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Research Article

Determination of Weibull Coefficients for Hatay Region by Polynomial Curve Fitting in Matlab

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Abstract

Today's ever-increasing energy demands necessitate the development of new energy sources. Renewable energy sources, in particular, have emerged as a critical source of energy for both industrialized and developing countries. Wind energy is one of the most important forms of renewable energy, however the constant variance in wind speed raises several concerns. The wind energy potential of the Hatay region was assessed in this study. The most essential factor for Hatay's selection is the region's high wind energy investments due to its wind potential, as contrasted to the actual wind potential. By using the wind data obtained from the general directorate of meteorology, the potential of the selected region in terms of wind energy has been evaluated. The coefficients of the Weibull distribution function were calculated using polynomial curve fitting in Matlab. The average wind speed of the region was estimated and using these coefficients, the average wind power of the selected region was determined. The performance of this method was evaluated using various statistical error analysis methods and the findings were compared with actual wind speed data.

Keywords: Weibull Distribution, Polynomial Curve Fitting, Statistical Test, Renewable Energy, Wind Energy.

Hatay Bölgesi İçin Matlabda Polinom Eğri Uydurma İle Weibull Katsayılarının Belirlenmesi

Öz

Günümüzün sürekli artan enerji talepleri, yeni enerji kaynaklarının geliştirilmesini zorunlu kılmaktadır. Özellikle yenilenebilir enerji kaynakları, hem sanayileşmiş hem de gelişmekte olan ülkeler için kritik bir enerji kaynağı olarak ortaya çıkmıştır. Rüzgar enerjisi, yenilenebilir enerjinin en önemli biçimlerinden biridir, ancak rüzgar hızındaki sabit değişkenlik bazı endişeleri beraberinde getirir. Bu çalışmada Hatay bölgesinin rüzgar enerjisi potansiyeli değerlendirilmiştir. Hatay'ın seçiminde en önemli etken, bölgenin rüzgar potansiyelinden dolayı gerçek rüzgar potansiyelinden farklı olarak yüksek rüzgar enerjisi yatırımlarıdır. Meteoroloji genel müdürlüğünden elde edilen rüzgar verileri kullanılarak seçilen bölgenin rüzgar enerjisi açısından potansiyeli değerlendirilmiştir. Weibull dağılım fonksiyonunun katsayıları, Matlab'da polinom eğri uydurma kullanılarak hesaplanmıştır. Bölgenin ortalama rüzgar hızı tahmin edilmiş ve bu katsayılar kullanılarak seçilen bölgenin ortalama rüzgar gücü belirlenmiştir. Bu yöntemin performansı, çeşitli istatistiksel hata analiz yöntemleri kullanılarak değerlendirilmiştir ve bulgular gerçek rüzgar hızı verileriyle karşılaştırılmıştır.

Anahtar Kelimeler: Weibull Dağılımı, Polinom Eğri Uydurma, İstatistiksel Test, Yenilenebilir Enerji, Rüzgar Enerjisi.

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1. Introduction

With population expansion and technological advancements, the demand for energy has been steadily increasing in recent years (Kaplan, 2015). As a result, the quest for new energy supplies has become a top priority for the entire world. Energy is the most essential aspect that influences a country's economic structure. As is generally known, energy is considered as a strategic case that impacts international relations, including political and military confrontations, as well as the internal dynamics of countries. Energy is also a critical component of global economic and social growth (Kaplan, 2017). Because wind energy is an environmentally favorable future energy supply, it has been used in irrigation, wheat processing, vessels, and many other fields. Furthermore, wind energy is employed to address the world's future energy needs, which will be the most pressing issue. Because of their economic clout, they are also a formidable political force. Wind energy is currently viewed as a viable alternative to fossil fuels, as well as a means of assisting local economies in the future. In order to meet the world's energy demands, renewable energy will be used instead of fossil fuels (Capika, Yılmaz & Cavusoglu, 2012)(Gabbasa, Sopian, Yaakob, Zonooz, Fudholi & Asim 2013).

The goal of this study is to determine Hatay's wind energy potential. The wind energy of the region is evaluated using five years of data from the General Directorate of State Meteorology on wind speed measured at a height of ten meters. The convenient of Weibull and Rayleigh Distribution Functions with measured real data scientifically analyzed for the region based on hourly-recorded wind speed data. The use of the least cross entropy concept in the calculation of wind speed distribution and wind power density functions was investigated and compared Weibull pdfs (probability density functions) with MinxEnt pdfs (minimal cross-entropy principle) pdfs (Kantar & Usta, 2008). The graphical, maximum likelihood, moment, and energy pattern approaches were all examined (Akdağ & Dinler, 2009). Weibull and Rayleigh probability density functions were used to analyze the wind energy density in the southern and southwestern regions of Turkey (Bilgili & Şahin, 2005). Wind speed data obtained in Camocim and Paracuru were used to evaluate and compare various numerical methods to evaluate efficiency in calculating parameters for the Weibull distribution function (Rocha, Sousa, Andrade & Silva, 2012). A new method was proposed to examine numerical methods to determine the Weibull distribution parameters for wind energy resource estimation (Freitas de Andrade, Maia Neto, Costa Rocha & Vieira da Silva, 2014). The six types of numerical approaches for calculating Weibull parameters that are generally employed were examined (Chang, 2011). Wind data was obtained over a one-year period between June 2012 and June 2013 (Bilir, İmir, Devrim & Albostan, 2015). Wind speed data was gathered from a measurement station situated in the Atlm University campus area (Ankara, Turkey) for two distinct heights (20 m and 30 m) and recorded as one minute average values using a data logger. Weibull's shape (k) and scale (c) parameters were obtained using five different methods.

2. Material and Method

2.1. The Wind Characteristic of Hatay Region

Hatay is located in the southern part of our country, as indicated in Figure 1. It is bordered on the west by the Mediterranean, on the south and east by Syria, on the northwest by Adana, on the north by Osmaniye, and on the northeast by Gaziantep. The goal of this research is to determine Hatay's wind energy potential. The General Directorate of State Meteorology provided us with five years of wind speed data taken at a height of ten meters. The region's wind energy potential has been statistically assessed using Weibull Distribution Functions based on hourly-measured wind speed data.

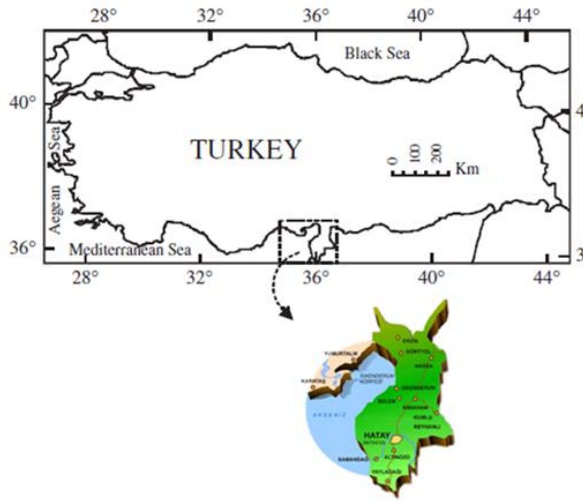

Figure 1. The map of Hatay (Şekil 1. Hatay haritası)

The density of wind directions is shown in Figure 2 as a function of wind frequency. A five-year wind data set is used to determine the main wind direction in Hatay. Summers are scorching hot and dry, while winters are mild and rainy. The average monthly temperature in Hatay, where the average yearly temperature ranges from 15.1 to 20 ° C, is highest in summer and lowest in winter.

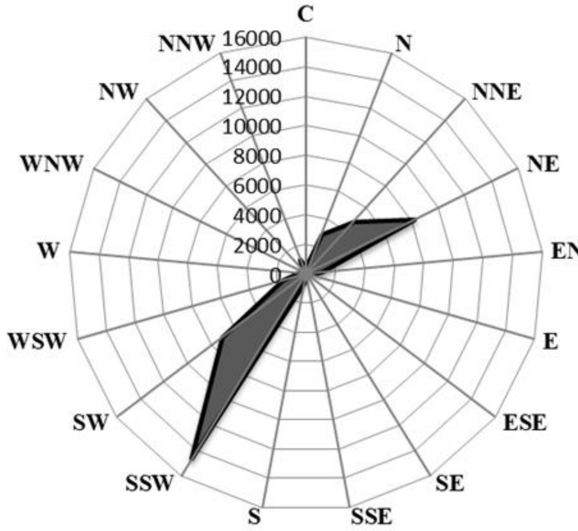

Figure 2: The variation of the wind directions. (Şekil 2. Rüzgar yön dağılımları)

2.2. Statistical Analysis

The wind speed distribution can be determined using a variety of distribution functions. The Weibull and Rayleigh distribution functions with two parameters are the most widely used. Because it is one-parameter, the Rayleigh distribution is less flexible than the Weibull. The Rayleigh distribution, on the other hand, makes parameter calculation easier.

2.2.1. Weibull Distribution Function

The Weibull Distribution Function is a good approximation for probability rules of many natural phenomena. For a long time this function has been used to show wind speed distributions for use in wind turbine studies. For more than half a century, the Weibull Distribution Function has attracted the attention of statisticians working on theory and methods and other branches of statistics (Azad, Rasul, Alam, Uddin & Mondal, 2014).

The wind data analysis of a region is prepared using pre-measured values to anticipate the region's potential performance. Hourly wind speed and direction information are observed in a location, and statistical results are computed to estimate the frequency and likelihood of the observed findings (Bilgili & Şahin, 2005)(Kim & Yum, 2008).

$$p(v_i) = \frac{f_i}{\sum_{i=1}^{N} f_i} \tag{1}$$

Here, the frequency of occurrence of each speed class is f_i, and the number of hours in the time period analyzed is n. $p(v_i)$ is the cumulative probability density.

For wind speed, the two-parameter Weibull distribution function is provided by Eq. (2) and as a cumulative distribution function by Eq. (3) (Ahmet Shata & Hanitsch, 2006)(Kose, Arif, Erbas & Tugcu, 2004):

The two-parameter Weibull's general statement is given by,

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

The cumulative function of wind speed can be attained by computing the integral of the probability dencity function is given by,

$$P(v) = 1 - \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \tag{3}$$

Where $p(v)$ is the observed probability density function, $P(v)$ is the cumulative probability density function , shape (k) and scale (c) parameter of Weibull distribution function)(Kose, Arif, Erbas & Tugcu, 2004) (Yıldırım, Gazibey & Güngör, 2012).

The following equations can be used to estimate the average wind speed 'V_m' and wind power density 'P_w' of the Weibull Distribution Function:

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

$$P_w = \frac{1}{2}\rho c^3 \Gamma\left(1 + \frac{3}{k}\right) \tag{5}$$

Here Γ denotes the gamma function given in the figure below.

$$\Gamma(x) = \int_0^{\infty} e^{-u} u^{x-1} du \quad \text{ve} \quad \Gamma(1+x) = x\Gamma(x) \tag{6}$$

Figure 3 shows the actual probability density function and cumulative probability distributions calculated from Hatay's long-term wind speed data.

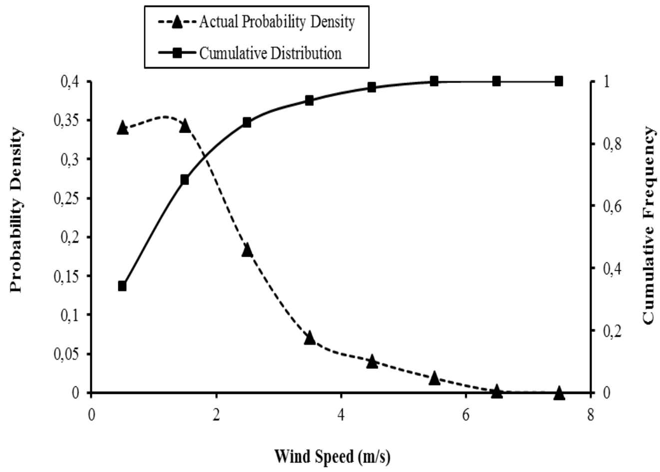

Figure 3: The wind speed probability density and cumulative distribution data of Hatay (Şekil 3. Hatay'ın rüzgar hız olasılık yoğunluğu ve kümülatif dağılım verisi)

2.2.2. Polynomial Curve Fitting

Generally, the data obtained as a result of experimental studies are point values. There is no continuous function definition between the data. In such cases, the data; $(x_1, y_1), \dots, (x_n, y_n)$ are given as pairs of points. For $j = 1, \dots, n$, it is desired to find the $f(x)$function so that $f(x_j) \approx y_j$.

The problem of "curve fitting" is the determination of another function closest to the function in the point-by-point values of a function, or the search for new functions that can facilitate calculations by replacing functions that are difficult to use in practice. The curve fitting problem can be easily done in Matlab. For this process, first of all, x_j and y_j data are needed (Yang, Cao, Chung & Morris, 2005).

3. Results and Discussion

3.1. Numerical Results

In this study, two distribution functions are compared that it was compatible with actual data. Using polynomial curve fitting in Matlab, a linear equation was obtained. Figure 4 depicts this graph.

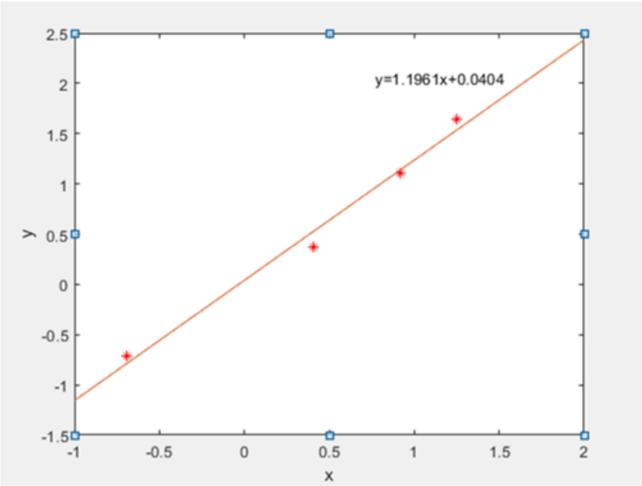

Figure 4: The linear curve fitting in Matlab program(Şekil 4. Matlab programında lineer eğri uydurma)

In order to evaluate the wind potential of the chosen area, long-term wind data must be measured. Each month's form and scale parameters are determined separately. To identify the parameters of distribution functions, polynomial curve fitting in Matlab program is utilized. The parameter values are calculated as $= 1.1961$ $c = 0.9668$.

3.2. Statistical Error Analysis

In this study, two different statistical error tests were performed to show the accuracy and suitability of the proposed method. The used statistical indicators are: The root mean square error (RMSE) and The analysis of variance (R^2) (Kaplan, 2017).

- The root mean square error (RMSE)

$$RMSE = \left[\frac{1}{n}\sum_{i=1}^{n}(y_i - x_i)^2\right]^{\frac{1}{2}} \tag{7}$$

- The analysis of variance (R^2)

$$R^2 = \frac{\sum_{i=1}^{n}(x_i - x_a)\times(y_i - y_a)}{\sqrt{\left[\sum_{i=1}^{n}(x_i - x_a)\right]\times\left[\sum_{i=1}^{n}(y_i - y_a)^2\right]}} \tag{8}$$

Table 1. Comparison of Real and Estimated Values(Tablo 1.Gerçek ve Tahmin Edilen Değerlerin Karşılaştırılması)

Actual Values		**Polynomial Curve Fitting Values**		**Statistical Error Tests**	
V_m	P_m	V_w	P_w	RMSE	R^2
1.5244	2.1697	0.9102	1.8561	0.0417	0.8979

Average wind speed and average wind power values were calculated with real data and estimated by weibull distribution function. These values were compared in Table 1 and the performance of the method used was evaluated in two separate statistical error tests.

4. Conclusions and Recommendations

The Hatay region, which has a lot of wind energy potential, was chosen for this investigation. The average wind speed and average wind energy potential of the region were estimated after an examination of the region's wind characteristics. The results generated using the Weibull distribution function were compared to the real wind speed and wind power values. Polynomial curve fitting in Matlab program was used to find the parameters of the Weibull distribution function. Obtained parameters were used to estimate the average wind energy power of the region. Different statistical error analysis tests were used to examine the concordance of the results with real data and the method's performance. The procedure adopted was successful, according to the results. The scope of this article can be expanded and detailed in future studies by comparing different numerical approaches to assess the region's wind energy potential.

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