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Full Length Research Paper

Diurnal characteristics of the wind potential along the North-western coast of Senegal

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This paper is aimed at determining the diurnal characteristics of the wind potential in Senegal. The data used in this study are collected from eight sites (Kayar, Potou, Gandon, Sine Moussa Abdou, Botla, Dara Andal, Nguebeul and Sakhor) located alongside the North-western coast of Senegal. These data cover the period of one year for each site. The annual wind speed distribution curves in all sites were obtained by using the Weibull distribution function. The results obtained show that the power density available is greater during the dry season than in the rainy season. In all sites, it appeared more important for the day-time than the night-time. For instance, the power density was 145.30 and 58.34 W/m² at the height of 20 m in the day and night, respectively in the site of Potou; it reveals 99.64 and 52.35 W/m² in the site of Kayar and 103.14 and 45.87 W/m² in Gandon during the same period and the same height. The corresponding average wind speeds are of 5.69 and 4.15 m/s in Potou, 5.04 and 3.80 m/s in Kayar and 5.13 and 3.77 m/s in Gandon.

Key words: Weibull distribution, wind potential, diurnal characteristics, seasonal characteristics.

INTRODUCTION

Fossil fuels are the main resources; they play a key role in meeting the global energy demand. However, fossil fuel reserves are limited and the use of these resources has adverse impacts on the environment. Therefore, the resort to renewable energy source is vital (Akdag and Dinler, 2009). The worldwide demand for renewable energy is rapidly increasing because of the climate problem and also because of the limited oil resources. Wind energy appears as a clean and good solution to cope with a great part of this energy demand (Raichle and Carson, 2009). However, the development of new wind projects continues to be hampered by lack of reliable and accurate wind resource data in many parts of the world. A characterization and analysis of wind energy resources are, thus, necessary and make it possible to assess the energy output by using a technology of wind turbines. Recently, many researchers (Irfan et al., 2010; Ahmed et al., 2010; Raichle and Carson, 2009; Ali, 2010) have conducted studies on the wind energy resources in all sites around the world.

In Senegal, the government has made much progress to reduce its dependence on imported oil products, which negatively affects the national trade balance. But, the development of new wind projects continues to be hampered by lack of knowledge of wind potential and the absence of reliable and accurate wind resource data in many parts of the country. Recent studies (Youm et al., 2005; Boudy et al., 2008a, b, 2010, Kébé et al., 2008) have concluded that the best area to use wind energy is along the coastal zone in Senegal. However, we have a little knowledge about seasonal and diurnal features of wind speed. These characteristics remain necessary to estimate the energy output, and subsequently fathom the influence of the seasonal and the average diurnal wind speed variation on the wind turbines output, and to choose suitable technologies for electricity generation.

So, the contribution of this paper is to evaluate the wind energy potential in eight sites located along the North-

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Figure 1. Localization of the eight sites used in this study.

western coast of Senegal by determining diurnal effect on characteristics of the wind speed for each season in order to evaluate the technical and economical feasibility of the wind turbines for electricity generation in these areas.

MATERIALS AND METHODS

The most important parameter that should be estimated in order to design a wind park is the average wind speed, the Weibull parameters, the wind power density and the factor and length of roughness. Thus, this work aims to determine the wind speed for each season in all sites and in setting the Weibull parameter and the power density for both times of day and night in a year. The annual average wind speed was calculated for all sites at each high level, and then the factor and length of roughness were determined. The diurnal Weibull distribution and the cumulative diurnal Weibull distribution were determined for all sites at the height of 20 m in the sites of Kayar, Potou and Gandon, and at the height of 12 m in sites Sine Moussa Abdou, Botla, Dara Anda, Nguebeul and Sakhor.

Some software packages, such as WasP and WindPro are available, whereby it is possible to assess the wind potential. However, these tools do not help estimate the seasonal and the diurnal parameters of wind potential and are very expensive. For this reason, programs to calculate the seasonal and diurnal wind potential are achieved by using Maltab. The method to evaluate the seasonal and diurnal wind potential is applied on aforementioned eight sites.

Description of the sites and the data collected

In this study, eight metrological stations were installed in the sites of Kayar, Potou, Gandon, Sine Moussa Abdou, Botla, Dara Anda, Nguebeul and Sakhor (Figure 1) located along the North-western coast of Senegal. The site of Sakhor is far from the sea but the presence of hallway coming from the sea can promote the acceleration of the wind speed, thus increasing the regular wind speed. Table 1 gives the locations of meteorological stations, the period of collection and the coverage rate of data for each site. These stations were equipped with a data acquisition system that records every 10 min the average, maximum and minimum values for each sensor. The data are saved in a flash memory card. The evaluation of the collected data in the sites has shown a coverage rate between 82 and 100%. The minimum value (82%) was observed for the site of Nguebeul. On the whole, the coverage rate value is very high and allows for the use of these data in order to calculate the wind potential for the sites.

Theoretical models

Average wind speed

In this study, wind speeds data measured every 10 min for one year in each site were used to calculate wind potential in the sites. The annual, seasonal and diurnal average wind speed values were

Table 1. Characteristics of the meteorological stations.

Site	Latitude north (°)	Longitude west (°)	Elevation (m)	Period of measurement	Coverage rate (%)
Kayar	14.92	17.12	06.00	August 2007 to July 2008	100
Potou	15.72	16.50	21.00	August 2007 to July 2008	100
Gandon	15.96	16.45	05.00	Jun 2004 to May 2005	99
Sine Moussa	15.18	16.74	54.00	November 2007 to October 2008	95
Botla	15.67	16.49	28.00	November 2007 to October 2008	94
Dara Andal	15.42	16.53	43.00	November 2007 to October 2008	86
Ngeubeul	15.35	16.59	51.00	November 2007 to October 2008	82
Sakhor	14.23	16.45	03.00	November 2007 to October 2008	96

calculated by using Equation 1, (Ali, 2003).

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

where n is the observation number and v_i is the wind speed in time stage *i*.

Extrapolation of wind speed with height

The wind speed measurements were collected for two heights in each site. For wind projects, it is necessary to estimate the wind speed at the wind turbine hub height. According to the literature, the most commonly used method to adjust the wind speed from one level to another is the power law method (Gholamreza et al., 2011; Omer, 2008) as illustrated in Equation 2:

$$v = v_0 \cdot \left(\frac{h}{h_0}\right)^{\alpha} \qquad (2)$$

where v_0 is the reference average wind speed (m/s) measured at the height of h_0 (m), v is the mean wind speed (m/s) to be determined for the desired height h and α is the roughness factor estimated by using the wind speeds measured at the two altitudes. The roughness length is, thus, calculated by using the Equation 3:

$$z = \frac{\exp\left[v \cdot \ln(h_0) - v_0 \cdot \ln(h)\right]}{v - v_0} \qquad (3)$$

When the wind speed was measured near the ground, the roughness factor and the roughness length were high. This explains the presence of lowland forest. That can lose the available wind speed.

Weibull distribution

Weibull distribution has been commonly used in the literature to express the wind speed frequency distribution and to estimate the wind power density. Weibull distribution is a proper match with the experimental data. The probability density function of Weibull and the cumulative distribution are given by Equations 4 and 5 (Gholamreza et al., 2011; Gokcek et al., 2007; Ali, 2003; Ulgen and Hepbasli, 2002):

$$f(v) = \frac{k}{c} \cdot \left(\frac{v}{c}\right)^{k-1} \exp\left(-\left(\frac{v}{c}\right)^{k}\right) \qquad (4)$$

$$F(v) = 1 - \exp\left(-\left(\frac{v}{c}\right)^{k}\right) \qquad (5)$$

with c and k respectively meaning the scale and the shape parameters of Weibull. To estimate the two parameters (k and c), numerous methods have been proposed over the last few years. In this study, the two parameters of Weibull (c and k) are determined by using Equations 6 and 7 (Ahmed and Hanitsch, 2006):

$$k = \left(\left(\frac{\sum_{i=1}^{n} v_i^{k} \cdot \ln(v_i)}{\sum_{i} v_i}\right) - \left(\frac{\sum_{i=1}^{n} \ln(v_i)}{n}\right)\right)^{-1} \qquad (6)$$

$$c = \left(\frac{\sum_{i=1}^{n} v_i^{k}}{n}\right)^{\frac{1}{k}} \qquad (7)$$

Wind power density

The evaluation of the wind power per unit area (wind power density) is of fundamental importance in assessing the wind power projects. The long-term wind speed distribution f (v) is combined with the available wind power to give the average wind power density, which can be expressed as follows (Gholamreza et al., 2011; Zhou et al., 2006):

$$\overline{P} = \frac{1}{2} \cdot \rho \cdot \int_{0}^{\infty} v^{3} \cdot f(v) \cdot dv \qquad (8)$$

Table 2. Annual mean wind speed in the all sites.

Site	Anemometer height (m)	Mean wind speed (m/s)	Alpha: α (-)	Roughness length (m)
Kayar	20 30	4.32 4.77	0.25	0.07
Potou	20 30	4.80 5.28	0.23	0.06
Gandon	20 40	4.10 5.23	0.27	0.08
Sine Moussa	07 12	3.60 4.47	0.4	0.16
Botla	07 12	3.40 4.16	0.37	0.14
Dara Andal	07 12	3.10 4.12	0.52	0.27
Ngeubeul	07 12	3.24 4.36	0.55	0.31
Sakhor	07 12	3.75 4.49	0.33	0.11

RESULTS AND DISCUSSION

Average wind speed along North-western coast of Senegal

As part of this study, the data collected over the period of one year for the Kayar, Potou, Gandon, Sine Moussa Abdou, Botla, Dara Anda, Nguebeul and Sakhor sites were used to calculate the wind potential, taking account the seasonal and the diurnal period effects on the wind potential.

The annual average wind speed was calculated by using Equation 1. It was calculated for all the heights and in each site. The results obtained (Table 2) show that the average wind speed varies between 5.28 and 4.10 m/s for heights between 30 and 12 m in all sites. These values exceed the cut-in wind speed for the most commercialized wind turbines and show that the sites present good wind resources. The lowest mean wind speed is 3.10 m/s observed for the site of Dara Andal at the height of 7 m.

The factor and length of roughness were calculated. Table 2 shows that the highest roughness factor corresponds to the site where the length of the roughness is higher. The highest values of roughness factor and of roughness length explain the presence of lowland forest because of the use of the wind data measured near the ground (at 7 and 12 m). The highest values of the roughness factor and the length roughness were 0.55 and 0.31 observed in the site of Ngeubeul, respectively. As such, this site is characterized by the presence of more obstacles to wind than the sites of Sine Moussa, Botla, Dara Andal and Sakhor.

Wind regimes along the North-western coast of Senegal

The wind regimes along the North-western coast of Senegal were determined by using the collected data at the height of 20 m in the sites of Kayar, Potou and Gandon, and by the use of the collected data at the height of 12 m in the sites of Sine Moussa Abdou, Botla, Dara Andal, Nguebeul and Sakhor. Two distinct seasons were noticed in these regions: a dry season (November to May) and a rainy season (June to October). The results show that the dry season is characterized by strong wind regimes; in contrast the rainy season is subject to lower average wind speeds (Figure 2). In all sites, the average mean wind speed varies between 4.21 and 5.23 m/s for the dry season and varies between 3.73 and 4.49 m/s for the rainy season. It is 4.66, 5.23 and4.63 m/s for the dry season in the sites of Kayar, Potou and Gandon observed at the height of 20 m. In

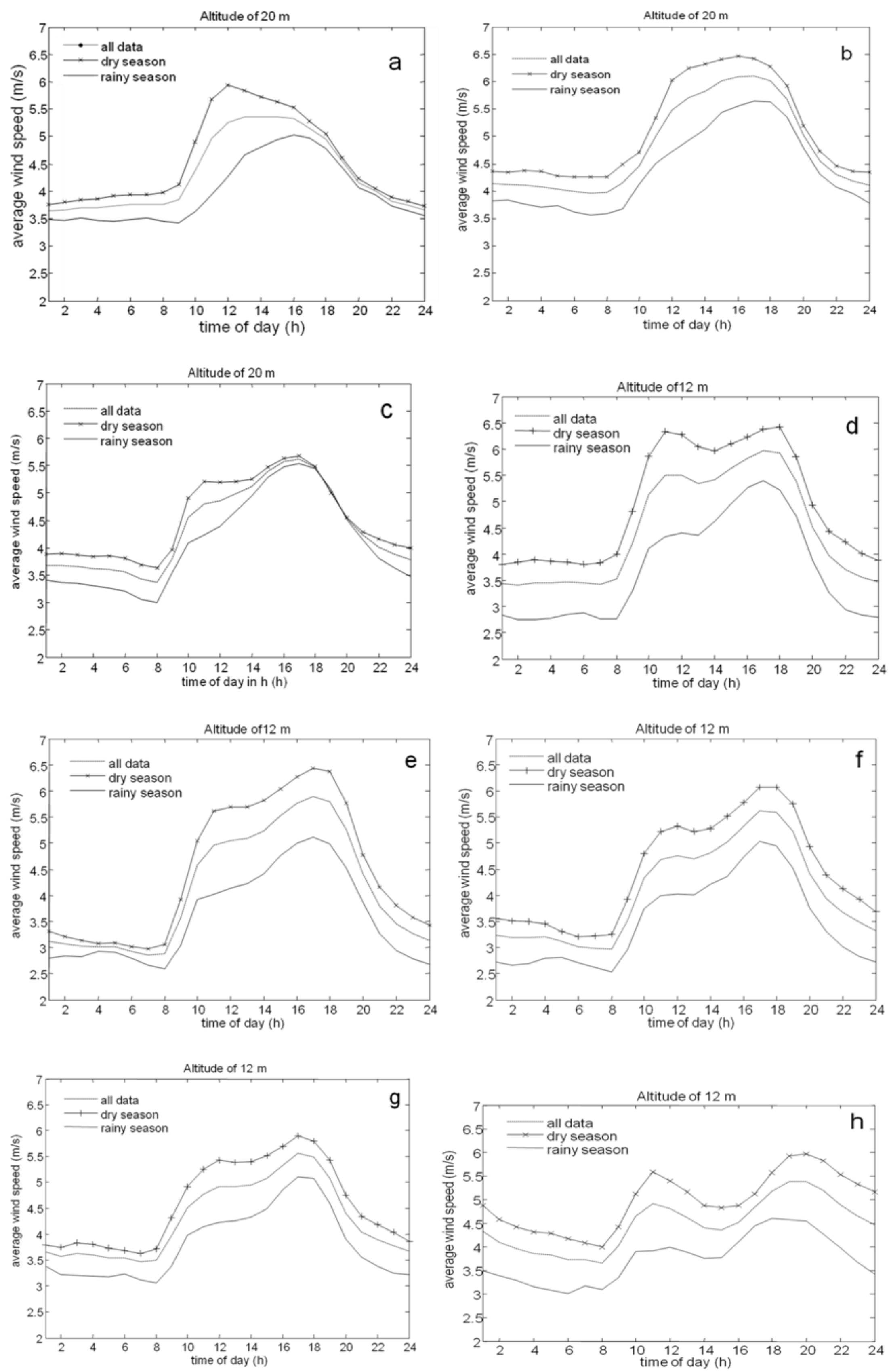

Figure 2. Hourly variation of mean wind speed in the site of the (a) Kayar, (b) Potou, (c) Gandon, (d) Sine Moussa Abdou, (e) Botla, (f) Dara Andal, (g) Nguebeul and (h) Sakhor.

Table 3. Seasonal mean wind speed for all sites.

Site	Height (m)	Wind speed (m/s)		Discrepancy (%)
		Dry season	Rainy season	
Kayar	20	4.66	4.07	13
Potou	20	5.23	4.50	14
Gandon	20	4.63	4.21	09
Sine Moussa Abdou	12	5.11	3.86	24
Botla	12	4.68	3.74	20
Dara Andal	12	4.62	3.82	17
Nguebeul	12	4.72	3.93	17
Sakhor (Sine Saloum)	12	5.18	3.81	26

Table 4. Daily mean wind speed in the all sites.

Site	Height (m)	Wind speed (m/s)		Discrepancy (%)
		Day	Night	
Kayar	20	5.04	3.8	25
Potou	20	5.69	4.15	27
Gandon	20	5.13	3.77	27
Sine Moussa Abdou	12	5.52	3.7	33
Botla	12	5.32	3.29	38
Dara Andal	12	5.03	3.39	33
Nguebeul	12	5.06	3.76	26
Sakhor (Sine Saloum)	12	4.83	4.22	13

contrast, it equals 4.07, 4.49 and 4.21 m/s in the same sites for the rainy season. The discrepancy of the mean wind speed between the dry season and the rainy season was calculated. The results obtained (Table 3) show that the highest discrepancy is 26% observed in the site of Sakhor.

Basically, estimating only the seasonal distribution of the winds would lead to an assessment that underestimates the wind power potential during daylight hours and overestimates the wind power potential at night. This can provoke a loss of load and unnecessary cost for electricity production from wind turbine.

The hourly study of the wind speed in the investigated sites was made. We have noted the existence of two characteristics periods: a period of strong wind speed, from 11 am to 08 pm, corresponding to the day and a period of low wind speed, from 09 pm to 10 am, corresponding to night. The two periods correspond to the sea breeze and land breeze, respectively. Figure 2 shows clearly that for both seasons and for the annual period, the average wind speed increases tremendously during the daytime for all sites. For example, it was noted that for the period of that year, the mean wind speed varies between 5.04 and 5.69 m/s during day-time and varies between 3.77 and 4.15 m/s during the period of night at the height of 20 m in the sites of Kayar, Potou and Gandon. The discrepancy of the mean wind speed between the day-time and night-time was calculated. The highest value obtained is 38% observed for the site of Botla. The lowest value (13%) was observed for the site of Sakhor. From these results, a wind turbine installed will generate more electricity during daylight than during the night-time.

The fact that the wind speed remains close to one another during the two periods (day-time and night-time) in Sakhor is due to the decreasing sea breeze effect, as the site of Sakhor is far from the sea as compared to the rest of the sites (Sine Moussa Abdou, Botla, Dara Andal and Nguebeul) which are exposed to the sea breeze. However, the average wind speed is greater for the site of Sakhor due to the effect tunnel that promotes the increase of wind speed. Table 4 gives the results obtained for the two periods (day and night) in all sites.

Determining the wind speed according to the wind direction for a site is important to conduct the wind energy assessment, but also to evaluate the impact of geographical features on the installation of wind turbines (Ould et al., 2008). The relative frequencies of wind directions are determined for the day-time and night-time in Figures 3 and 4. According to these figures, the dominant wind direction is north-north-eastern in all sites for the day-time and for night-time. However, the dominant

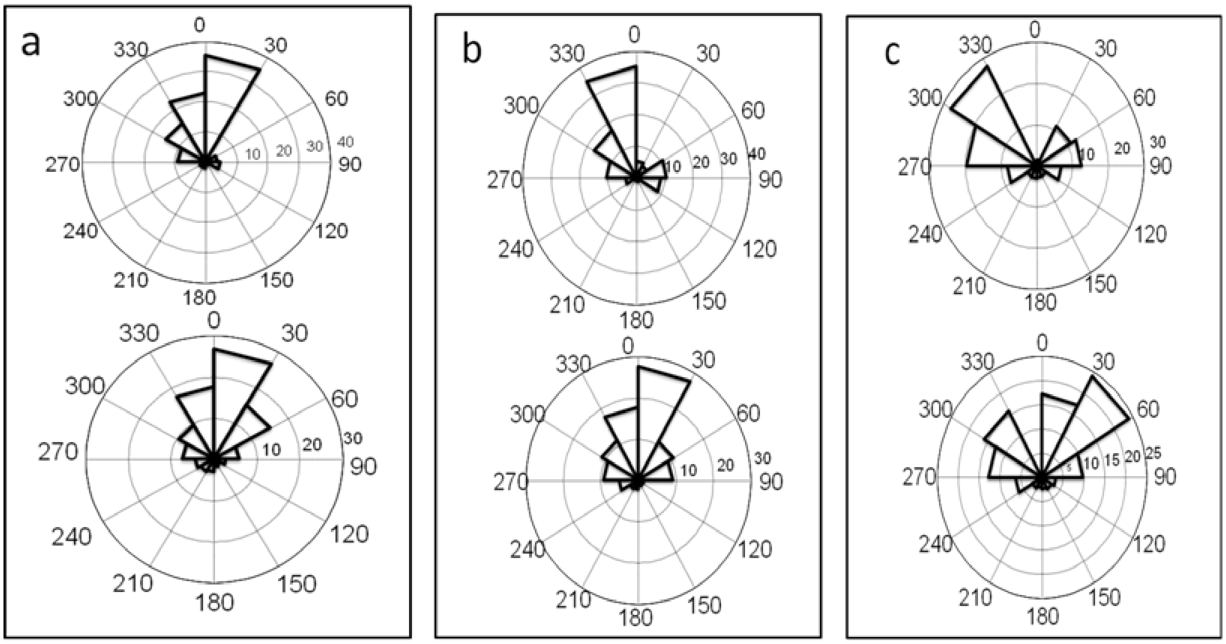

Figure 3. Diurnal wind direction in the sites of (a) Kayar, (b) Potou and (c) Gandon (top figure indicates the period of the day-time and below figure shows the period of the night).

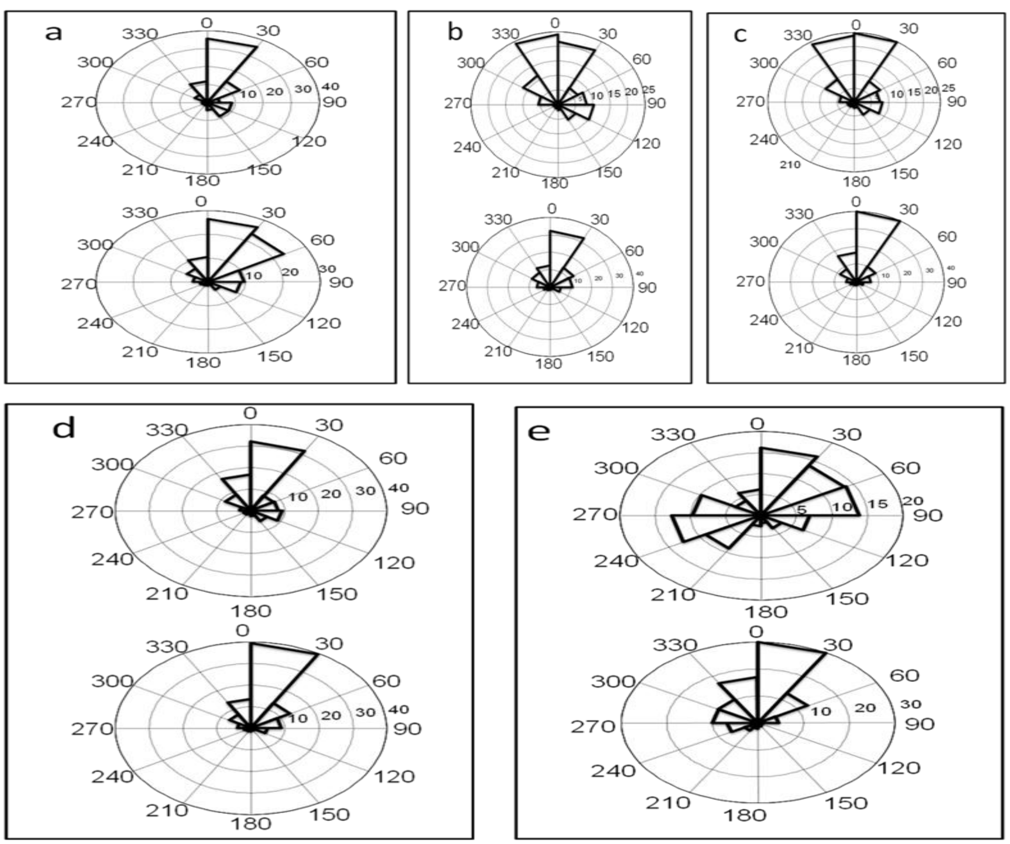

Figure 4. Diurnal wind direction in the sites of (a) Sine Moussa Abdou, (b) Botla, (c) Dara Andal, (d) Nguebeul and (e) Sakhor (top figure indicates the period of the day below figure shows the period of the night).

north-north-western direction was observed for day-time in the sites of Potou and Gandon. The dominant wind direction is North-eastern and South-western in the site of Sakhor for day time.

Weibull distribution

The expansion of electricity capacities or application of electricity generation in small isolated power systems requires not only the monthly or seasonal probability distribution of the mean wind speed, but also needs to assess at least hourly probabilities of the wind speeds.

In particular, a duration curve of electricity demand varies significantly throughout the day. For this reason, the diurnal probability distribution of the wind speed was determined in the sites by using the Weibull distribution function as given in Equation 4. The study has been carried out using the collected data at the height of 20 m for Kayar, Potou and Gandon, and at 12 m for Sine Moussa Abdou, Botla Dara Andal, Nguebeul and Sakhor.

Figure 5 shows the probability distribution during the day-time and night-time in all sites. A significant deviation was noted between the daily and nightly distribution, underscoring the importance of considering the time of the day and night. The highest peak probability is observed as 12.50, 10.50 and 13% for the day time in Kayar, Potou and Gandon. It is equal to 12% in Kayar and 14% in Gandon and Potou for the night time. The highest frequency is 8.7 and 10% for the day-time and night-time, respectively in the site of Sakhor (Figure 5h). These two frequencies correspond to the same mean wind speed (4 m/s). The diurnal distributions in the daytime and night-time are close to each other in this site, so, the distributions are similar.

As seen in Table 4, the discrepancy between day-time and night-time mean wind speed was lower (13%) for Sakhor than for the other sites. Away from the mean wind speed (4 m/s), the frequency is higher for day-time than for the night-time.

The cumulative probability obtained from the observed and the Weibull distribution functions was achieved for the site of Kayar at the height of 20 m. Figure 6a and b shows that the cumulative probability distributions have a good correspondence between the Weibull and the observed distribution with a maximum discrepancy of 0.4% observed during the day time. The observed cumulative distribution for the day and night times was given on one figure for one hand in the sites of Kayar (Figure 7a) and on the other hand, the site of Sakhor (Figure 7b). It was noted that the cumulative probability, whereby the mean wind speed is lower than a given mean wind speed value that was greater at night than during the day. The frequency corresponds to the mean wind speed which is inferior to 4.32 m/s (annual mean wind speed in the site of Kayar at 20 m) is 33% for the day-time and is 65% for the night time.

However, for the site of Sakhor which is far from the sea, the cumulative frequency is 50 and 65% for the day and night periods, respectively. These recent comments were noted for the annual mean wind speed of 4.45 m/s. The maximum discrepancy of the observed cumulative frequencies between the day-time and the night-time in site of Sakhor is 21%; in contrast, it is 62% for the site of Kayar.

The mean wind speed diurnal characteristics study by determining the Weibull parameter and the power density was carried out. The results obtained are given in Table 5. As seen from this table, the highest value of scale parameters is observed for the day time; and it is between 5.44 and 6.31 m/s for the day time and between 3.71 and 4.76 m/s for night time. These values show that the sites present good wind resources, as indicated previously (Table 4). The power density obtained is between 99.64 W/m² (Kayar) and 145.30 W/m² (Potou) for the day time, and is between 37.07 W/m² (Botla) and 75.89 W/m² (Sakhor) for the night time. The highest discrepancy between daily and nightly power density is 71% for the site of Botla, and the lowest value is 35% for Sakhor.

DISCUSSION

Results obtained in this work show that the mean wind speed is higher for the day-time than for the night-time. It is due to the fact that the day-time has the sea breeze and in the night-time has the land breeze. These two breezes are caused by the difference of temperature gradient between the sea and the land. This temperature gradient is higher in the day-time than in the night-time. These results are observed for the all sites. The site of Sakhor presents the particularity that the discrepancy between the mean wind speed in the day-time and the night-time is lower as compared to the others sites. That is because, the site of Sakhor is far from the sea. However, the presence of the tunnel effect allows daily mean wind speed favorable for the harnessing of the wind potential in this site.

From the wind rose determined for the all sites (Figures 3 and 4), it is observed that dominated wind direction was north-northeast, respectively for the day time and night-time. During the night, the dominant wind direction was a little oriented towards the east direction. That is because of the presence of land breeze which decreases the wind coming from the sea during the night.

In Sakhor, it was observed that two wind directions (north-northeast and south-southwest) for day-time and one dominant direction in the night-time. These two wind directions, observed in the day-time are due to the perturbation of the wind observed during the rainy season. That perturbation is more observed during the day-time than the night time. For this reason, the wind direction is more stable for the night-time.

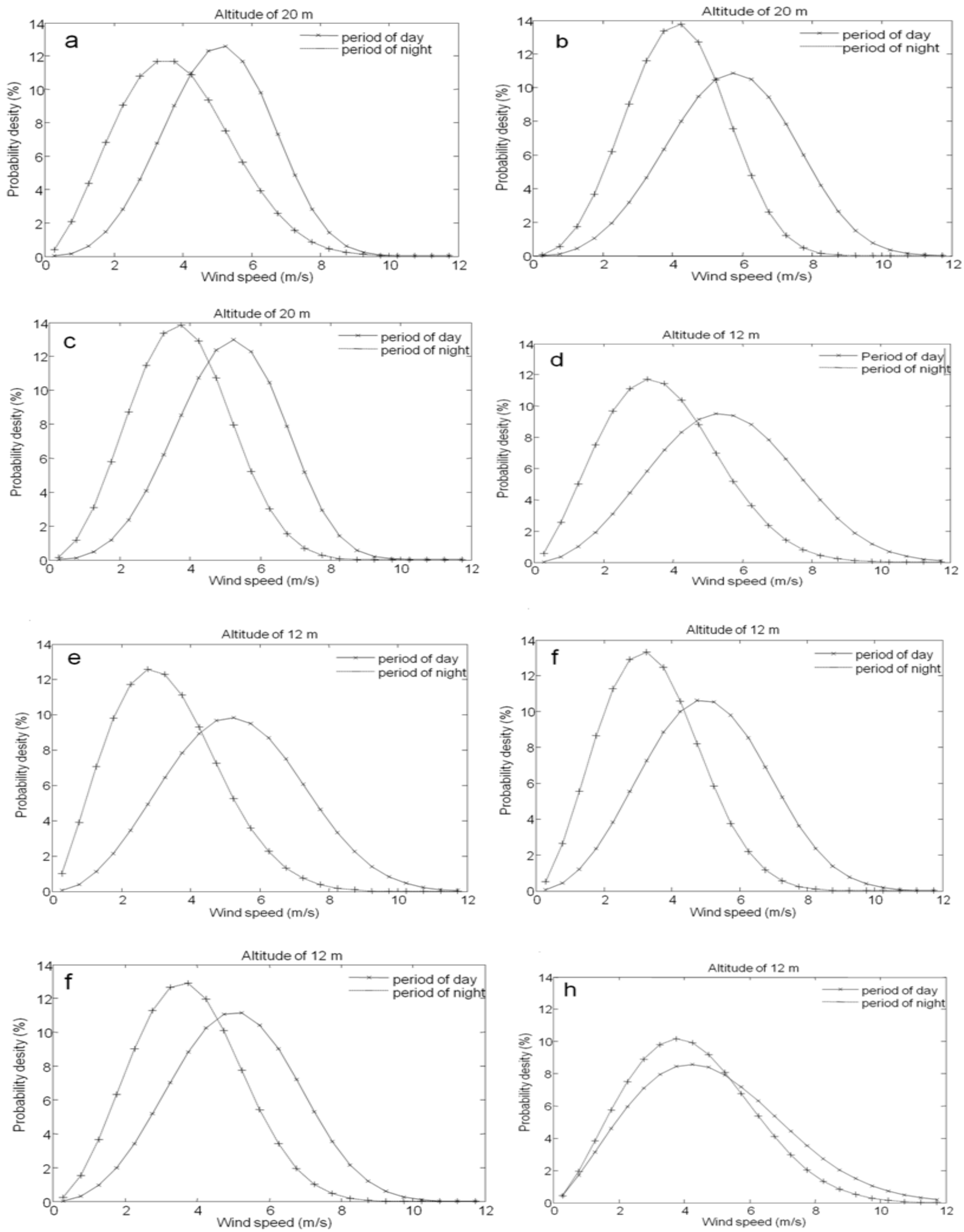

Figure 5. Comparison between diurnal wind speed distribution in the site of the (a) Kayar, (b) Potou, (c) Gandon, (d) Sine Moussa Abdou, (e) Botla, (f) Dara Andal, (g) Nguebeul and (h) Sakhor.

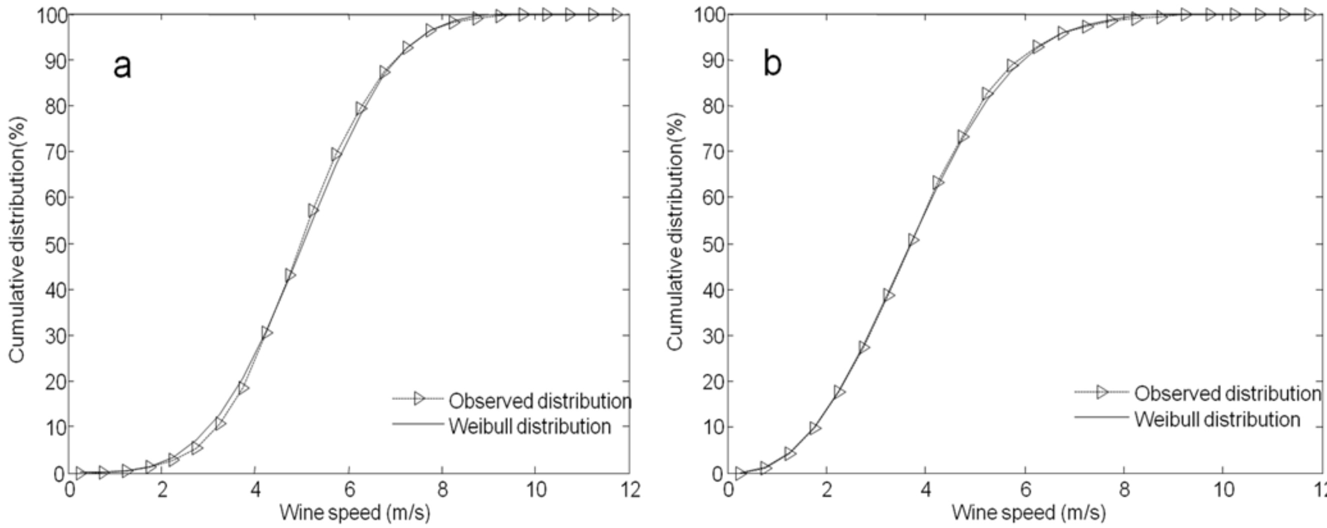

Figure 6. Comparison between observed and calculated cumulative distribution in Kayar: (a) day-time, (b) night-time.

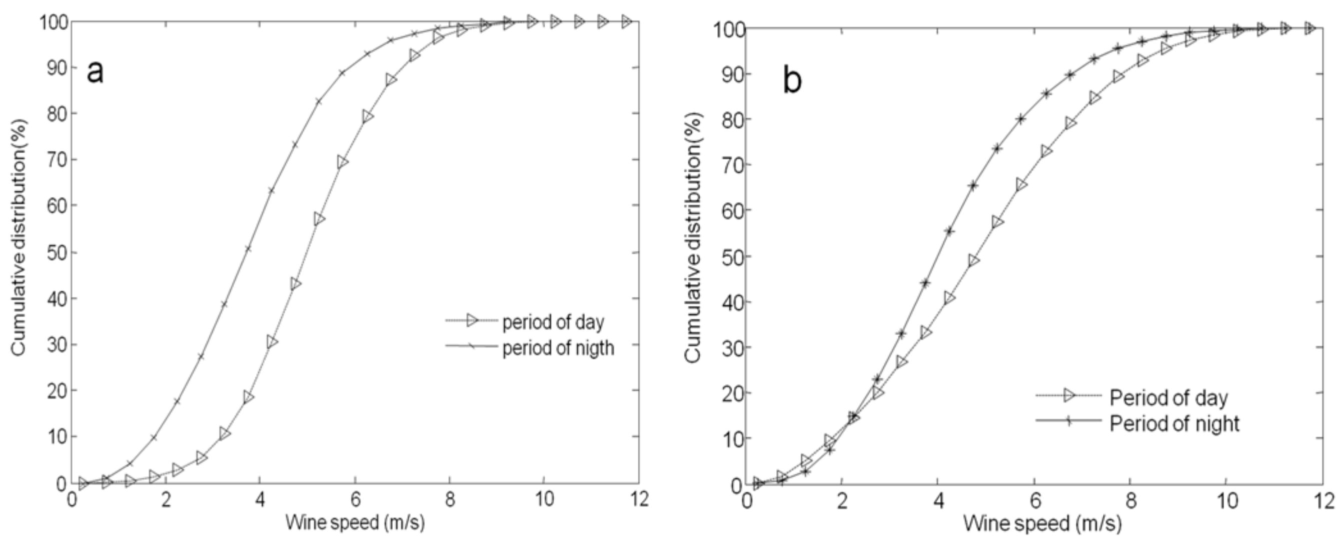

Figure 7. Comparison observed between the day and night periods in the site of (a) Kayar at 20 m and (b) Sakhor at 12 m.

Table 5. Diurnal Weibull parameters and wind power density in the all sites.

Site	Height (m)	Scale parameter (m/s)		Shape parameter (-)		Power density (W/m²)		Discrepancy (%)
		Day	Night	Day	night	Day	night	
Kayar	20	5.58	4.28	2.67	2.51	99.64	52.95	47
Potou	20	6.31	4.62	2.57	2.30	145.30	58.34	60
Gandon	20	5.66	4.21	3.85	2.98	103.14	45.87	56
Sine Moussa	12	6.16	4.16	3.00	2.40	143.00	50.19	65
Botla	12	5.94	3.71	2.99	2.27	128.59	37.07	71
Dara Andal	12	5.62	3.83	3.07	2.54	107.74	37.56	65
Nguebeul	12	5.64	4.22	3.26	2.76	106.61	48.14	55
Sakhor	12	5.44	4.76	2.26	2.37	117.53	75.89	35

Conclusion

The main purpose of this work was to determine the seasonal and diurnal characteristics of the wind potential by using the wind speed data measured in eight sites located along the North-western coast of Senegal. This is of great importance in evaluating electricity generation by using suited wind turbines.

The diurnal wind speed was evaluated for each season and for the period of one year in all sites. The wind speed frequency distribution was found by using Weibull distribution functions. From this statistical data, we can conclude that: two distinct seasons have been noticed in these regions: a dry season (November to May) and a rainy season (June to October). The dry season is characterized by strong wind regimes, whereas, the rainy season is subject to lower mean wind speeds, the highest discrepancy between the mean wind speed in the dry season and the mean wind speed in rainy season was 26% observed for the site of Sakhor.

The diurnal characteristics of the mean wind speed in all sites were assessed. The results show that the wind speed in the day-time is higher than the one at night. The highest discrepancy between the mean wind speed for the day-time and the mean wind speed at night was 38%, as observed in Botla. The lowest value was 13%, as observed for the site of Sakhor.

This study showed, also, a best match between the Weibull and the cumulative measured distribution with maximum discrepancy of 0.4% observed for the site of Kayar. The diurnal Weibull parameters and the power density have been determined for all sites. The highest discrepancy between daily and nightly power density was 71%, observed for the site of Botla, while the lowest value was 35%, observed for Sakhor.

The results obtained in this study are very important for the study of the variability of the wind energy temporally and spatially. Then, it is important to extend this study to other sites in Senegal and the sub-region in order to achieve a wind map and a producible energy map. It is, also, interesting to realize an economic analysis of wind electricity generation in the corresponding areas.

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Nomenclature: **c,** Scale parameter of Weibull (m/s); **f,** probability density function of Weibull distribution (%); **h,** height above the ground level (m); $\mathbf{H_0}$**,** reference height (m); **k,** Shape parameter of Weibull (-); **n,** observation. number (-); $\bar{P}$**,** wind power density (W/m²); $\mathbf{v_0}$**,** wind speed measured at the height h_0 (m/s); **z,** roughness length (m); **ρ,** air density (kg/m3); **α,** roughness factor (-).

REFERENCES

Ahmed O, Hanane D, Roberto S, Abdelaziz M (2010). Monthly and seasonal assessment of wind energy characteristics at four monitored locations in Liguria region (Italy). Renewable and Sustainable Energy Reviews, 14: 1959-1968.

Ahmed SAS, Hanitsch R (2006). Evaluation of wind energy potential and electricity generation on the coast of Mediterranean Seain Egypt. Renewable Energy, 31:1183–202.

Akdag SA, Dinler A (2009). A new method to estimate Weibull parameters for wind energy applications. Energy. Conver. Manage., 50: 1761–176.

Ali M (2010). Feasibility study of harnessing wind energy for turbine installation in province of Yazd in Iran. Renewable and Sustainable Energy Reviews, 14: 93–111.

Ali NC (2003). A statistical analysis of wind power density based on the Weibull and Rayleigh models at the southern region of Turkey. Renewable Energy, 29: 593–604

Boudy OB, Kébé CMF, Sambou V, Ndongo M, Ndiaye PA (2008a). Etude et modélisation du potentiel éolien du site de Nouakchott. Journal des Sciences Pour l'Ingénieur, 9: 28-34.

Boudy OB Sambou V, Kébé CMF, Ndongo M, Ndiaye PA (2008b). Study and modelling of solar and wind power potential: Comparative Study of three sites in the West Coast of Africa, World Renewable Energy Congress X, Glasgow, Scotland, pp 1-6.

Boudy OB, Ndiaye PA, Kébé CMF, Sambou V (2010). Méthodologie de caractérisation d'un site éolien : Application au choix d'une éolienne adaptée au site. WORKSHOP Casamansun EnR 2010, du14 au 17 Ziguinchor, Sénégal. pp 1-10.

Gholamreza JG, Bahram G, Bagher S (2011). Statistical evaluation of wind speed and energy potential for the construction of a power plant in Baladeh, Nur, Northern Iran. Int. J. Phys. Sci., 6(19): 4621-4628.

Gokcek M, Bayulken A, Bekdemir S (2007). Investigation of wind characteristics and wind energy potential in Kirklareli, Turkey. Renew Energy, 32: 1739–1752.

Irfan U, Qamar-uz-Zaman C, Andrew JC (2010). An evaluation of wind energy potential at Kati Bandar, Pakistan. Renewable and Sustainable Energy Reviews. 14: 856–861.

Kébé CMF, Sambou V, Ould Bilal B, Ndiaye PA, Lo S (2008). Evaluation du potentiel éolien du site de Gandon dans la région nord du Sénégal. International Metrology Conference CAFMET; pp 1-6.

Omer AM (2008). On the wind energy resources of Sudan. Renewable and Sustainable Energy Reviews; 39(12): 2117.

Raichle BW, Carson WR (2009). Wind resource assessment of the Southern Appala- chian Ridges in the Southeastern United States. Renewable and Sustainable Energy Reviews. 13: 1104 –1110.

Ulgen K, Hepbasli A (2002). Determination of Weibull parameters for wind energy analysis of Izmir, Turkey. Int. J. Energy. Res., 26 (6): 495–506.

Youm I, Sarr J, Sall M, Ndiaye A, Kane MM (2005). Analysis of wind data and wind energy potential along the northern coast of Senegal. Rev. Energ. Ren., 8: 95-108.

Zhou W, Yang H, Fang Z (2006). Wind power potential and characteristics analysis of the Pearl River Delta Region. Renew Energy, 31: 739–753.