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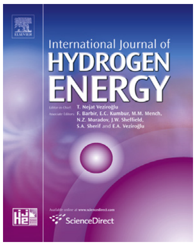

Seasonal and yearly wind speed distribution and wind power density analysis based on Weibull distribution function

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A B S T R A C T

Wind energy, which is among the most promising renewable energy resources, is used throughout the world as an alternative to fossil fuels. In the assessment of wind energy for a region, the use of two-parameter Weibull distribution is an important tool. In this study, wind speed data, collected for a one year period between June 2012 and June 2013, were evaluated. Wind speed data, collected for two different heights (20 m and 30 m) from a measurement station installed in Atılım University campus area (Ankara, Turkey), were recorded using a data logger as one minute average values. Yearly average hourly wind speed values for 20 m and 30 m heights were determined as 2.9859 m/s and 3.3216 m/s, respectively. Yearly and seasonal shape (k) and scale (c) parameter of Weibull distribution for wind speed were calculated for each height using five different methods. Additionally, since the hub height of many wind turbines is higher than these measurement heights, Weibull parameters were also calculated for 50 m height. Root mean square error values of Weibull distribution functions for each height, derived using five different methods, show that a satisfactory representation of wind data is achieved for all methods. Yearly and seasonal wind power density values of the region were calculated using the best Weibull parameters for each case. As a conclusion, the highest wind power density value was found to be in winter season while the lowest value was encountered in autumn season. Yearly wind power densities were calculated as 39.955 (W/m^2), 51.282 (W/m^2) and 72.615 (W/m^2) for 20 m, 30 m and 50 m height, respectively. The prevailing wind direction was also determined as southeast for the region. It can be concluded that the wind power density value at the region is considerable and can be exploited using small scale wind turbines.

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Introduction

Energy is crucial for human life and energy demand of mankind has increased constantly since the industrial revolution. Because, manufacturing processes which are largely accomplished by handcraftsmanship are then realized by mechanization. Firstly, steam power was used in many industries as well as for transportation. The comfort and easiness provided by the use of energy increased the energy need by a large amount. This demand was met entirely using fossil fuels such as oil, coal etc. until very near past. As there were many fossil fuel reserves, and the greenhouse gases were not at harmful levels in the atmosphere, the use of fossil fuels was popular for a very long time. However, fossil fuel consumption became a very serious problem in the current era. The consumption of fossil fuels releases large amount of greenhouse gases and these gases have increased their effects on atmospheric conditions in recent years more severely. The global temperature increase results in abnormal atmospheric conditions such as hurricanes, floods etc. As a result of this temperature increase, large amount of ice melts at the pole regions of Earth. This melting process causes the sea level to increase and it is estimated that the increasing sea level will be very harmful for many countries if the greenhouse gas release continues at the current rate. Renewable energy resources have gained more importance due to these environmental concerns. Another reason of alternative energy resource use is the fact that fossil fuels will be depleted in near future. Wind energy, which is among the most promising renewable energy resources, is used throughout the world as an alternative energy resource to fossil fuels. There are many wind farms throughout the world which provide important amount of energy. In the assessment of wind energy for a region, the use of two-parameter Weibull distribution is an important tool. Many studies were made for different locations in order to determine the shape (k) and scale (c) parameters of Weibull distribution for the region.

Seguro and Lambert determined the Weibull distribution parameters for a sample wind data set using maximum likelihood, modified maximum likelihood and graphical methods. They reported that graphical method is the less accurate one, while maximum likelihood method is recommended for wind energy analysis [1]. Fun and Lam calculated the two Weibull parameters for three different locations; a city area, an extremely exposed area in a city center and an open sea area in Hong Kong. They used graphical method in order to calculate monthly and yearly Weibull parameters using wind speed data collected for 30 years. They observed that both two parameters show an increasing trend after 1982 [2]. Karsli and Geçit reported the Weibull parameters for the region of Nurdağı-Gaziantep of Turkey using the graphical method. They also evaluated the power density of the region and found a 222 (W/m^2) value at 10 (m) [3]. Ozerdem and Turkeli used 'Wasp" and 'WindPro' software to evaluate wind data collected from İzmir Institute of Technology campus area, Turkey for 16 months. They determined Weibull parameters for different wind directions [4]. Weisser found Weibull parameters using empirical method and assessed the wind power density for Grenada. He showed the average variation and the variation in a day of power density for the periods between June–November and December–May. He also compared the variation of the parameters for night and day periods [5]. Akdağ and Dinler emphasized the use of power density method (also called as energy pattern factor method). They compared this method with graphical method, moment method and maximum likelihood method using wind data for Maden, Gökçeada, Çanakkale and Bozcaada regions in Turkey. They reported that power density method gives more satisfactory results according to goodness of fit tests. They found a maximum power density of about 300 (W/m^2) at Bozcaada [6]. Akdağ, Bagiorgas and Mihalakakou investigated wind speed characteristics for nine buoys located in Aegean and Ionian seas. They determined the parameters of two-parameter Weibull distribution and of two-component mixture Weibull distribution for each site using a software which uses maximum likelihood method. They concluded that for most sites two component mixture Weibull distribution while for the other sites mixtured Weibull distribution fits the wind data better [7]. Safari and Gasore investigated wind energy potential for six different regions in Rwanda. For this purpose, they determined the Weibull parameters for long-term wind data at different heights using the maximum likelihood method. They found a maximum power density of 109.89 (W/m^2) at 60 (m) height in Gisenyi [8]. Islam, Saidur and Rahim carried out a study about the wind potential assessment in two different regions in Malaysia. They determined monthly scale and shape parameters for the two regions for each year for which wind speed data are taken. Finally, they found wind power density values for the regions. A maximum power density of 67.40 (W/m^2) was encountered at Kudat region [9]. Chang compared the performance of six numerical methods used for the determination of two parameters of Weibull distribution by applying four different test methods. He found maximum likelihood method as the best one for the case in which the wind speed distribution does not match well with Weibull function. All six methods are reported as applicable for the opposite case [10]. Costa Rocha, de Sousa, de Andrade and da Silva presented the comparison of seven different numerical methods applied in the determination of Weibull parameters using wind speed data for two different cities in Brazil. They tested the performance of these seven methods by applying analysis of variance, root mean square error and chi-square tests. Their results revealed that the methods which use numerical iterations provide more accurate parameter values [11]. Saleh, Aly and Abdel-Hady used five methods in order to assess Weibull distribution parameters for Zafarana, Egypt. They also tested the accuracy of the methods based on root mean square errors. The findings show that the empirical method and the maximum likelihood method are appropriate for the region [12]. Dabhi, Benatiallah and Sellam determined the scale and shape parameters for Sahara site in Algeria and made power predictions. Firstly, they found the two parameters using yearly wind data and secondly using monthly wind data. The power predictions are performed using monthly scale and shape parameters [13]. Khahro, Tabbassum, Soomro, Dong and Liao investigated the wind power production