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Wind Energy Assessment of the Zawiya Region, in Northwest Libya

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Abstract

The objective of this paper is to evaluate the annual, monthly and the seasonal performance of the wind resource at the Zawiya region in northwest of Libya. In this study, the wind data are obtained from the coastal site located in the northwest of Libya at height of 50 meters above the ground level. The results show that the annual average speed is 6.14 m/s, and the annual Weibull parameters are shape factor K = 3.2, scale factor C = 6.9 m/s, and the annual energy production of 750 kw wind turbine is 2.70 Gwh/year.

Keywords

Zawiya Region, Libya, Weibull, Latitude

1. Introduction

The generated energy from renewable sources like wind reduces toxic gases released from traditional power plants, and saves oil consumption. Outfitting the wind is one of the cleanest, most reasonable approaches to create power. Wind vitality is the quickest developing wellspring of power on the planet. The wind is generated due to the pressure gradient comes from uneven heating of the earth's surface by the sun. As the very driving force causing this movement is derived from the sun, wind energy is basically being indirect form of solar energy; this means that the wind is driven by the temperature difference [1]. In this study, we analyze wind resource of the Zawiya region in Libya. The power demand in Libya increases each year. Based on a study of economic and Statistics Research Office at Ministry of Electricity of Libya, the energy demand will reach to 87.935 Gwh by the end of 2017 [2], where this cannot be covered by generation stations in the country. Renewable energy resources of both solar and wind are available along the 2000 km coast in Libya, south of the Mediterranean Sea.

2. Site and Weather Data

In this paper, data obtained from the metrological coastal station have been analyzed [3]. The geographic coordinates of the site are summarized in Table 1. The measurements are made at 50 meters above the ground level. Figure 1 shows the location of the studied coastal station.

3. Methodology

3.1. Weibull Distribution

Weibull probability density function is commonly used and widely adopted in wind power study [4]. The Weibull distribution function is defined as:

$$f(v)=\left(\frac{k}{C}\right)\left(\frac{V}{C}\right)^{K-1}\exp\left[-\left[\frac{V}{C}\right]^{K}\right] \quad (1)$$

where $f(v)$ is the probability density function, and Parameters k, c and v are the shape factor (dimensionless), the scale factor (m/s), and wind velocity respectively. Usually, the shape factor describes the symmetry of the distribution, while the scale factor is very close to the average speed of the wind [2] [5]. The cumulative distribution function given in Equation (2) is the integral of the probability density function, and it can be used for estimating the time for which wind speed is within a certain speed period [6] [7].

$$f(v)=1-\exp\left(-\left(\frac{v}{c}\right)^{k}\right) \quad (2)$$

Figure 1. The Zawiya region on Libyan map.

Table 1. Geographical coordinates of the data collection station used in this study.

Location	Longitude	Latitude	Altitude (m)	Measurement years
Zawiya	32.45 N	12.43 E	17	01/01/2013 01/01/2016

3.2. Air Density and Wind Energy

The air density affects the power generated by a wind turbine which can be expressed by the following equation [8]:

$$P(v) = \frac{1}{2}\rho v^3 \tag{3}$$

where ρ is density of the air (Kg/m^3), and s is swept area in m^2.

The wind kinetic energy is converted to electrical energy by the wind turbine, and the effective power generated is expressed in the following relation [9] [10]:

$$P_e(v) = C_{e*}P(v) \tag{4}$$

where C_e is wind turbine efficiency, and the wind turbine technical specifications parameters for this site are listed in Table 2.

4. Results and Discussion

The wind analyses for the Zawiya region show that the annual shape factor K = 3.2, and scale factor is 6.9 (m/s), as illustrated in Table 3. The region is windy and promising with renewable energy. It can be observed from Figure 2 that the monthly mean speed at 50 meters high varies between 5.12 m/s in July and a maximum value of 7.92 m/s in February. Moreover, at 50 m high, the monthly mean power density varies between 155.81 w/m^2 in July and 503.21 w/m^2 in February as shown Table 4, while the mean monthly energy variation represents in Figure 3. For the cumulative speed distribution, Figure 4 illustrates that about 55% of speed frequencies is greater than 6 m/s. Figure 5 represents a monthly shape factor and scale factor of Weibull wind distribution. The result yields that the greatest shape factor k in July with 4.49, and the worst value in April with 2.42. The result also yields good scale factor C with a greatest value in February equal to 7.92.

Table 2. Wind turbine specifications.

Model	FL750
Rated Power Kw	750
Rotor Diameter (m)	50
Hub height (m)	50
Cut-in Speed (m/s)	3
Rated wind Speed (m/s)	14
Cut-Out Speed (m/s)	20
Swept area of Rotor(m^2)	1960
Efficiency %	60

Table 3. Annual mean speed and Weibull parameters at 50 m from the ground level.

Location	Shape factor (K)	Scale factor (C)	V (m/s)
Al zawiya	3.2	6.9	6.14

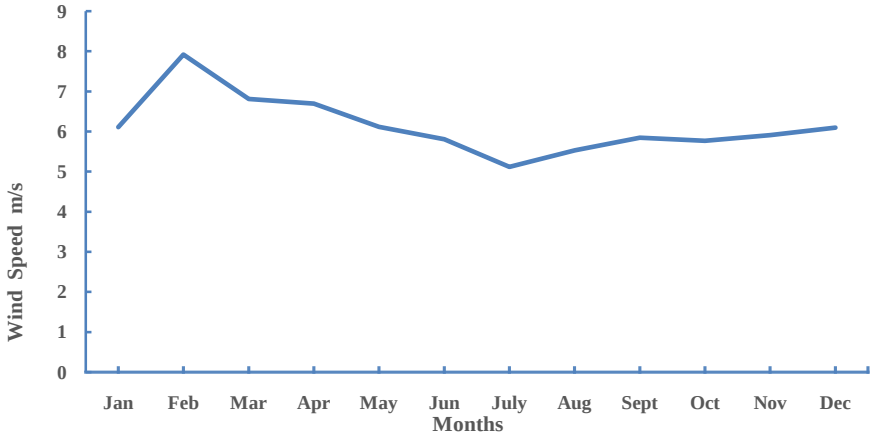

Figure 2. Monthly mean wind speed.

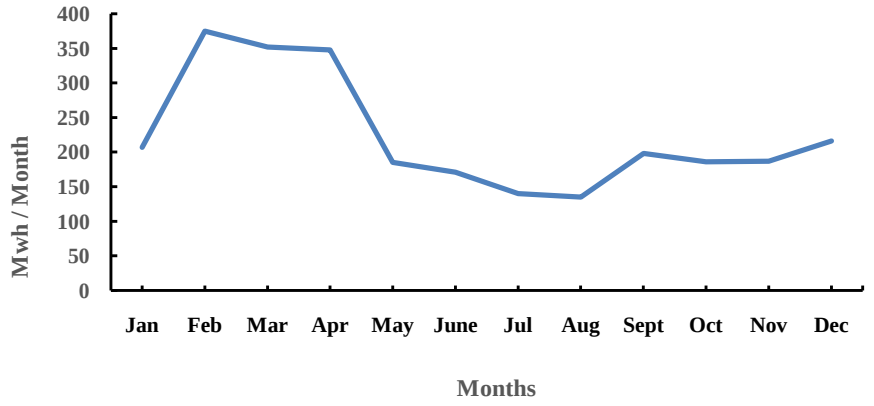

Figure 3. Monthly wind energy produced.

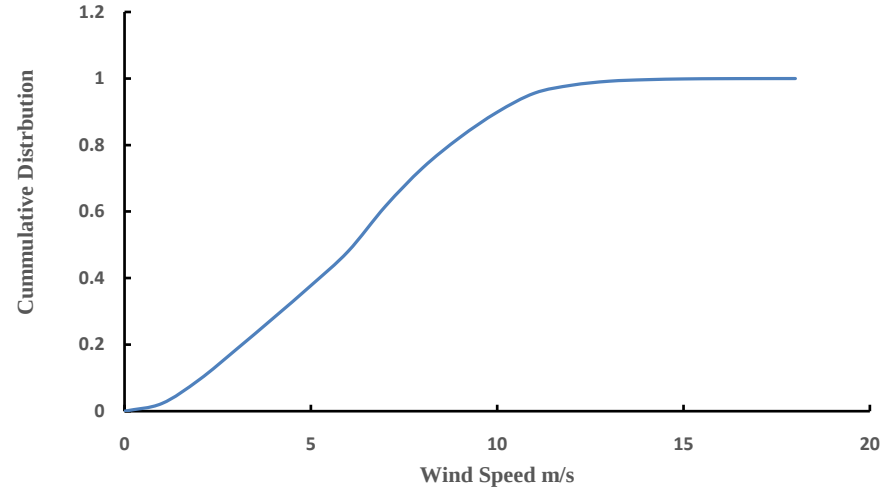

Figure 4. Annual cumulative distribution.

The seasonal Weibull wind distribution at 50 m is shown in Figure 6. The seasonal variation of mean wind speed and mean power density at 50 m are listed in Table 4. For the Zawiya region, the minimum mean wind speed is in summer with 5.5 m/s while the maximum value of mean wind speed is in winter

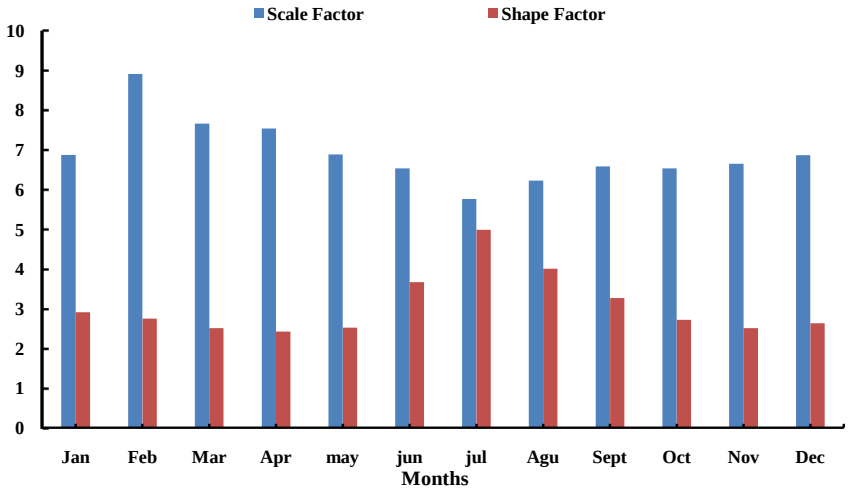

Figure 5. Monthly Weibull distribution parameters at 50 meters.

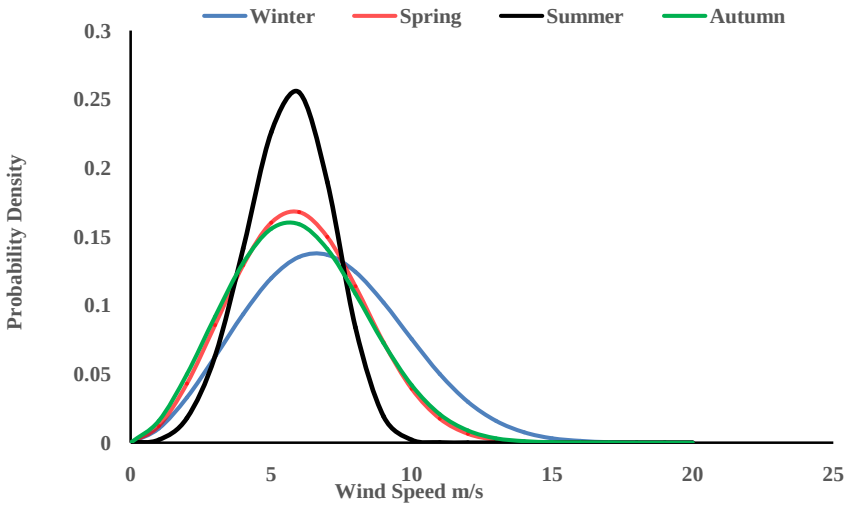

Figure 6. Seasonal Weibull wind distribution at 50 meters.

with 6.95 m/s. Moreover, the mean seasonal power density at 50 m varies between 183.78 w/m^2 in summer and 401.34 w/m^2 in winter.

From Weibull distribution, as shown in Table 5, the speed variation is maximum in winter where it reaches [0 - 16 m/s], and minimum variation is in summer where speed variation is between 0, and 10 m/s. In the Weibull wind distribution, the greatest shape factor is 4.2 in summer season, while the worst shape factor is 2.71 in Winter. The annual Weibull distribution is illustrated in Figure 7. The production of monthly wind energy output of 750 kw wind turbine is illustrated in Table 4 with annual energy production about 2.70 Gwh/year.

5. Conclusion

The monthly, seasonal and annual Weibull parameters, mean wind speed, and wind power densities at a height of 50 meter in the Zawiya region in northwest of Libya have been determined in this study. The study shows that the site is

Table 4. Monthly mean wind speed and power density variations at the studied site.

Elevation	50 m		
Parameters	V [m/s]	P [w/m^2]	Energy Mwh/month
January	6.11	230	207
February	7.92	503.21	375
March	6.81	470.51	352
April	6.7	465.2	348
May	6.12	206.31	185
June	5.81	190.91	171
July	5.12	155.81	140
August	5.53	180.42	135
September	5.85	220.31	198
October	5.77	207.31	186
November	5.91	209.11	187
December	6.10	240.52	216

Table 5. The seasonal mean speed and power density.

Zawiya	50 m	
Parameter	Wind Speed (m/s)	Power Density P(w/m^2)
Winter	6.95	401.34
Spring	6.11	287.50
Summer	5.5	183.78
Autumn	5.92	218.98

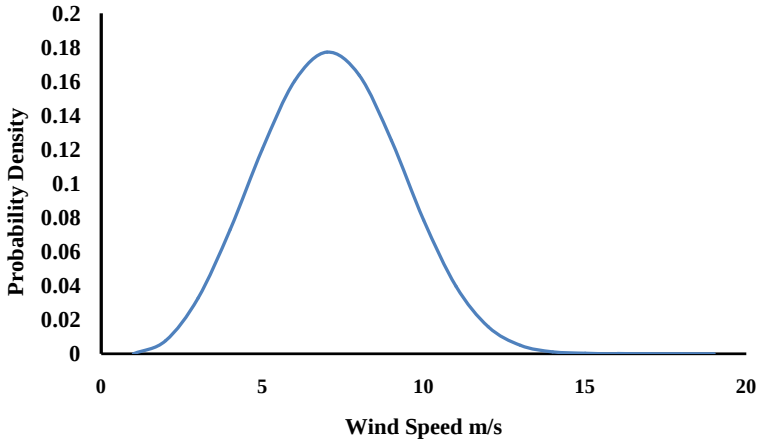

Figure 7. Annual Weibull Wind Distribution at 50 meters.

windy, and can be used to generate electricity where annual mean speed V = 6.14 m/s and 7934 hours' wind speed are between 3 - 19 m/s. The better performance of wind is in the winter season, as the site is in a costal side of Libya and facing to the Mediterranean Sea. The annual expectation of energy production by this site makes it virgin and promising land. The General Electric Network

Office of Libya should integrate renewable resources through Libya's grid, where a 750 kw wind turbine produces about 2.70 Gwh/year.

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