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Modeling and Calculation of Wind Energy Potential Using Measured Values for a Specific Area

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ABSTRACT

There are now many software applications such as WASP,Windpro,…, all of which are based on the Weibull distribution and are based on data from meteorological stations relative to the calculation of the energy obtainable from the wind. In this study, a twenty-degree polynomial curve is used to increase the computational accuracy, instead of using the Weibull distribution. The results show that the precision of this method is greater and the actual amount of energy that can be obtained is usually more than 10% the amount calculated by existing software, which sometimes indicates a significant difference.

Keywords: Wind Energy, Potentiometry, Wind Speed Distribution, Kalateh Mullah

INTRODUCTION

Although most of the IRAN's electricity production is based on fossil fuels, and the cost of investing in wind farms is higher than fossil power plants, but with the advent of technology in wind turbines, and the inclusion of these social and environmental costs, It has become economical in the IRAN. No pollution and environmental protection, the use of free energy, the use of fossil fuels for electricity, the time of installation and commissioning, the preservation of oil reserves for the next generation, job creation and industrial development. Benefits of using wind energy and new energies in the IRAN. Obviously, the location of the wind generator should have a high average velocity and a good wind blow. Therefore, the study of speed and other parameters of wind is the first and most important step in assessing the potential of an area for the installation of wind power plants. The parameters that can be obtained from wind time measurements are: average wind speed; wind speed as a function of its direction, Frequency distribution of speed, Distribution of wind speed connection, Weibull parameters for the probability distribution of wind speed, Weibull parameters as a function of the wind direction, instantaneous wind speed for hourly intervals. In order to identify areas with high wind potential, the center for the development of new energies in the Kalateh Mullah region performs wind turbine placement. The method of this research is to install a meteorological station with a height of 40 meters and to record daily weather data and wind speed in a time interval of 10 minutes. Then, the recorded data, the initial analysis and the potential of the suburbs are estimated and compared with standard indices. The construction of a power plant will be decided. In this paper, the first potential of the Kalateh Mullah wind potential has been calculated by computational code and using the Weibull distribution, and the results of the validated and well-known bundles of the world (WASP,Windpro) are compared. Then a new method for calculating the wind potential is presented. The results indicate that this area has a good potential for the construction of wind turbines. In several countries, many studies have been carried out in recent decades to evaluate the potential of wind power, and significant advances have been made. Boudia and Guerri studied the wind energy potential of the Algerian coastline using the WAsP software and meteorological data from the metering stations (which contributes to providing the lowest wind energy costs based on the correct assessment of wind resources.) [1]. Ohunakin, a statistical analysis of the wind characteristics of five locations obtained from meteorological stations in Nigeria and evaluated wind resources [2]. Keyhani used seven-year wind speed data from the Meteorological Department to identify the wind energy potential in Tehran [3]. Based on wind speed data obtained between June 2012 and June 2013, Bilir evaluated the wind energy potential in Ankara, Turkey, by metering stations located in the Atilim University courtyard. These data require a large amount of data from weather stations (which cannot be used in locations away from weather stations). Expensive and high weather meteorites were installed with audio anomalies and cupboards at the proposed locations. The cost of towers over 60 m is significant.The cost of a 80-meter network tower is more than $ 85,000 in a two-year life cycle [4]. Mostafaeipour investigated the wind energy source in Kerman (Iran) using the 14-year (1991-2004) wind data at an altitude of 10 m from the local airport aerodrome. He obtained wind speed data in another study using the power law model [5]. Durisic and Mikulovic discussed the source of wind energy in the South Banat region of Serbia based on wind data collected at altitudes of 10 m, 40 m, 50 m and 60 m from the 60 m mounted anemometer rig. [6]

METHODS TO CALCULATE ENERGY EXTRACTED FROM WIND

In order to achieve annual energy estimate wind speed histogram can be used. The average output power of a wind turbine (P) can be estimated from the following relationship,Which P(V) is a function of the output power for wind speed at the height of the hub and the density function f(V) of the wind speed probability. Because wind power factor converters is a function of wind speed, so the power can be displayed as follows:

$$P = \int_{V_I}^{V_R} P(V) f(V) dV \qquad (1)$$

$$P = C_P(V) \times \left(\frac{1}{2}\rho A V^3\right) \qquad (2)$$

((A) The area is swept by the rotor). Therefore, the average output power of a turbine wind is as follows:

$$P = \frac{1}{2}\rho A \int_{V_I}^{V_R} C_P(V)(V^3) f(V) dV \qquad (3)$$

Given the random nature of the wind, with long measurements at different time intervals, the Weibull wind speed probability density function is used to calculate wind energy. Also, the aggregate distribution function is:

$$f(V) = \frac{K}{C}\left(\frac{V}{C}\right)^{K-1} e^{-\left(\frac{V}{C}\right)^K} \quad (4)$$

$$F(V) = 1 - e^{-\left(\frac{V}{C}\right)^K} \quad (5)$$

Where V the wind speed and C,K the scale and shape factors respectively. These parameters can be calculated using the repeated method from the following equations:

$$K = \left(\frac{\sum_{i=1}^{n} V_i^K \ln(V_i)}{\sum_{i=1}^{n} V_i^K} - \frac{\sum_{i=1}^{n} \ln(V_i)}{n}\right)^{-1} \quad C = \left(\frac{1}{n}\sum_{i=1}^{n} V_i^K\right)^{\frac{1}{k}} \quad (6)$$

V_i The wind speed in the period (i , n) is the number of non-zero wind speed .According to the equation 1, density power of a site based on the Weibull distribution is calculated as follows:

$$P = \int_0^{\infty} P(V) f(V) dV = \frac{1}{2}\rho A C^3 \Gamma\left(\frac{K+3}{K}\right) \quad (7)$$

Γ The gamma function and T as time period are considered. In an ideal turbine, the rotor starts at V_I to spin at the starting speed and the generating energy increases the rated speed V_R, and then the produced energy V_o stays constant until it stops. At higher speeds of V_o, the turbine stops to prevent damage.

The turbine produced energy during the time period is:

$$E_{TW} = T\left(\int_{V_I}^{V_R} P(V) f(V) dV + \int_{V_R}^{V_O} P_R f(V) dV\right) \quad (8)$$

$$\frac{E_{TW}}{AT}\left[\frac{W}{m^2}\right] = \frac{\rho}{2}\left(\int_{V_I}^{V_R} V^3 \frac{K}{C}\left(\frac{V}{C}\right)^{K-1} e^{-\left(\frac{V}{C}\right)^K} dV\right) + \frac{\rho}{2}\left(V_R^3 \int_{V_R}^{V_O} \frac{K}{C}\left(\frac{V}{C}\right)^{K-1} e^{-\left(\frac{V}{C}\right)^K} dV\right) \quad (9)$$

The rated integral of an analytic method cannot be solved, and numerical methods must be used. In order to calculate the actual turbine output energy, its efficiency should be considered in the above relation.

RESULTS OF MODEL IMPLEMENTATION AND ENERGY ANALYSIS AVAILABLE IN KALATEH MULLA REGION

Kalateh Molla area is located in Semnan Province and in western part of Shahrud city. The area has plain plains and low altitude hills and accessible roads, and is geographically equipped to install wind turbines

Figure1. Kalateh Mullah region in Shahrud

However, wind conditions are the most important parameter for determining the suitability of an area for the construction of wind power plants, but a site with favorable wind conditions may have limitations on the construction of these types of power plants. Therefore, in the feasibility study, in addition to studying the wind conditions, there are other studies on the site that include: mapping of lands, geographic study of the region, studying limiting factors legally, studying cultural and ancient works, access Transmission lines, proximity to roads, landslide conditions, examination of substations and domestic transport, study of interference between radio and radio broadcasting, noise survey, vegetation and animal studies, survey of landscape and survey of Residents around the sites. In order to estimate the initial energy available from the wind flow in Kalateh Mullah, the calculations were made on wind directional data for the period from August to July. According to these calculations, the average annual speed is in altitude. Using the probability distribution function of Weibull wind speed, the density is the average annual wind power at altitude. Both the average velocity and the wind power density are well-suited.

Annual Kalabat Mullah district The site class (wind power category) is an indicator of the average energy of wind resources, and is based on the average wind power density at height of 50m above ground level In order to increase the accuracy in the calculations of the mean wind power density, a polynomial of degree is fitted with real values (approximated of the velocity distribution), in which, using a number that is polynomial coefficients, the distribution is much better. By doing this, the polynomial is put in the equation and after the potential integration of the site is obtained in Watts per square meter. The least squared error in this case is less than the use of Weibull distribution and the results will be more accurate. In Fig. 2, the Weibull distribution is shown along with the real velocity distribution values

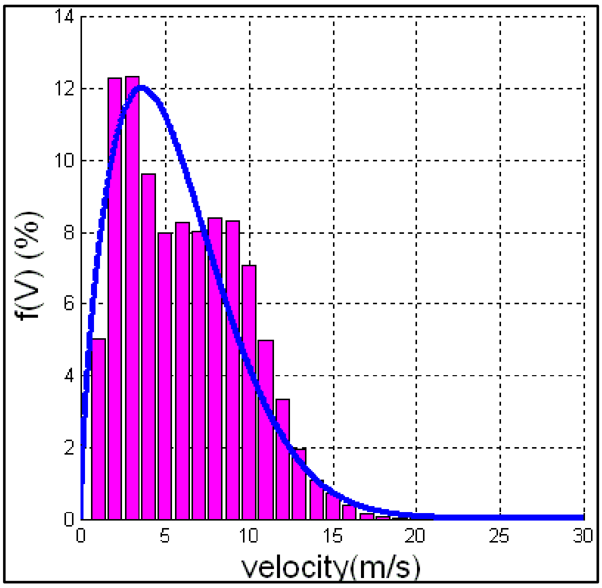

Figure2. Weibull distribution, along with actual velocity distribution

In Fig. 2, a polynomial of degree 20 is shown along with the real values of the velocity distribution.

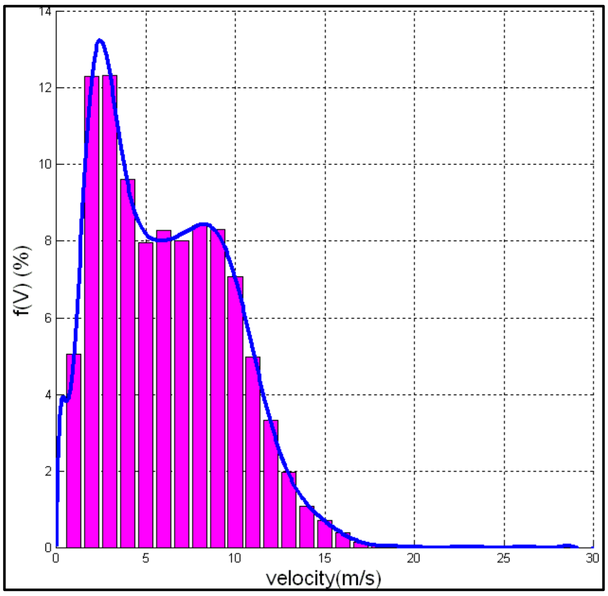

Figure 3. A polynomial of degree 20 along with real values of velocity distribution

The error of approximation Weibull probability density function is derived by the least squares method is as follows:

$$Error = \sum_{i=1}^{m} \frac{d^2(V_i)}{m} = \sum_{i=1}^{m} \frac{\{[f(V_i)]_{Weibull} - [f(V_i)]_{Actual}\}^2}{m} \quad (10)$$

And the least squares error is obtained by considering the polynomial of degree using the following equation:

$$Error = \sum_{i=1}^{m} \frac{d^2(V_i)}{m} = \sum_{i=1}^{m} \frac{\{[f(V_i)]_{Polynomial} - [f(V_i)]_{Actual}\}^2}{m} \quad (11)$$

In the above relations, the value is the real probability density function obtained from empirical data and the value of the probability density function obtained from the fitting of the Weibull distribution and the probability density function obtained from the fitting of a polynomial degree of degree and the number of points Curves to calculate the error value.

Figure 4 shows the distribution of wind velocity in geographic directions. It is observed that velocities are of desirable proportions and that wind velocities are accumulated in the west and southwest directions.

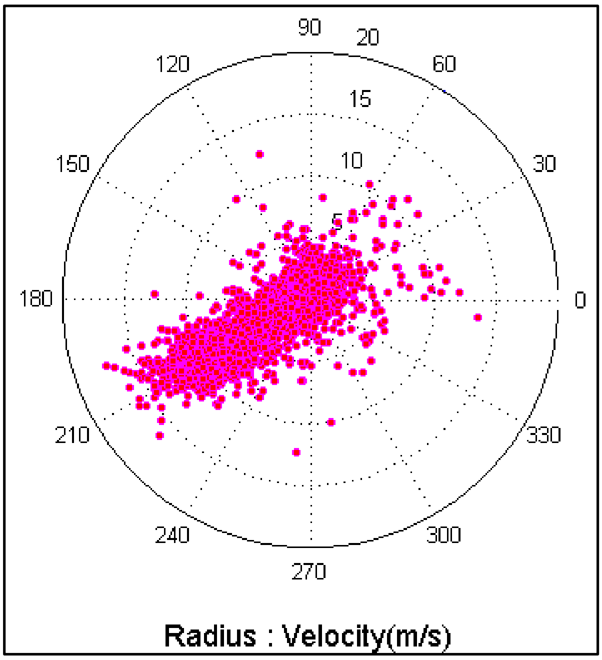

Figure 4. Annual Kalateh Mullah Region

The probability density distribution function of Weibull Given the relationships of the parameters, it is obtained as follows:

$$K=1.6514 \quad , \quad C=6.4109 \quad (12)$$

VALIDATION

In this section, the results of calculating the wind energy density in the Kalateh Mulla region are compared with the results obtained using the software (WASP,Windpro) in the region using the probability distribution function of Weibull using numerical coding. According to these calculations, the average annual velocity is 5/73 m/s at the 40 meters height. Using the probability distribution function of Weibull wind speed, the density average of annual wind power at 40 meters height is 280 W/m 2.

Due to Eq.11 for this particular region, the amount of errors caused by the curve fitting of Weibull is 1.6836 which is also used in software, is equal to the magnitude of 0.0076 the error caused by the curve fitting by 20th order polynomial function. It is seen that there is a huge difference between the errors. This amount of error there is a huge difference in the calculation of energy potential.

Given the Eq. 11 between the energy potential calculated by the Weibull distribution that is used in the software, the calculated energy potential is 280.5 W/m2 and energy potential calculated by polynomial curve fitting is 314/9 W/m2, the error from the energy calculation is equal :

Table 1. Comparison of Weibull fitting (software) and degree curve fitting

	Energy potential (W/m^2)	**Error**
Weibull Curve fitting (software)	208.5	1.6836
20th order polynomial curve fitting	314.9	0.0076

CONCLUSION

1. In order to obtain the energy density of the wind that can be extracted from the wind, using the Weibull distribution in the software, the energy potential is calculated, while the degree of curvature fitting is equal to this.

2. The error rate due to the approximation of Weibull probability density function is more than the error caused by the fitting of 20^{th} order polynomial function

3- According to the classification of wind power potential in terms of wind power density, the Kalateh Mullah region has a suitable and frontier point in terms of wind speed and wind power density

NOMENCLATURE

A Area
C Scale Factor
E Energy
K Shape Factor
P Power
s Second
T Time
V Wind Speed
W Watt
C_P Power Coefficient
f(V) Weibull distribution function
□ Density
Γ Gamma Function

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