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Analysis Of Wind Power Density In Azmar Mountain (Sulaimani Region- North Iraq)

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Abstract:

In this study, we present a statistical analysis of wind speeds at Azmar Mountain in Sulaimani region. Wind data, consisting of hourly wind speed recorded over one year. The monthly averaged wind speed at a height of 5m above ground level was found to range from 4.65 to 11.86 (m/s) and after extrapolation at 50m found to be from 6.41 to 16.36 (m/s).

The monthly Weibull distributions parameters (c and k) were found to vary between 5.21 and 13.46 (m/s) and 1.60 to 3.47 respectively, with average power density ranging from 70.89 to 1559.16 (W/m^2) at 5m above ground level while at 50m ranging from 186.71 to 4096.20 (W/m^2).

Keywords: Azmar/Sulaimani, Mean wind speed, Weibull distribution function, Wind power density.

1. Introduction

Increasing negative effects of fossil fuel combustion on the environment in addition to its limited stock have forced many countries to explore and change to environmentally friendly alternative that are renewable to sustain the increasing energy demand [1].

Currently, the wind energy is one of the fastest developing renewable energy source technology across the globe, wind energy is an alternative clean energy source compared to fossil fuel, which pollute the lower layer of the atmosphere. It has the advantage of being suitable to be used locally in rural and remote areas [2].

Coastal areas and mountains with high wind potential are considered most suitable for wind energy utilization. Therefore this study aims in investigating the prospects of harnessing and useful conversion of wind energy potential for the mountain area of Kurdistan region/north Iraq. Electrical energy in Iraq is mainly produced by fossil fuels (oil and natural gas) and hydropower, because of abundant energy resources. Iraq is heavily dependent on exported oil and gas [3,4].

2. Site and Data Description

The present work is based on the time series wind data collected over a period of one year. The location concerned in this study is situated in north Sulaimani 35°37'11" North latitude, 45°28'41" East longitude and it is at an elevation of 1962.86 meters above sea level. There is no obstacle around wind speed measuring location. The wind potential energy of this location is analyzed based on one year of recorded wind data from a mechanical cup type anemometer at height of 5 meters above the ground level.

The aim of the present work is to evaluate the wind power density in Azmar Mountain area; this is done through investigating the wind characteristics at the location using statistical analysis techniques.

3. Statistical Analysis Model

The mean horizontal wind speed is zero at the earth's surface and increases with altitude in the atmospheric boundary layer. The variation of wind speed with elevation is referred to as the vertical profile of wind speed or wind shear. The variation of wind speed with elevation above the ground has important influence on both the assessment of wind energy resources and the design of wind turbine.

A power law for vertical profile of steady wind is commonly used in wind energy for defining vertical profile [5]. The computational steps required to extrapolate the available wind speeds to turbine hub height are given below. The basic equation of wind shear- law is [6,7]

$$v = v_h \left(\frac{z}{z_h} \right)^{\alpha} \quad (1)$$

Where v is the wind velocity at elevation z, v_h is the wind velocity at height elevation (hub height) and α is the empirical wind shear exponent.

In order to evaluate the wind energy potential of any site, it is important to drive the expected probability distribution of the site's wind speed. Regarding this aspect much attention has been given to Weibull function, which give a good match with experimental data according to researchers [4,8].

The Weibull distribution is characterized by two parameters, the dimensionless shape k, and the scale parameter c, which has a units similar to the speed (m/sec).

The probability density function for the wind velocity v is calculated by [9,10]

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

One method often used to determine the parameters k and c of the Weibull distribution from wind data is the maximum likelihood method, this method is conveniently expressed the parameter c in terms of the parameter k [11,12]

$$c=\left(\frac{1}{n}\sum_{i=1}^{n}v_i^k\right)^{1/k} \quad (3)$$

Where n is the number of wind observations and v_i the observed wind speed for observation i , in this method k is evaluated by solving the equation

$$k=\left[\frac{\sum_{i=1}^{n}v_i^k \ln v_i}{\sum_{i=1}^{n}v_i^k}-\frac{1}{n}\sum_{i=1}^{n}\ln v_i\right] \quad (4)$$

Because k appears on both sides of the equation, the equation must be solved iteratively and to find a convergent value of k, several iterations are required. It was concluded by some researchers that the maximum likelihood method is recommended for use with time series wind data and has proved to be most efficient in determining the parameters of the two- Weibull probability distribution function [12,13].

4. Wind Power Density Function

Wind power density or power flux expressed in watt per meter-square (w/m^2). It is considered to be the best indicator to determine the potential wind resource, which is critical to all aspect of wind energy exploitation [9]. It is well known that the power of the wind at speed v through a blade sweep are A increases as the cube of it's velocity and is given by [14,15]

$$p(v)=\tfrac{1}{2}\rho A v^3 \quad (5)$$

Where ρ is the mean air density, which depend on altitude, air pressure and temperature in accordance with the gas law

$$\rho=\frac{p}{RT} \quad (6)$$

where p=air pressure, T=temperature on the absolute scale and R=gas constant.

The temperature and the air pressure both in turn vary with altitude, their combined effect on the air density is given by the following equation [16]

$$\rho=\rho_0\exp\left(-\frac{0.297H_m}{3048}\right) \quad (7)$$

Where ρ_o is standard or reference air density (1.225 kg/m^3) and H_m is the site elevation in meter, equation (7) is often written in a simple form

$$\rho=\rho_0-1.194x10^{-4}H_m \quad (8)$$

The expected monthly or annual wind power density per unit area of a site based on a Weibull probability density function can be expressed as follows [17]

$$P_w=\tfrac{1}{2}\rho c^3\Gamma\left(1+\tfrac{3}{k}\right) \quad (9)$$

where c is the Weibull scale parameter (m/sec) and is given by

$$c=\frac{v_m}{\Gamma\left(1+\frac{1}{k}\right)} \quad (10)$$

Γn is a gamma function given by $\int_{o}^{\infty}e^{-x}x^{n-1}dx$ and v_m is the mean value of the wind speed.

5. Result and Discussion

The wind profile power law equation 1. has often been suggested as a useful tool for the extrapolation of measured winds to a height where measurements are not available. The exponent power (α) which appears in equation 1. is an empirically derived variable coefficient which depend on, for example, the height, nature of the terrain and wind speed.

In this work the value 0.14 is used for (α), where this value come from laboratory studies and has been found to give a good approximation of the wind profile in the neutral atmosphere boundary layer.

Weibull function is usually used to describe wind speed distribution of a given location over a certain period of time, typically monthly or annually. In present study, the annual mean wind speeds are derived from the available data and shown in Table 1. and Figure 1.

Table 1. Monthly mean wind speed, wind power density at both elevations 5 and 50 meters and Weibull parameters

	Mean Wind Speed (m/s)		Wind Power Density (W/m^2)		Weibull Parameters	
Month	At 5 m	At 50 m	At 5 m	At 50 m	C (m/s)	K
Jan	**5.43**	**7.49**	**119.01**	**310.05**	**6.11**	**2.82**
Feb	**4.65**	**6.41**	**70.89**	**186.71**	**5.21**	**3.09**
Mar	**6.91**	**9.53**	**223.30**	**601.10**	**7.69**	**3.32**
April	**6.68**	**9.21**	**297.32**	**783.43**	**7.57**	**1.97**
May	**6.46**	**8.91**	**180.21**	**445.36**	**7.21**	**3.47**
Jun	**8.80**	**12.14**	**549.21**	**1459.50**	**9.95**	**2.53**
July	**5.59**	**7.71**	**124.22**	**328.24**	**6.26**	**3.05**
Aug	**5.06**	**6.98**	**105.30**	**279.95**	**5.72**	**2.48**
Sept	**11.86**	**16.36**	**1559.16**	**4096.20**	**13.46**	**2.11**
Oct	**9.25**	**12.76**	**794.8**	**2098.96**	**10.48**	**1.96**
Nov	**7.24**	**9.99**	**277.26**	**735.68**	**8.1**	**2.85**
Dec	**5.02**	**6.92**	**165.96**	**423.49**	**5.67**	**1.6**

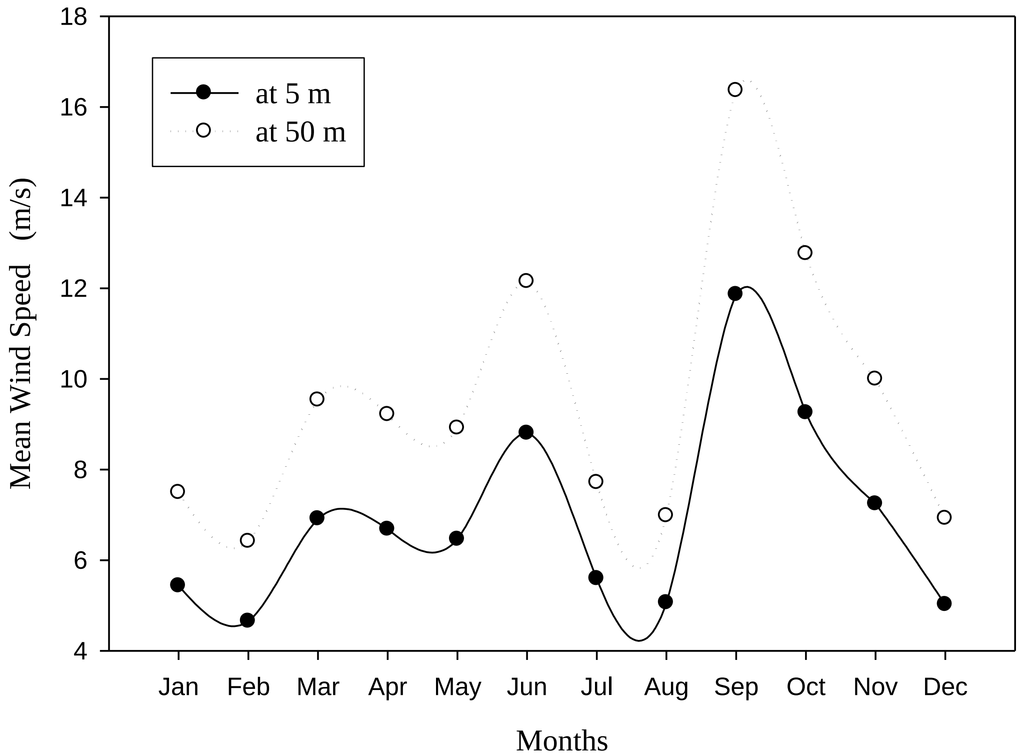

Figure 1. Monthly mean wind speed at 5 and 50 meters

6. Conclusion

The result shows that Azmar is the windy place with the largest scale parameter c (7.83 m/sec), shape parameter k (1.89) and it's most possible mean wind speed is 6.91m/sec. The wind speed for the whole year has the maximum value of 30 m/sec and a minimum value of 1 m/sec with the standard deviation of 3.91m/sec, while observed wind speed distribution and the Weibull probability distribution function are illustrated in Figure 2. This positively confirms the validity of the Weibull density function as a modeling device for estimating wind regimes and thereby providing a basic for power output estimation from wind turbine types.

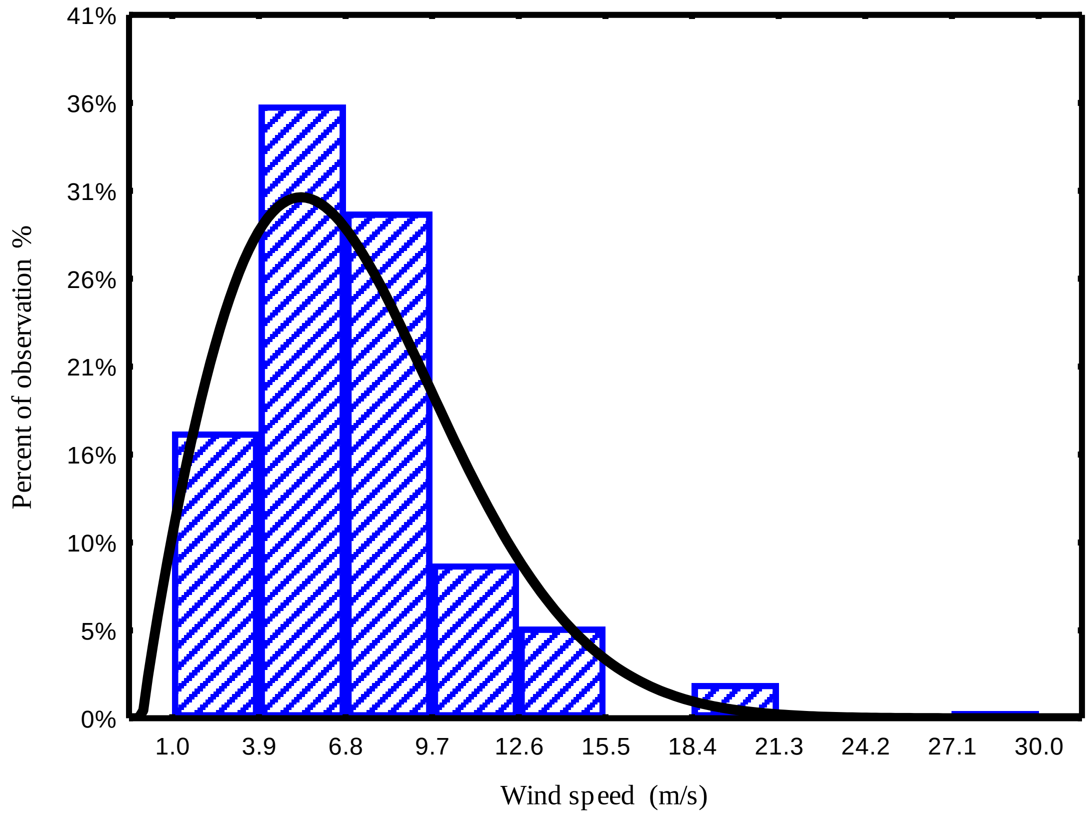

Figure 2. Wind speed (smooth curve) Weibull function prediction and (histogram) actual wind data in Azmar Mountain.

The monthly mean wind power density calculated at both 5 and 50 m above ground level and are depicted in Fig.(3). Over the year, a large variation was seen in wind power density values at both heights. The long term mean values were found to be in the range of 70.89 and 1559.16 W/m^2 at 5m height. At 50m elevation, the wind power density values were found to be above 186.71 W/m^2 during most of the months.

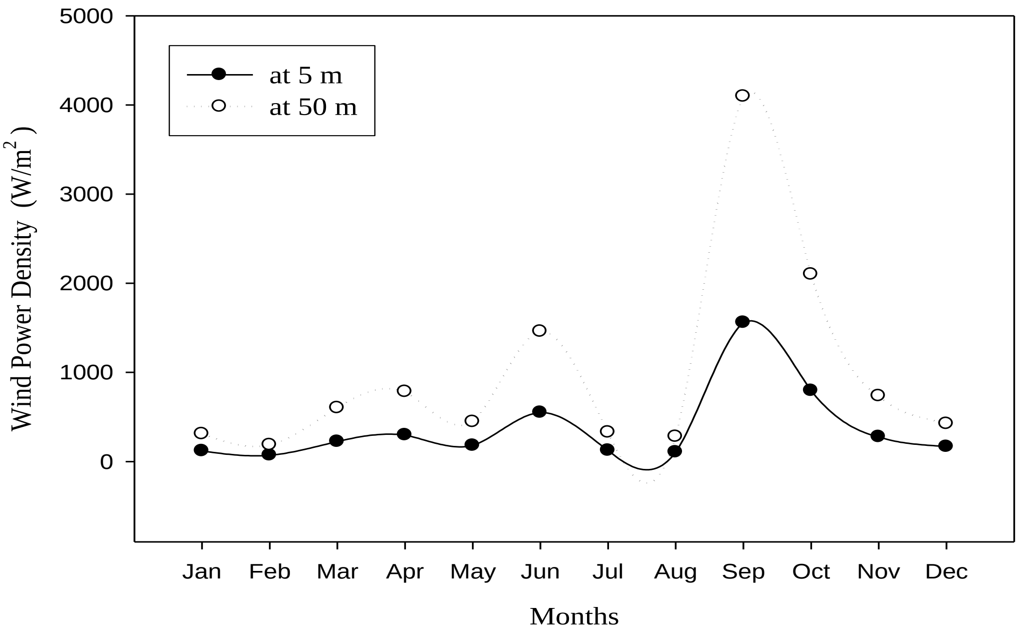

Figure 3. Monthly mean wind power density at 5 and 50 m heights

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