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Wind energy resource assessment of Izmit in the West Black Sea Coastal Region of Turkey

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ABSTRACT

The wind energy potential of Izmit (41.19 N, 30.30 E), which is located in the West Black Sea Coastal Region of Turkey, is assessed with the statistical analysis of the gathered wind data at the 50-m height measurement mast covering the period of 06/2008-06/2009. The annual average wind speed is calculated as 6 m/s and the prevailing wind direction is ENE (60°). The Weibull distribution parameters of shape and scale factor are found as 2.03 and 6.73 m/s, respectively. The measured wind speed data are compared with the data of nearby meteorological stations and the results show that there is a considerable difference between the onsite measurements and the measurements of the meteorological stations. Moreover, a turbulence analysis is carried out and the turbulence intensity is negatively correlated with the normalized height from ground level with canopy height. The energy generation performances of three different wind turbines are evaluated by using the onsite wind speed measurements and the assessment shows that the capacity factor increase by a factor of two from 17% to 34% depending on the type of the turbine. Furthermore, an economic analysis is carried out for a 50 MW wind energy project for the potential site and the proposed project benefit/cost ratio is calculated as 8.

Contents

1. Introduction

Turkey has a considerable wind energy potential with its coastal length of 7.200 km and an average elevation of 1.132 m. However, the country has a complex topography which requires more detailed information for choosing the optimum locations for wind power plants [1]. It was specified by Turkey Wind Energy Potential Atlas (REPA) that there is an 114,173 MW of wind energy potential in regions where wind speed is higher than 7.0 m/s at 50 m height (Table 1). The atlas, however does not allow a detailed examination of the region due to low resolution and high uncertainty [2,3]. The West Black Sea, Marmara, Aegean, and East Mediterranean coastal regions are appeared to be the most suitable sites for wind energy development in Turkey (Fig. 1). Canakkale and Balikesir, cities located on North Aegean and Marmara coastal areas, are alone responsible for 23.5% of the country's wind energy potential (Fig. 1).

After the enactment of the Turkish Renewable Energy Law in May 2005, the wind energy project owners have received a guaranteed price of 73 $/MWh for the generated electricity for a duration of 10 years under the feed-in tariff mechanism. This support scheme has given rise to a dynamic growth of wind

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energy projects in Turkey: the total installed capacity of wind energy which was 18 MW by the year 2004 reached to 2312 MW by 2012. Turkey's objective is to reach 20 GW of installed capacity by 2023 [2].

Several researches used the wind speed data of the meteorological stations to assess the wind energy potential of coastal regions in Turkey (Table 2). In addition to these studies, wind speed estimation of the target station in the Southeastern Anatolian Region of Turkey was carried out by determining wind speed correlation between neighboring stations and using Artificial Neural Network (ANN) [10]. Similarly, ANN was also used for short term estimation of wind speed in the region of Batman, Turkey [11]. For the western region of Turkey, wind energy potential of Kırklareli was examined by use of statistical data of the last three years [12]. But, neither of those studies questioned how representative and reliable the meteorological wind speed measurements for the assessment of the coastal wind energy potential of the country. Common problems include height of anemometer is low ($y=10$ m); anemometer mast is surrounded by obstacles like buildings and trees (Fig. 2). Therefore, the uncertainty of coastal wind energy assessment based on meteorological datasets is expected to be high.

Table 1
Wind power potential of Turkey by regions where wind speed is higher than 7.0 m/s at 50 m height. The raw data was obtained from EIE [4] for each of the cities located in the region and the wind power potential of the regions was calculated by the authors.

Region	Wind power potential (MW)	Percentage
Aegean	26,150	22.9
Marmara	43,917	38.5
Mediterranean	11,214	9.8
Black Sea	14,312	12.5
Eastern Anatolia	2974	2.6
Central Anatolia	10,904	9.6
Southeastern Anatolia	4703	4.1

This study aims to evaluate the wind energy potential of Izmit which is located in the West Black Sea of Turkey. For this purpose, one-year wind speed records of a measurement mast are assessed and compared with the data of nearby meteorological stations. Moreover, a statistical analysis is performed to evaluate the wind energy potential of the site and an economic analysis is carried out for a 50 MW wind energy project for the potential site.

2. Wind energy resource assessment

The starting point of any wind energy project is the resource assessment. It helps to identify suitable sites for wind turbines and also undertake an early economic cost analysis. Due to the rather large capital investment involved with wind energy projects, it is crucial to undertake the resource assessment as precisely as possible. The speed of the wind and its annual frequency are key parameters that determine the net output of a wind turbine.

Wind turbines convert air flow kinetic energy into mechanical energy, which can be used to drive an electricity generator. Wind turbines can convert as much as 50% of the available wind energy into electricity and power output P of the wind turbine is expressed by the following formula:

$$P=\frac{1}{2}\rho A V^3 C_p \quad (1)$$

where ρ is the density of air and it is assumed to be 1.225 kg/m^3, A is the swept area, V (m/s) is the wind speed, and C_p is the power coefficient of the wind turbine for the corresponding wind speed. Wind energy generation is a cubic function of wind speed and this implies that small changes in wind speed estimates can cause large changes in wind energy estimates. In recent years, Weibull distribution has been one of the most commonly used, accepted, and recommended distribution to determine wind energy potential and it is also used as a reference distribution for commercial wind energy software such as Wind Atlas Analysis and Application Program (WASP) [13]. Its probability density function (PDF)

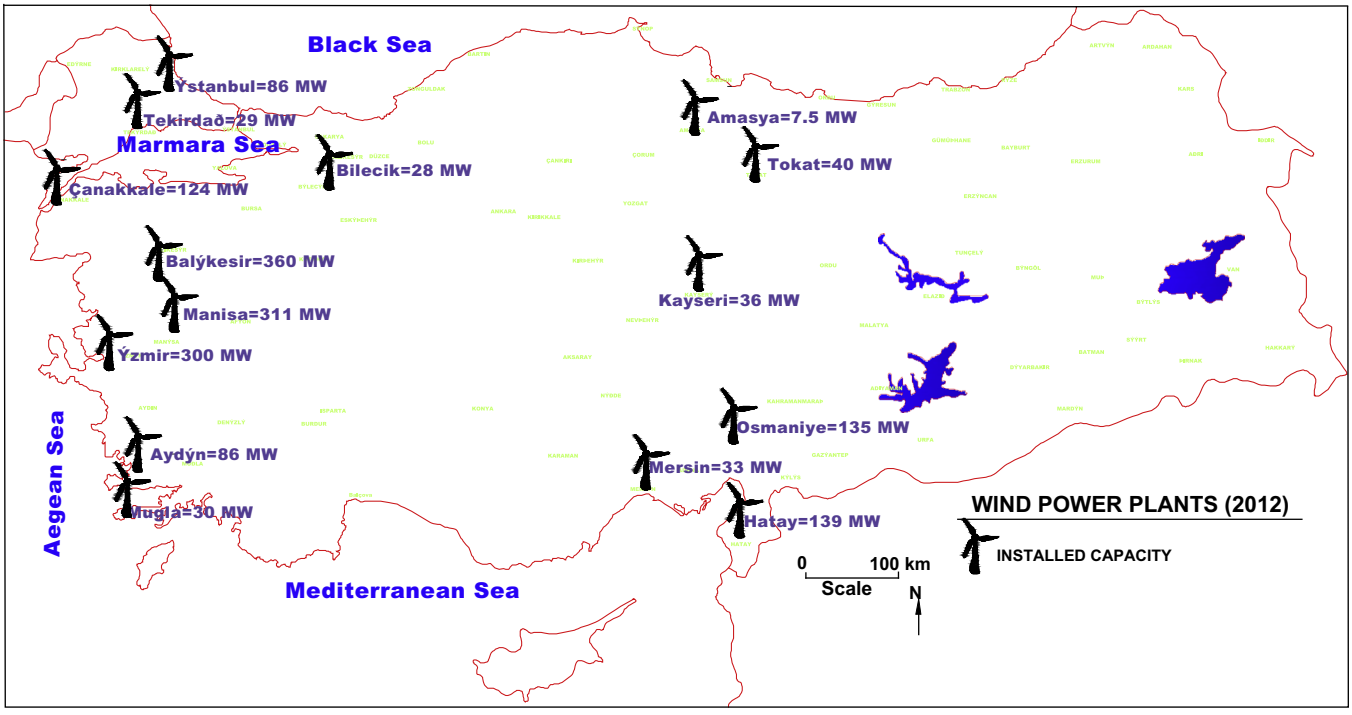

Fig. 1. Distribution of wind power plants in Turkey by May 2012. The wind parks grouped based on cities.
Source: EMRA [5].