Journal of Energy Technologies and Policy
ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online)
Vol.5, No.12, 2015

Evaluation of Wind Energy Potential in Tindouf, South West of Algeria

M. DAHBI
Department of Science and technology,University of Bechar, BP.417, Algeria

M.SELLAM
ENERGARID, Laboratory, University of Bechar, BP.417, Algeria

A. BENATIALLAHc
LEESI, Laboratory , University of Adrar, Algeria, Adrar 0100 Algeria

Abstract
The wind energy is one of the most significant and rapidly developing renewable energy sources in the world and it provides a clean energy resource, which is a promising alternative in the short term in Algeria. The main purpose of this paper is to discuss the wind potential in Tindouf (south west of Algeria) and to perform an investigation on the wind power potential of desert of Algeria. The Weibull density function has been used to estimate the monthly power wind density and to determine the characteristics of monthly parameters of Weibull. A simulation model has been established to describe the characteristics of a particular wind turbine. The monthly power generated and the monthly operating hours by the wind turbine to be simulated. The simulation based on the data wind speed measured at the 10th meters and collected during 8760hours by wind observation station web site weather underground (The global weather data could be obtained from internet).
Keywords: Weibull distribution; Parameters of Wiebull; Wind energy; Wind turbine ; operating hours.

1. Introduction

Limited reserves of fossil fuels and their negative impacts on the environment lead institutions, organization and governments to find out more efficient technologies and new and renewable energy resources to produce energy in the natural environment. Recently, wind energy is the growing energy source of energy in the world and wind power is one of the most widely used alternative sources[1].The distribution of wind speeds is important for the desing of wind farms, power generators and agricultural applications such as the irrigation. It is not easy task to choose a site for a wind turbine because many factors have to be taken into account [1]. Compared to the other renewable energy resources, such as tidal or solar energy, wind energy has a more variable and diffuses energy flux. In order to maximize the benefit of this resource it is very important to be able to describe the variation of wind velocity at any given site under consideration for the development of WECTS.[2].The variation of wind velocity using the Weibull two parameter density function .

There are several methods to calculate the two Weibull parameters, c, and k such as the maximum likelihood method, the proposed modified maximum likelihood method and the commonly used graphical method [3-4]. Here the Weibull density function is used.

Algeria has a vast uninhabited land area where the south (desert) represents the part with considerable wind regime [5].

In Algeria, work on wind energy resource assessment dates back to 1976 when a wind atlas was developed by using wind speed data from 37 locations [6]. This atlas presented the monthly mean wind speed contour end frequency distribution for all the months during the year.

Dahbi and all [7-8] calculated the monthly and seasonally Weibull parameters for Bechar and Adrar sites at 10m and found that the wind speed was well represented by the Weibull distribution function, based on wind speed data measured at 10 m height and collected along 12 years by the Algerian Meteorological Office.

This Paper present the monthly wind speed and wind power density to assess the wind power potential for the site of Tindouf (South Western of Algeria) which geographical coordinates are Latitude=27°40'N, Longitude=8°06'W, Altitude=401m [6].

The Weibull density function has been used to estimate the two monthly Weibull parameters, c, and k.

The monthly power output of a wind turbine and the monthly operating hours for BWC XL.1 1KW wind turbine are calculated and simulated. Simulation is performed using Matlab software environment.

2. Simulation of wind power and wind turbine characteristics.

2.1. Weibull density function

The wind speed probability density function can be calculated as [9]:

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

Where $f(v)$ is the probability of observing wind speed v, c is the Weibull scale parameter and k is the dimensionless Weibull shape parameter.

Basically , the scale parameter, c indicates how 'windy' a wind location under consideration is, whereas the shape parameter, k, indicates how peaked the wind distrubution is (i.e. if the wind speeds tend to be very close to a certain value, the distribution will have a high k value and be very peaked)[10-11].

Once the mean speed $\bar{v}$ is known, the following approximation can be used to calculate the Weibull parameters , k and c [12] :

$$k = 1.09 + 0.2\bar{v} \qquad (2)$$

$$c = \frac{\bar{v}}{\Gamma\left(1+\frac{1}{k}\right)} \qquad (3)$$

Where the average wind speed $\bar{v}$ is

$$\bar{v} = \frac{1}{n_i}\sum_{i=1}^{n} v_i$$

And the gamma function of (x) (standard formula) calculated

$$\Gamma(x) = \int_0^{\infty} e^{-u} u^{x-1} du$$

3. The average power in the wind

The average power in the wind can be expressed as [13]:

$$\bar{p} = \frac{1}{2}\rho A \int_0^{\infty} v^3 f(v) dv \qquad (4)$$

If is the Weibull density function, the average power becomes:

$$\bar{p} = \frac{\rho \bar{v}^3 \Gamma\left(1+\frac{3}{k}\right)}{2\left[\Gamma\left(1+\frac{1}{k}\right)\right]^3} \qquad (5)$$

Where $\bar{p}$ is the average power in the wind [W/m^2]; Γ is the gamma function ; k is the Weibull shape parameter; $\bar{v}$ is the average wind speed[m/s], ρ is the air density (Kg/m3)

4. Power output characteristics of wind turbine

As different generators have different power output performance curves, so the model used to describe the performance is also different .In literature [14-15], the following equation is used to simulate the power output of wind turbine:

$$P_w(v) = \begin{cases} P_R * \frac{v^k - v_C^k}{v_R^k - v_C^k} & (v_C \le v < v_R) \\ P_R & (v_R \le v < v_f) \\ 0 & (v \le v_C \;\&\; v > v_f) \end{cases} \qquad (6)$$

Where P_R is the rated electrical power [W]; v_c is the cut-in wind speed[m/s]; v_R is the rated wind speed[m/s] ; v_f is the cut-off wind speed of the wind turbine[m/s]; k is the Weibull shape parameter.

5. The operating hours of the wind turbine

The cumulative distribution function can be used for estimating the time for which wind is within a certain velocity interval. The monthly operating hours in a year can be calculated like follow [16]:

Journal of Energy Technologies and Policy
ISSN 2224-3232 (Paper) ISSN 2225-0573 (Online)
Vol.5, No.12, 2015

$$\tau(v_c < v < v_f) = \left[\exp\left[-\left(\frac{v_c}{c} \right) \right]^k - \exp\left[-\left(\frac{v_f}{c} \right) \right]^k \right] * t_m \quad (7)$$

Where v_c is the cut-in speed, v_f is the cut-of speed, t_m is the monthly hours number (30 day chosen for each month) , k is the Weibull shape factor and c is the Weibull scale factor.

6. A case study for wind power potential analysis

The Tindouf (South West Algerian) in new valley was selected as the site under consideration in this work. It is based around an oasis of the Sahara Desert .

A meteorological data collected during 8760hours by a wind observation station web site weather underground (The global whether data could be obtained from internet) is used for analysis in this paper.

6.1. Yearly Weibull density function

The calculation results meet the Weibull distribution. From the recorded wind data , the shape parameter k is found to be = 2.03, and the scale parameter c is 5.33m/s using Equ.1-3.The distribution is shown in fig1.

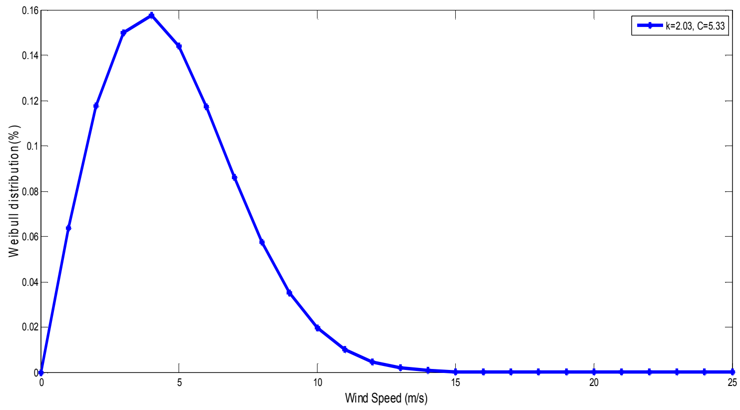

Fig.1 : Yearly *Weibull density function in Tindouf*

It is clear from the figure that the site of Tindouf has the highest value of k and c. It can be seen, that the Weibull approximation of this site encouraging prospect for wind energy applications .

7. Monthly Weibull parameters and wind power density

Once the monthly mean wind speed is known, the monthly probability density can be obtained, as shown in table 1.

Table.1: Monthly Weibull parameters and wind power density.

Months	Mean wind speed (m/s)	Shape parameter k	Scale parameter C (m/s)	Avrage power $\overline{P}$ (W/m2)
Jan.	4.32	1.95	4.87	102.71
Feb.	3.63	1.81	4.09	66.17
Mar.	4.20	1.93	4.74	95.63
Apr.	5.99	2.28	6.76	236.47
May	5.69	2.22	6.42	207.32
Jun.	6.00	2.29	6.77	237.08
Jul.	4.97	2.08	5.61	146.47
Aug.	4.38	1.96	4.94	106.29
Sep.	5.15	2.12	5.81	160.39
Oct.	4.55	2.00	5.14	117.57
Nov.	4.32	1.95	4.88	103.06
Dec.	3.50	1.79	3.93	60.02

It is clear from the tabl.1,that the shape parameter k varies between 1.79 and 2.29 while the scale parameter c varies between 6.77 and 3.93.It can be seen that the highest values of k and c are found in June . Whereas the lowest values of the two parameters were found in December.

The results show that the parameters are distinctive for different months in a year, which means the monthly wind speed distribution differs over a whole year. It is clear that the mean wind speed increases during spring months and decrease during fall months. For comparison, tow typical monthly Weibull distribution with different shape and scale parameters are given in fig.2. It is clear from the figure that the value of c is low in December and most of the wind speeds are in the lower speed range, but in June the value is highest.

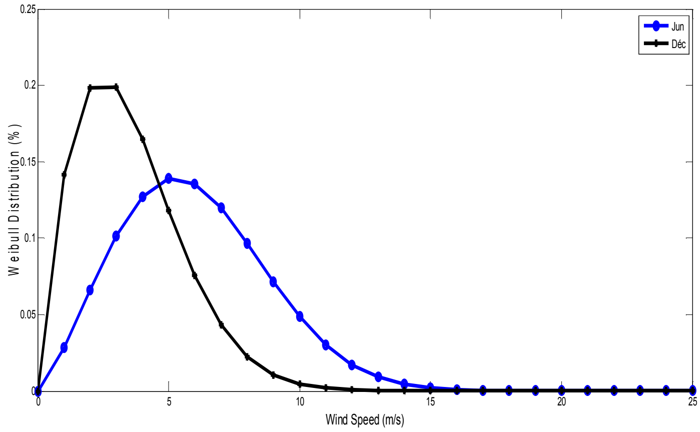

Fig. 2 : The Weibull distribution in June and December

8. Monthly wind power density

Using Eq.(5), the average annual wind power density is found as 2690.5wh/day, so that the power potential is 982.11kWh/m^2 per year . With the above equation and the monthly Weibull parameters, the monthly wind power density can also be calculated. The results are given in fig.3 and tabl.1

It is clear from the results that the mean wind speed and average wind power density are distinctive for different months. In February to June, the wind power is high, but low in the fall months. The tow curves have similar changing trend, but the rate of change is not the same. This is because, for the power density, it is determined not only by the mean speed bat also by the Weibull shape parameter k.

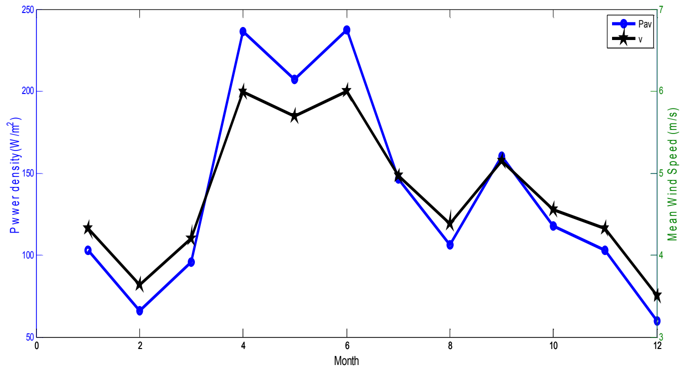

Fig.3: Monthly wind power density and .mean wind speed

It can be seen from this figure (fig.3) that the wind speed varies between 3.5m/s and 6m/s. According to these results, the power density vary between 60.02w/m^2 and 237.08w/m^2 .The mean value of wind power density has been calculated as 130w/m^2. The wind power is maximum in June (237.08w/m^2) and its minimum level (60.02w/m^2) in December. This is due to the variation of the wind speed and Weibull parameters between summer months and winter months.

9. Monthly wind power produced by BWC XL.1 turbine

To analysis the effect of the wind turbine characteristics on the wind power generation, a wind turbine of BWC XL.1 1KW generator with a synchronous permanent magnets machine is chosen in this study based on the calculated monthly mean wind speed (is high to 2.5 and low to 13m/s). The cut-in speed is 2.5m/s , the cut-off speed is 13m/s and the rated electrical power of the turbine is 1kW(at rated wind speed 11m/s).Using the eq.6 and Eq.7 ,the average monthly power generated by the wind turbine and the operating hours of the wind turbine in a year can be calculated, as shown in fig .5. it is clear from the figure that the operating hours changes in different months. The highest 22h/day occurs in June while the lowest is 15h/day in December. The total operating hours of the site of Tindouf are 7621h in a year .the trend is not in accordance with the trend of monthly wind power density, because the operating hours is determined not only the wind data distribution but also by the performance of the wind turbine. For different months, the monthly power generated is calculated and the results are given in fig5.The results shows that for each month the power generated is different , varying from 113.54 W to 370.58W .The highest power output is generated in June , while the lowest in December. The wind turbine can generate electrical power in the site of Tindouf amounting to 78410W (1559.400kWh) per year. The trend is similar to that for power density, but with some difference. This is because the power generated by a wind turbine is determined not only by the wind speed's Weibull function (parameters c and k),but also by the characteristics of wind turbines, while power density is determined only by the Weibull distribution (c and k).

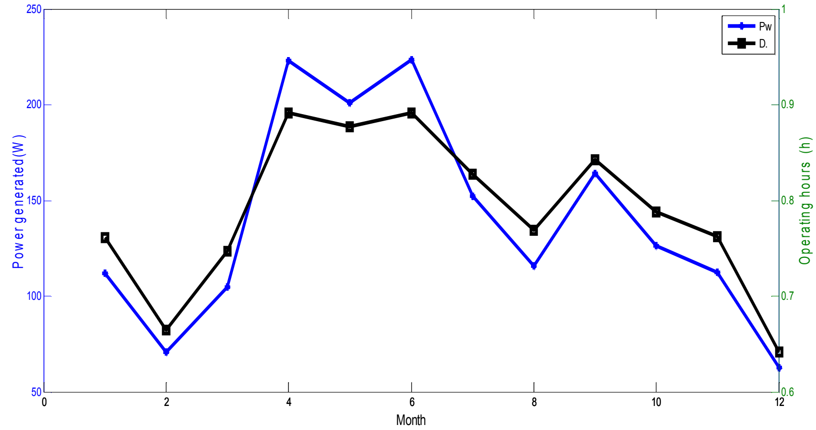

Fig.5: Monthly operating percentage and monthly power output of the wind turbine

11.Conclusion

The proposed simulation model is found applicable for assessing the potential of wind power generation at a location. From the case study, it is found that it is imperative to account for the monthly difference of wind speed using Weibull estimation as the wind energy potential can vary significantly. According to result's of simulation, it is shown that the parameters of Weibull influence directly the wind power available like over the duration of production of electrical energy . In June, the wind power available in 143.42 KWh with one duration of availability of 22h h per day. In September, the wind power available is 28.95KWh with one duration of availability of 15h per day.

The analysis shows that there are good prospects for wind energy utilization in the selected Algerian Sahara site. The southwest area located in the west of 0° longitude and between 25° N and 30° N latitudes is the windiest part of southern Algeria with an average win speed exceeding 5 m/s for Tindouf at a height of 10 m.

In the case of Tindouf, it is fortunate that the windy season coincides with the high temperature seasons (45°-55°) which causes an increased demand for electricity could be covered by exploitation of wind energy. Therefore, accurate wind predictability and its correlation with electricity load demand may allow for a high penetration of wind energy and could make it an economically attractive supplement to diesel-fuelled power station.

It is recommended to undertake further studies to explore other locations in the Sahara of Algeria and to develop this renewable energy resource.

References

[1] S. Mathew; K. P. Pandey., and A.Kumar,(2002) "Analysis of Wind Regimes for Energy Estimation", *Renewable Energy*, vol.25 n.3, ,pp. 381-399

[2] K .Ulgen, A.Hepbasli,(2002) " Determination of Weibull parameters for Wind Energy analysis fo Ismir", Turkey. *Int. J. Energy Res*. Vol.26 n.6, pp.495-506.

[3] I.Y.F. Lun; JC. Lam (2000) "A Study of Weibull Parametre using Long –term Wind Observations" *Renew Energy* , vol. 20 n. 2, pp. 145-153.

[4] JV. Seguro, TW.Lambert (2000) "Modern Estimation of the Parameters of the Weibull wind speed Distribution for Wind Power Energy Analysis", J. *Wind Energy Ind Aerodyn*, vol.85 n. 1, , pp. 75-84.

[5] S .Diaf; M. Belhamel; M.Haddad., A.Louche (2007,) "Assesment of Wind Energy Ressource in Southern Algeria", *Rev.Energ. Ren.* Vol. 10 (3), pp. 321-333

[6] R. Hammouche,(1991) " Wind Atlas of Algeria", Meteorological National Office, University Publications Office. Algiers, Algeria,.

[7] M. Dahbi; A.Benatiallah ; T. Benslimane (2008) , "Analyse du Potentiel Eolien dans Le Site de Bechar : Caractérisation des Paramètres de Weibull", The First International Workshop on Renewable Energies and their Applications (1WIERA) ,Laghouat, Algeria, May 10-12,pp. 231-236.

[8] M. Dahbi, A. Benatiallah, M. Sellam, (2013) "The Analysis of Wind Power Potential in Sahara Site of Algeria-an Estimation Using the 'Weibull' Density Function", *Energy Procedia* 36 ,pp. 179 – 188

[9] L Gary Johnson(2001) , " Wind Energy Systems" . Manhatan KS.; November 20, pp. 30-38.
[10] C. G Justus.(1978.) "Wind and Wind System Performance". Franklin Institute Press; Philaelphia;
[11] D. Weisser (2003,)" A Wind Energyr Analysis of Grenada: An Estimation Using the 'Weibull' Density Function", *Renew Energy*, vol. 28, pp. 1803-1812
[12] S. Essalaimeh , A. Al-Salaymeh , Y. Abdullat (2013) " Electrical production for domestic and industrial applications using hybrid PV-wind system", *Energy Conversion and Management* , vol.65 , pp. 736–743.
[13] S .Persaud ; D.Flynn, B..Fox (1999) , " Potential for Wind Generation on the Guyana Coastlands", *Renew Energy,* vol.18 n.2, , pp.175—189.
[14] L Lin.; Y. Hongxing ,B .John (2002,) " Investigation on Wind Power Potentiale on Hong Kong Island-an Analysis of Wind Power and Wind Turbine Characteristics", *Renew Energy*, vol.27, pp.1-12..
[15] FMA.Ghali, MM. Abd el Aziz.; Syam FA (1997)."Simulation and analysis of Hybrid system Using Probabilistic techniques". *In.Power Conversion Conference*; Nagaoka , pp.831-835 .
[16] ES .Gavanidou.; AG. Bakirtzis (1999) " Design of a Stand Alone System with Renewable Energy Sources Using trade of methods". *IEEE, Trans. Energy Conversion,*vol. 7 n.1,pp.42-48.