was observed that wind power density is maximum at 100 m height in all the hours considered when compared to other heights especially 10 m height with little wind power distribution across the year. This is in support of the observation made by ([12]) that the more the height as movement is made towards the mountain level, the more the wind energy that will be generated hence bringing forth a high wind speed and wind power density.

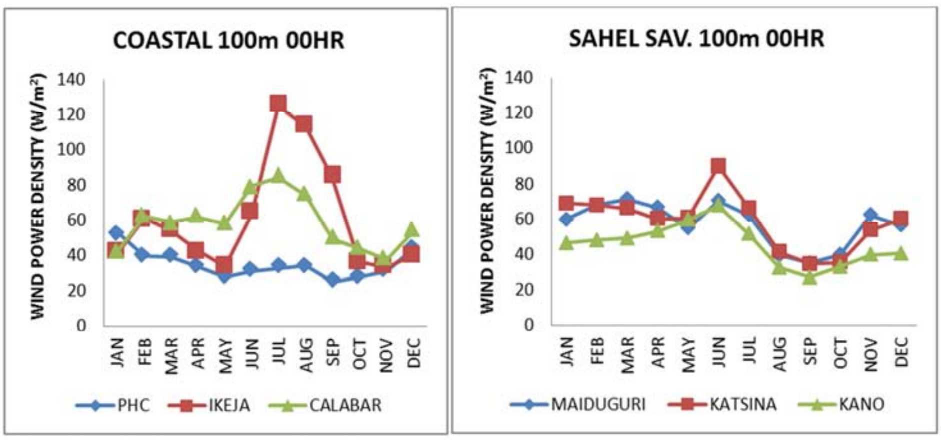

Figure 2. *Monthly variation of Wind Power Density at 00:00 hrs., at 100m height over all the selected Stations in Coastal region and Sahel region.*

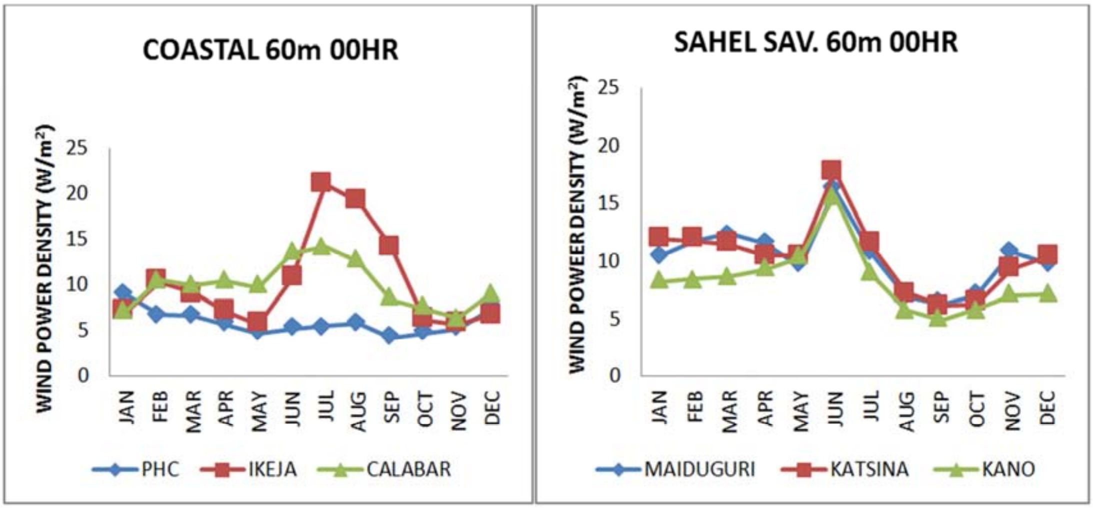

Figure 3. *Monthly variation of Wind Power Density at 00:00 hrs., at 60 m height over all the selected Stations in Coastal region and Sahel region.*

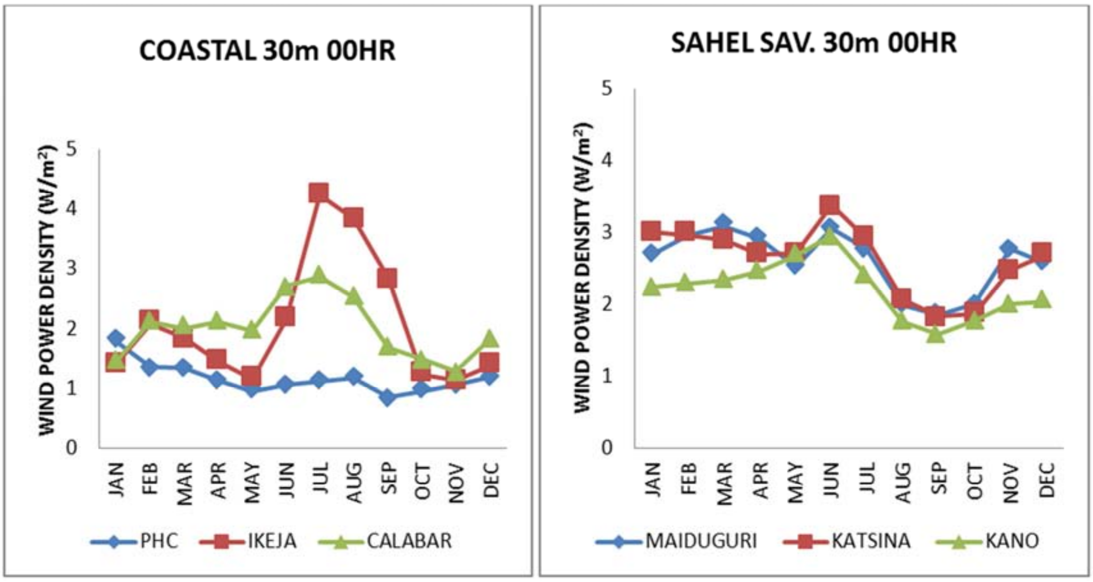

Figure 4. *Monthly variation of Wind Power Density at 00:00 hr, at 30 m height over all the selected Stations in Coastal region and Sahel region.*

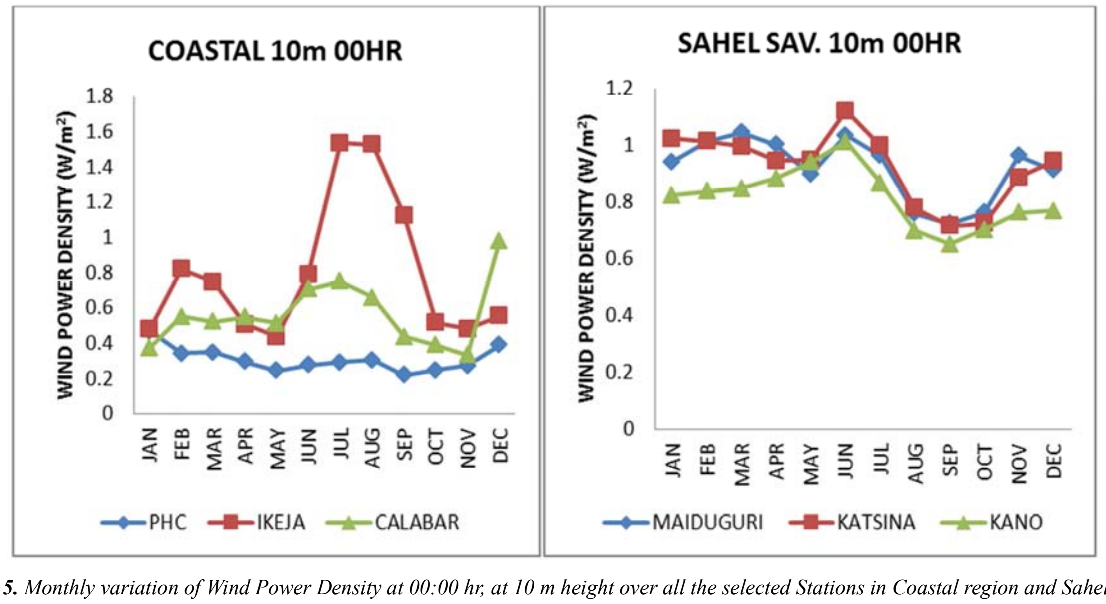

Figure 5. *Monthly variation of Wind Power Density at 00:00 hr, at 10 m height over all the selected Stations in Coastal region and Sahel region.*

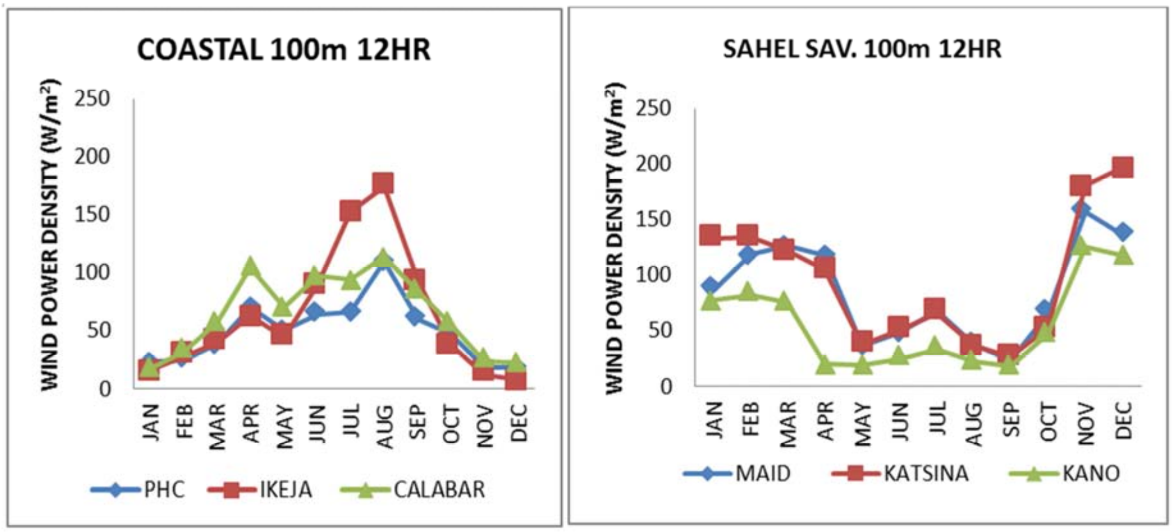

Figure 6. *Monthly variation of Wind Power Density at 12:00 hrs., at 100 m height over all the selected Stations in Coastal region and Sahel region.*

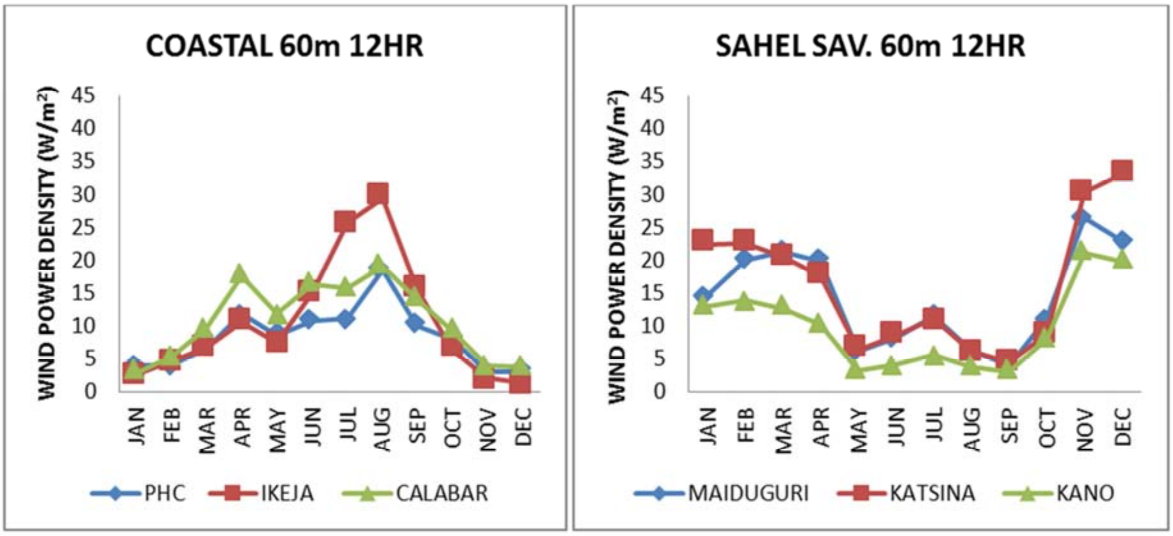

Figure 7. *Monthly variation of Wind Power Density at 12:00 hrs., at 60 m height over all the selected Stations in (i) Coastal region and Sahel region.*

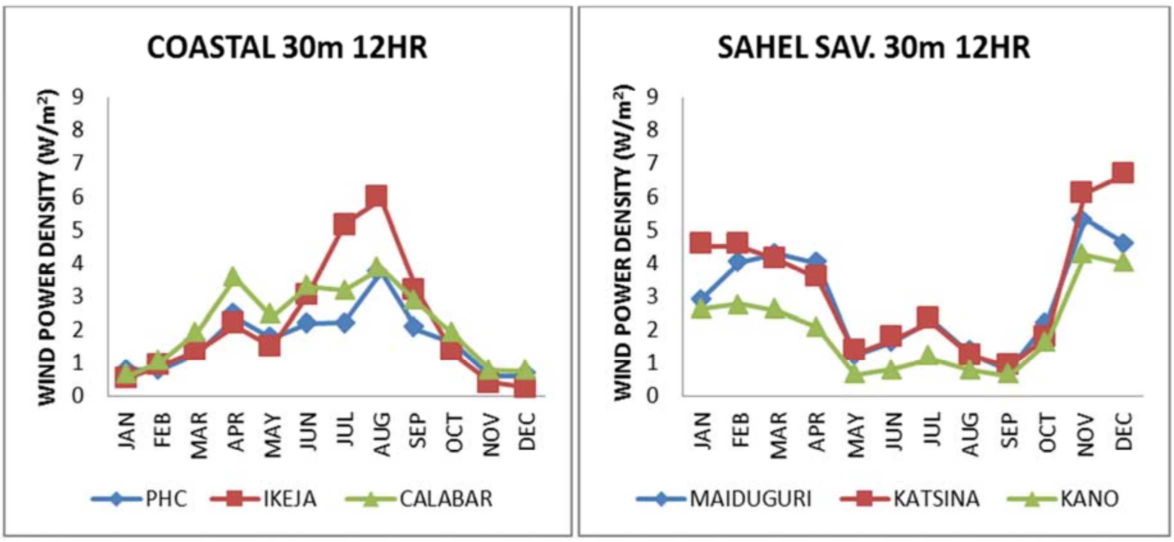

Figure 8. *Monthly variation of Wind Power Density at 12:00 hrs., at 30 m height over all the selected Stations in Coastal region and Sahel region.*

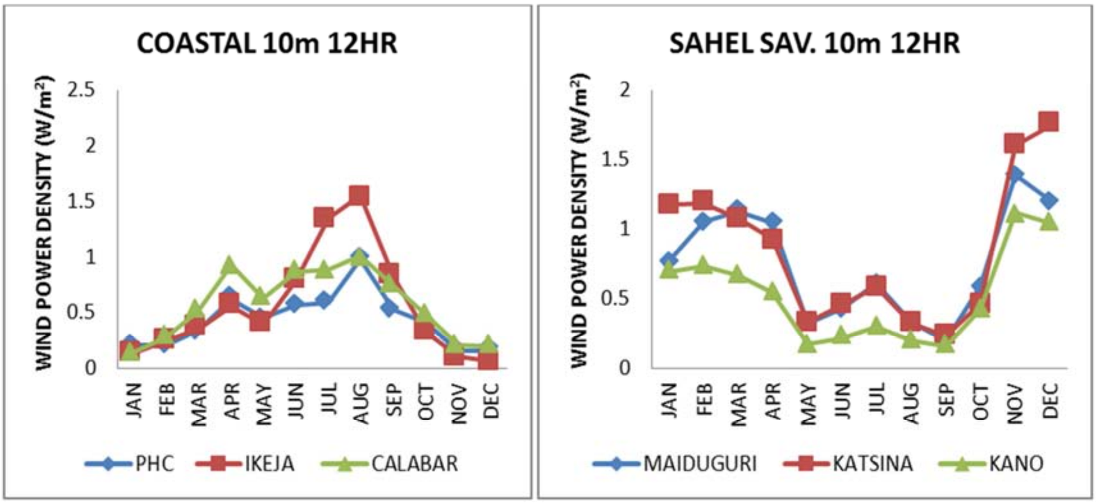

Figure 9. *Monthly variation of Wind Power Density at 12:00 hrs., at 10 m height over all the selected Stations Coastal region and Sahel region. Regional Wind Energy Potentials for different Heights at 00:00 and 12:00 hours.*

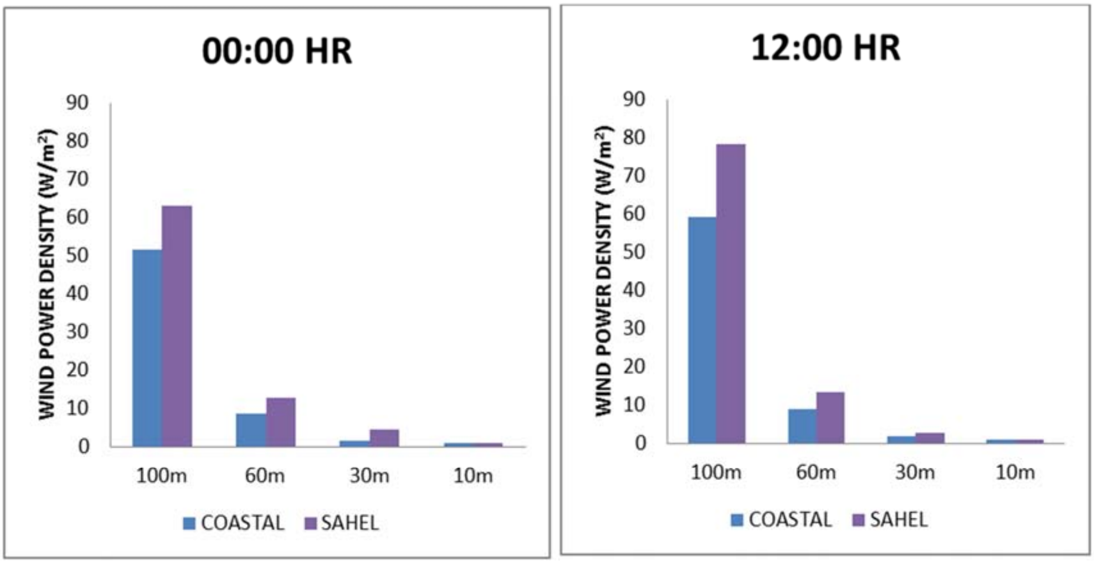

Figure 10. *Spatial Distribution of Wind Power Density for 00:00 hrs. and 12:00 hrs. at different heights over the Coastal region and Sahel region.*

5. Conclusions

In this study, the assessment of wind power potential in some Coastal and Sahel savannah stations in Nigeria for wind energy generation was carried out. Five years hourly mean wind speed data at different pressure heights from ERA-Interim reanalysed data set were assessed and subjected to Weibull distribution function. Based on the analysis the following conclusion can be made: Wind speed was high in Ikeja and Katsina stations for both Coastal and Sahel savannah regions respectively especially at 100 m height. The turbine could be best installed at 100 m height which could be the best height to generate maximum wind energy potential and at 12:00 hour of the day. In conclusion, Ikeja and Katsina areas from the Coastal and Sahel savannah regions of Nigeria respectively are well endowed with abundant wind energy resources which can be used to generate electricity. Therefore, these areas are very well suitable for wind turbine application thus, the wind power potential in these areas should be adequately harnessed in order to increase the power supply and reduce the carbon dioxide emissions which contribute to global warming and lower long term overdependence on fossil fuels in those areas and in Nigeria at large.

References

[1] J. T. Oladeji, “Utilization of Potential of Melon Shells for Pyrolysis as Biomass Fuels,” *World Rural Obs.*, vol. 4, no. 2, pp. 60–64, 2012.

[2] D. J. Obadote, “Energy crisis in Nigeria: technical issues and solutions,” in *Power sector prayer conference*, 2009, p. 4.

[3] S. O. Oyedepo, “Energy and sustainable development in Nigeria: the way forward,” *Energy. Sustain. Soc.*, vol. 2, no. 1, p. 15, 2012.

[4] Y. S. Mohammed, M. W. N. Mustafa, N. Bashir, and A. S. Mokhtar, “Renewable energy resources for distributed power generation in Nigeria: a review of the potential,” *Renew. Sustain. Energy Rev.*, vol. 22, pp. 257–268, 2013.

[5] O. S. Ohunakin, “Energy utilization and renewable energy sources in Nigeria,” *J. Eng. Appl. Sci.*, vol. 5, no. 2, pp. 171–177, 2010.

[6] O. E. O., “Characterization of Wind Speed in some Tropical Stations in Nigeria,” *Niger. Assoc. Math. Phys.*, vol. 26, pp. 550–565, 2014.

[7] N. Nze-Esiaga and E. C. Okogbue, “Assessment of wind energy potential as a power generation source in five locations of South Western Nigeria,” *J. Power Energy Eng.*, vol. 2, no. 05, p. 1, 2014.

[8] A. Öztopal, A. D. \cSahin, N. Akgün, and Z. \cSen, “On the regional wind energy potential of Turkey,” *Energy*, vol. 25, no. 2, pp. 189–200, 2000.

[9] A. S. Ahmed, “Wind energy as a potential generation source at Ras Benas, Egypt,” *Renew. Sustain. Energy Rev.*, vol. 14, no. 8, pp. 2167–2173, 2010.

[10] M. H. Albadi, E. F. El-Saadany, and H. A. Albadi, “Wind to power a new city in Oman,” *Energy*, vol. 34, no. 10, pp. 1579–1586, 2009.

[11] D. Feretić, Ž. Tomšić, and N. Čavlina, “Feasibility analysis of wind-energy utilization in Croatia,” *Energy*, vol. 24, no. 3, pp. 239–246, 1999.

[12] D. A. Fadare, “A statistical analysis of wind energy potential in Ibadan, Nigeria, based on Weibull distribution function,” 2008.

[13] R. O. Fagbenle, J. Katende, O. O. Ajayi, and J. O. Okeniyi, “Assessment of wind energy potential of two sites in North-East, Nigeria,” *Renew. energy*, vol. 36, no. 4, pp. 1277–1283, 2011.

[14] E. K. Akpinar and S. Akpinar, “An assessment on seasonal analysis of wind energy characteristics and wind turbine characteristics,” *Energy Convers. Manag.*, vol. 46, no. 11–12, pp. 1848–1867, 2005.

[15] A. Keyhani, M. Ghasemi-Varnamkhasti, M. Khanali, and R. Abbaszadeh, “An assessment of wind energy potential as a power generation source in the capital of Iran, Tehran,” *Energy*, vol. 35, no. 1, pp. 188–201, 2010.

[16] O. S. Ojo and J. B. Tawose, “Impact of Solar Flux Ratios on Sky Condition Over Regional Climate of Nigeria,” *IJOS Int. J. Opt. Sci.*, vol. 3, no. 2, pp. 6–17, 2017.

[17] O. S. Ohunakin, “Wind characteristics and wind energy potential assessment in Uyo, Nigeria,” *J. Eng. Appl. Sci.*, vol. 6, no. 2, pp. 141–146, 2011.

[18] Z. O. Olaofe, “On the Remapping and Identification of Potential Wind Sites in Nigeria,” *Energy Power Eng.*, vol. 7, no. 10, p. 477, 2015.

[19] M. A. Ayoade and others, *Disused offshore installations and pipelines: towards sustainable decommissioning*. Kluwer Law International, 2002.

[20] J.-F. K. Akinbami, “Renewable energy resources and technologies in Nigeria: present situation, future prospects and policy framework,” *Mitig. Adapt. Strateg. Glob. Chang.*, vol. 6, no. 2, pp. 155–182, 2001.

[21] A. D. Asiegbu and G. S. Iwuoha, “Studies of wind resources in Umudike, South East Nigeria--An assessment of economic viability,” *J. Eng. Appl. Sci*, vol. 2, no. 10, pp. 1539–1541, 2007.