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Statistical analysis of wind speed using two-parameter Weibull distribution in Alaçatı region

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ABSTRACT

Weibull Statistical Distribution is a common method for analyzing wind speed measurements and determining wind energy potential. Weibull probability density function can be used to forecast wind speed, wind density and wind energy potential. In this study a two-parameter Weibull statistical distribution is used to analyze the wind characteristics of Alaçatı region, located in Çeşme, İzmir. The data used in the density function are acquired from a wind measurement station in Alaçatı. Measurements were gathered on three different heights respectively 70, 50 and 30 m between 10 min intervals for five and half years. As a result of this study; wind speed frequency distribution, wind direction trends, mean wind speed, and the shape and the scale (*k*&*c*) Weibull parameters have been calculated for the region. Mean wind speed for the entirety of the data set is found to be 8.11 m/s. k&c parameters are found as 2.05 and 9.16 in relative order. Wind direction analysis along with a wind rose graph for the region is also provided with the study. Analysis suggests that higher wind speeds which range from 6–12 m/s are prevalent between the sectors 340–360°. Lower wind speeds, from 3 to 6 m/s occur between sectors 10-29°. Results of this study contribute to the general knowledge about the regions wind energy potential and can be used as a source for investors and academics.

1. Introduction

As the world's fossil fuel supplies continue to diminish, global interest in energy production from renewable sources grow every year. Detrimental effects like air pollution and heavy amounts of greenhouse gas emissions have also degraded public opinion on conventional energy sources. On the other hand, renewable energy production like wind power, concentrated solar and photovoltaics have no greenhouse gas emissions and have very little environmental impact when compared to more conventional methods [1]. Wind energy is one of the most efficient renewable energy sources available but it also requires a very detailed analysis of the wind characteristics of the selected region. The wind characteristics like wind speed density and wind direction can have massive differences between regions even when in close proximity. That is why a thorough analysis of the wind measurement data is always necessary before implementing a wind energy project [2].

Turkey has a land surface area of about 800,000 km^2. According to the population, Turkey's energy demand is increasing rapidly (annualy 8%) [3,4]. Population projections are very important for future energy policy-making. Determination of current population trends and predicting future population structure according to these trends provide making healthier demands. According to Turkish Statistical Institute, the population of Turkey will be 84.2 million in 2023. The population will increase slowly to the year 2050, and it will reach to its highest value with 93.4 million people in this year. After 2050, the population will start to decline, and it is expected to be 89 million people in 2075 [5]. This approach makes it necessary to invest. Turkey has started to investment renewable energy, especially wind energy, which has a high potential in the country [6].

As it is with the rest of the world, interest in wind energy production in Turkey has increased dramatically over the last decade. After the distribution of 2007 wind energy production licenses the total wind energy power plant capacity has gone up 146.3 MW's to 2958.4 MW's in 2013 [7]. There has been an average of 300 MW's of annual installations since 2007 and the highest number was seen in 2013 with 646.3 MW's of wind energy power plant (WEPP) installation within the year. Wind energy production is still a rather new market for Turkey. There are currently 75 WEPP's operational in Turkey, most of them starting production between 2010–2014. The total wind energy capacity accounts for less than 5% of the gross national capacity are expected to grow as accordance with its potential. The national WEPP density is around Aegean

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Table 1
Measurement sensors and failure rates from the measurement station.

Sensor	Missing data	Data failure period (h)
Anemometer (70 m)	2.82%	1330 h
Anemometer (50 m)	0.00%	1 h
Anemometer (30 m)	0.96%	451 h
Wind Vane (70 m)	2.02%	950 h
Wind Vane (50 m)	0.00%	0 h

Table 2
Monthly mean wind speed, Std. deviation and Weibull parameters.

	V mean	Std. Dev.	c	k	V_{mp}	V_{maxE}
Jan	8.81	4.90	9.93	1.88	6.64	14.58
Feb	8.69	4.68	9.80	1.95	6.77	14.09
Mar	8.41	4.38	9.50	2.02	6.78	13.34
Apr	8.09	3.92	9.13	2.18	6.89	12.32
May	6.38	3.41	7.20	1.96	5.01	10.30
Jun	7.30	3.40	8.24	2.28	6.40	10.86
July	9.10	3.25	10.17	3.11	8.98	11.94
Aug	8.85	3.52	9.94	2.73	8.42	12.15
Sep	7.25	3.38	8.19	2.28	6.36	10.78
Oct	7.43	3.79	8.39	2.07	6.10	11.63
Nov	7.97	4.62	8.96	1.81	5.74	13.53
Dec	8.96	4.85	10.10	1.93	6.93	14.59
All data	8.11	4.16	9.16	2.05	6.61	12.77

and Marmara regions with Aegean region housing more than 40% of the total WEPP capacity.

Many studies focus on Turkey's wind characteristics to locate regions that are highly suitable for wind energy applications. For instance, Ucar and Balo [8] investigated the wind energy potential at twelve locations in the coastal regions of Turkey. Ozerdem and Turkeli [9] carried out a wind potential estimation study for Izmir Institute of Technology campus area located in Çesme peninsula in Izmir. They evaluated the wind speed data collected for 16 months between July 2000 and November 2001. Weibull parameters for 12 sectors were determined for 10 m and 30 m heights for the observation period using 'Windpro' and 'Wasp' softwares. They reported high energy potential for the region. The wind energy potential of various regions and the exploitation of wind energy were investigated by analyzing wind data that were measured hourly at windy locations in Turkey [10].

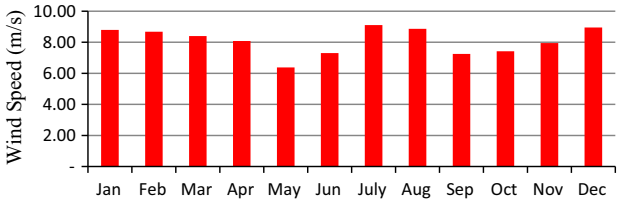

Fig. 1. Monthly variation of wind speed (2008–2014).

The city of İzmir, located in the center of Aegean region, has 576.9 MW's worth of WEPP projects in operation and another 124 MW under construction. Therefore, İzmir is currently the leading wind energy production center of Turkey by having the most licensed WEPP applications within its borders [7]. Most of the WEPP capacity in İzmir is also realized in Çeşme region which is where this study has taken place. General Directorate of Renewable Energy (GDRE) has estimated that İzmir region has a WEPP potential of 11.8 GW so it is safe to assume that the region will continue to see new applications in the oncoming years [11].

Energy Market Regulatory Agency (EMRA) has introduced mandatory meteorological measurement procedure for wind and solar energy power plant application in 2010. With these new set of rules, all new license application for WEPP projects require a

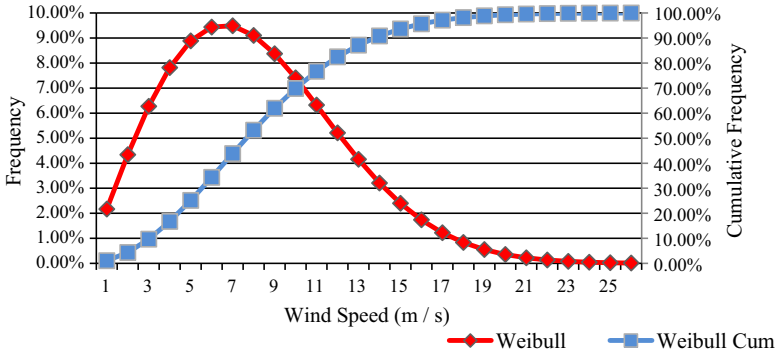

Fig. 2. Weibull distribution of wind speed (2008–2014).

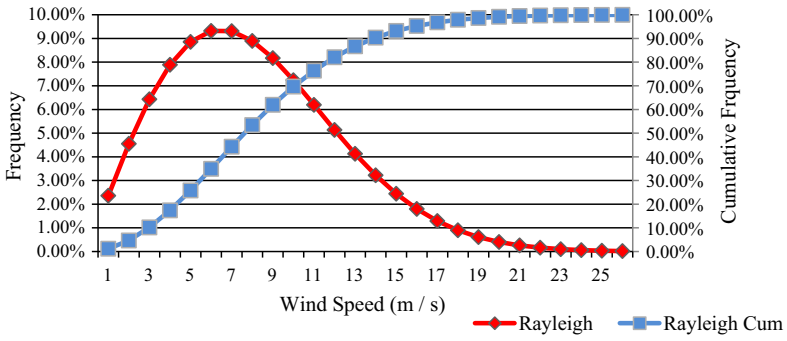

Fig. 3. Rayleigh distribution of wind speed (2008–2014).