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COMPARISON OF MOMENT AND ENERGY TREND FACTOR METHODS ON CALCULATING WIND ENERGY POTENTIAL

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ABSTRACT
In this study, two kinds of numerical methods commonly used for estimating Weibull parameters are reviewed; i.e. the moment and energy trend factor method. Both methods used the coefficient of determination (R^2) and root mean square error (RMSE) was compared with failure analysis. The statistical data of two years' wind speed measurements of Nigde, Turkey, are used to find out the wind energy potential and obtained values are discussed monthly. According to the results of failure analysis that moment method have better results than energy trend factor method.
Keywords: weibull distribution, wind energy, wind potential

1. INTRODUCTION
Two-parameter Weibull distribution function has been commonly used in many fields including wind energy assessment, rainfall and water level prediction, sky clearness index classification, life length analysis of material, etc. Wind power is proportional to the cube of wind speed, estimating the speed distribution for a particular wind farm is very important. Weibull scale parameter controls the abscissa scale of a plot of data distribution. Shape parameter describes the width of data distribution, the larger the shape parameter the narrower the distribution and the higher its peak value [1].

For a given data set several numerical methods can be applied to estimate the Weibull parameters. For example, the widely used moment method, empirical method, graphical method, maximum likelihood method, modified maximum likelihood method and energy pattern factor method [1-5]. Akdag and Dinler [2] reviewed three conventional methods, i.e. the graphical, maximum likelihood and moment methods and proposed a new method (called energy pattern factor method) for estimating Weibull parameters. They stated that the new method has better suitability than others based on the comparisons of power density and mean wind speed. Chang [1] used six kind of numerical methods to analyze the wind power density at 46 and 64.7 m heights in Taiwan, two Weibull parameters were estimated and compared.

In this paper, the moment method and energy trend factor method with the failure analysis are compared. The main objective of the present study is to propose a better method to estimate Weibull parameters for wind energy applications.

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2. METHODS FOR EVALUATING WEIBULL PARAMETERS

Many researchers have devoted to develop an adequate statistical model to describe wind speed frequency distribution. The Weibull and Rayleigh functions are commonly used for fitting the measured wind speed probability distribution. Patel [3] claims that the Weibull probability distribution function with two constant parameters is the best one to describe the variation in wind speed. Weibull distribution can be described by its probability density function f(v) and cumulative distribution function F(v) given as [3]:

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

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

where v is the wind speed, k the dimensionless shape parameter, and c is the scale parameter having the same unit with v. The unknown parameters k and c can be determined with several different methods.

2.1 Moment Method

When the mean wind speed $\bar{V}$ and standard deviation σ are available, shape and scale parameters can be estimated with this method using by these two equations [1].

$$k=\left(\frac{\sigma}{\bar{V}}\right)^{-1.086} \qquad 1\leq k\leq 10 \tag{3}$$

$$c=\frac{\bar{V}}{\Gamma\left(1+\frac{1}{k}\right)} \tag{4}$$

2.2 Energy Trend Factor Method

$$E_{PF}=\frac{\bar{V}^{3}}{\left(\bar{V}\right)^{3}}=\frac{\frac{1}{n}\sum_{i=1}^{n}\bar{V}_i^{3}}{\left(\frac{1}{n}\sum_{i=1}^{n}\bar{V}_i\right)^{3}} \tag{5}$$

where $\bar{V}^3$ is mean of wind speed cubes and $\bar{V}^3/\left(\bar{V}\right)^3$ is known as energy pattern factor (E_{PF}) and according to the literature survey conducted for this study shows that E_{PF} is between 1.45 and 4.4 for most wind distribution in the world. Shape and scale parameters of Weibull distribution are estimated by these two equations [2].

$$k=3.9557E_{PF}^{-0.898} \tag{6}$$

$$c=\left(\frac{1}{n}\sum_{i=1}^{n}\bar{V}_i^{k}\right)^{1/k} \tag{7}$$

where $\overline{V}$ is the wind speed and n is the number of nonzero wind speeds.

Particularly, we will compare moment and energy trend factor methods in Section 2 using two different analyses; first one is R^2,

$$R^2 = 1 - \frac{\sum_{i=1}^{n}\left(y_i - x_i\right)^2}{\sum_{i=1}^{n}\left(y_i - \overline{y}\right)^2} \tag{8}$$

and second is RMSE,

$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{n}\left(y_i - x_i\right)^2\right]^{0.5} \tag{9}$$

where N is the total number of intervals, y_i the frequencies of observed wind speed data, x_i the frequency distribution value calculated with Weibull distribution, $\overline{y}$ the average of y_i values. It is concluded as ‘‘better method” if R^2 magnitude is bigger or RMSE value is smaller [2].

3. RESULT AND DISCUSSION

In order to compare the methods hourly mean wind data used for Nigde region is obtained from Turkish State Meteorological Service cover the period of 2008-2009. Wind speed measurements were carried out at 10 m above ground level. In this part of this study air density is assumed to be equal to 1.072 kg/m^3 and constant for Nigde region. Weibull parameters according to the two methods have been calculated and shown Table 1 with R^2 and RMSE analyses results. According to the results of failure analysis has been determined that moment method has better results than energy trend factor method.

Table 1. Weibull parameters and statistical analyses results.

Regions	**Parameters**	**Moment Method (MM)**	**Energy Trend Factor Method (ETFM)**
Nigde	k (-)	1.64050	1.52220
	c (m/s)	2.83820	2.81750
	R^2	0.92710	0.88501
	RMSE	0.02935	0.03686

Fig.1a. shows comparison of the probability density distributions and Fig.1b. show comparison of the cumulative distributions. It can be seen that the theoretical curves of both Weibull probability density function and cumulative distribution function calculated with the same parameters match very well with the generated data. The mean wind speed and power density values are shown in Table 2. It is clear that the highest value of wind power density was in December followed by February and March while the lowest one was found to be in October. The wind power density values range between 10 and 70 W/m^2 . As December, January and February are the three months that the average wind speeds are the highest all around the year. The wind speed values range between 2 and 4 m/s.

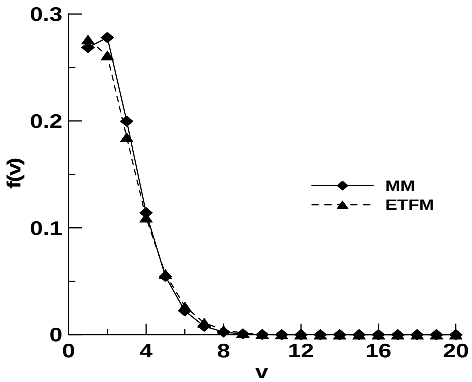

Figure 1a. Comparison of probability density distributions for Nigde. MM: moment method, ETFM: energy trend factor method

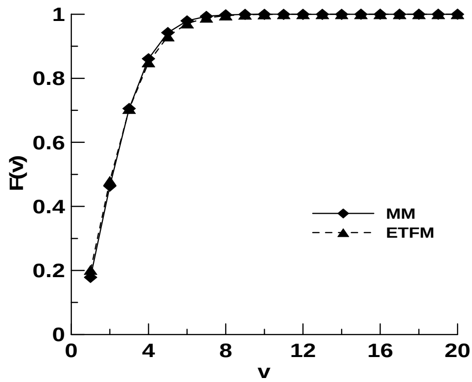

Figure 1b. Comparison of cumulative distributions for Nigde. MM: moment method, ETFM: energy trend factor method

Table 2. Mean wind speed and wind power density.

Month	$\bar{V}$ (m/s)	P/A (W/m²)
January	3.1570	42.48
February	3.7781	66.52
March	3.4810	54.59
April	2.4871	22.19
May	2.5560	21.69
June	2.5230	18.17
July	2.5480	17.59
August	2.3161	14.72
September	2.5558	12.76
October	2.1505	11.58
November	2.4979	18.68
December	3.7804	66.72

4. CONCLUSION

In this paper, the performance of two numerical methods in estimating Weibull function for wind energy application has been systematically compared. According to the results of this study, it is concluded that the moment method is very suitable and efficient in order to estimate Weibull parameters for wind energy applications.

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