Determination of the suitable wind turbine for the location in Yalova, Turkey considering the regional wind characteristics

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Abstract

Aim of this paper is to analyze the wind energy characteristics of a location in Yalova, Turkey and to determine the suitable some usable options about how to make use of wind of such places. One year hourly wind data in time series format was obtained from The Turkish State Meteorological Service (TSMS) in 2012 and analyzed considering some statistical formulations and approaches. In this study, all the wind characteristics of the location such as average wind speed, dominant wind direction, power density values, and Weibull parameters are calculated. As a result, it was determined that this location has less wind potential and non-traditional wind turbines that can even generate electricity at very low wind speeds can be utilized there.

1. Introduction

Determining the wind characteristics for a location taking at least one-year wind data into consideration is the first step before installing wind turbines here to generate electricity. In this context, this operation is very important in terms of determination of wind energy potential of a location and also installation of the most economic and suitable wind turbines in location. There have been many studies about determination of wind characteristics [1][2][3][4]. In this study, the 10 year-wind energy data in time series format for a location in Yalova-Turkey, which was obtained from Turkish meteorology station, was statistically considered and classified. According to the classified data, wind characteristics of the location was firstly determined and then analyzing the wind characteristics of the location, the most suitable wind turbine for the location owning such wind characteristics was identified. Finally, non-traditional wind turbines that can even generate electricity at very low wind speeds are discussed there.

2. Wind characteristics of the location in Yalova

Yalova is a small city in the Marmara region and its population is 121,479 and it has a fairly small surface area of 847 km^2. It has a border to the west of the Marmara sea [5].

After classifying the one-year wind data in time series format, that was taken from TSMS in 2012 [6], cumulative frequency distribution of the location was determined. Fig. 1 shows the cumulative frequency distribution of the location in Yalova. It indicates that average wind speed and power density of the location appears low.

One of the important parameters is the dominant wind direction, too. Fig. 2 shows the frequency distribution (%) of the wind direction. It indicates that the dominant wind direction is SSE.

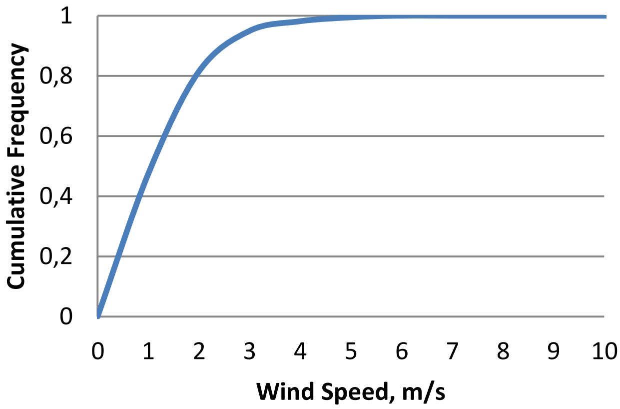

Fig. 1. Cumulative frequency versus wind speed graph

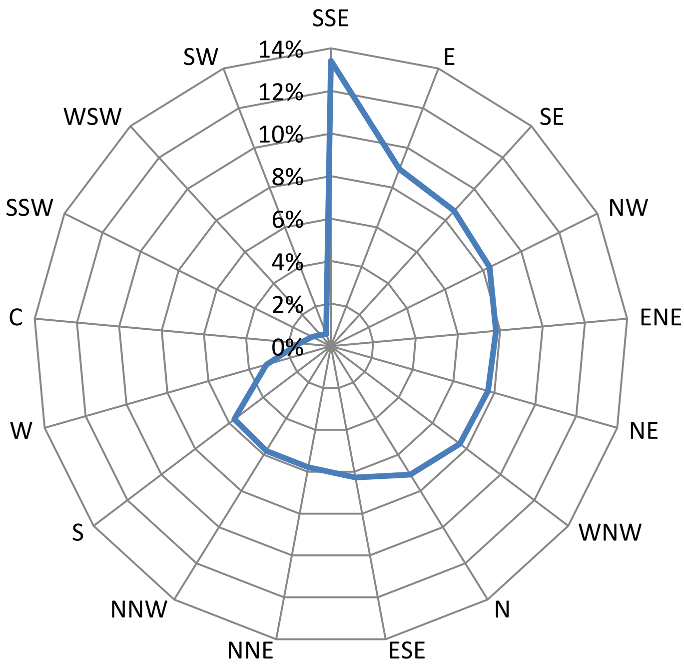

Fig. 2. The frequency distribution of the wind direction

However, all the findings obtained from this study states that the dominant wind direction is NW because the highest power density value is obtained in this direction. Otherwise, the wind direction SSE has the fourth place in terms of wind power density value. The dominant wind direction NW generates the highest annual (yearly) wind power of 6500 MW/m^2.

Average wind speed of a location can be usually calculated by using the Eq. (1). As a result of the calculation by means of this formulation, average wind speed of the location is obtained as 1.3 m/s [7] [8].

$$V_m = \frac{\sum_i^n f_i V_i}{\sum f} \tag{1}$$

Eq. (2), called as "Power law formulation" is used to determine the wind speed values for different heights considering the wind speed data measured at 10m [1][8][9].

$$\frac{V}{V_0} = \left(\frac{h}{h_0}\right)^{\propto} \tag{2}$$

where, alpha is power law exponent and its value is considered as 0,14 in the study.

h: the reference height (10m), m
h_o: the desired height, m
V: wind speed value calculated at the desired height, m/s
V_o: wind speed value at the referenced heihgt(10m), m/s

For different heights, variation of average wind speed values is shown in Fig. 3. According to the results related to the average wind speeds of the location, this location is said to be a low windy region.

Average power density is calculated by using Eq. (3) regarding all the hourly wind speed values [3][7][8].

$$P = \frac{1}{2}\rho V^3 \tag{3}$$

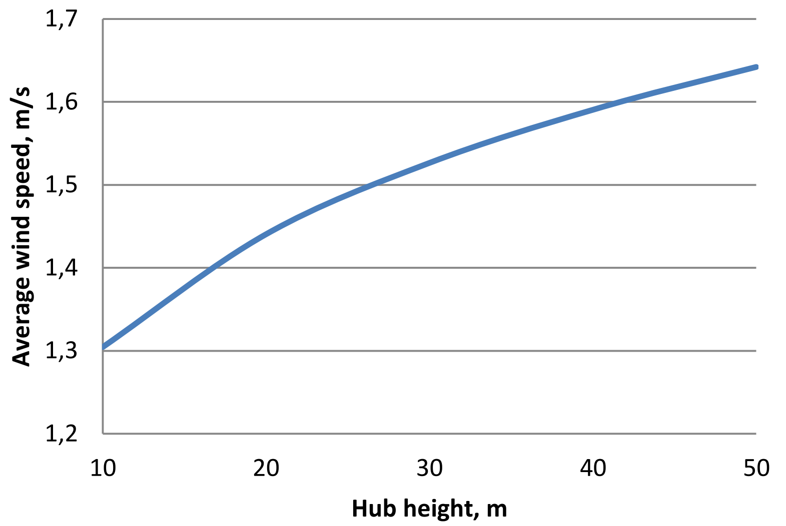

Fig. 3. Variation of wind speed with different hub heights

As clearly seen in Fig. 4, power generated in this location is too small to generate electricity in order to meet electricity demand of a town. It can only meet the electricity demand of a small house.

Furthermore, using mean speed-standard deviation method, Weibull parameters was calculated. k and c are calculated as 1,56 and 1,45 m/s, respectively [7][8][10]. Fig. 5 shows the Weibull frequency distribution obtained using the calculated weibull parameters.

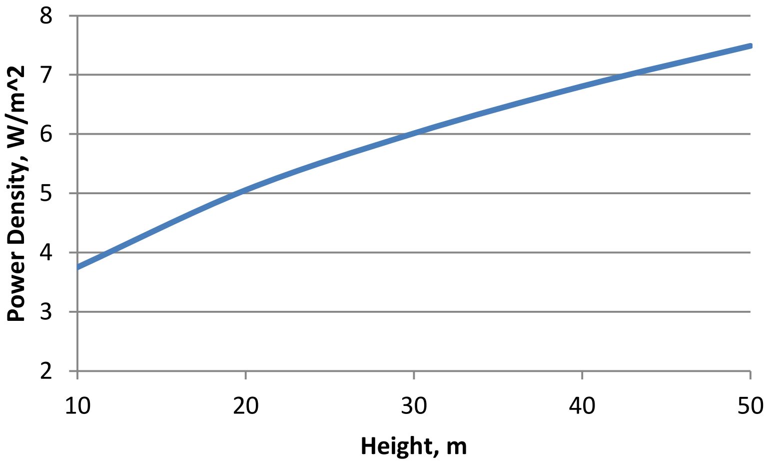

Fig. 4. Variation of the power generated at the different heights

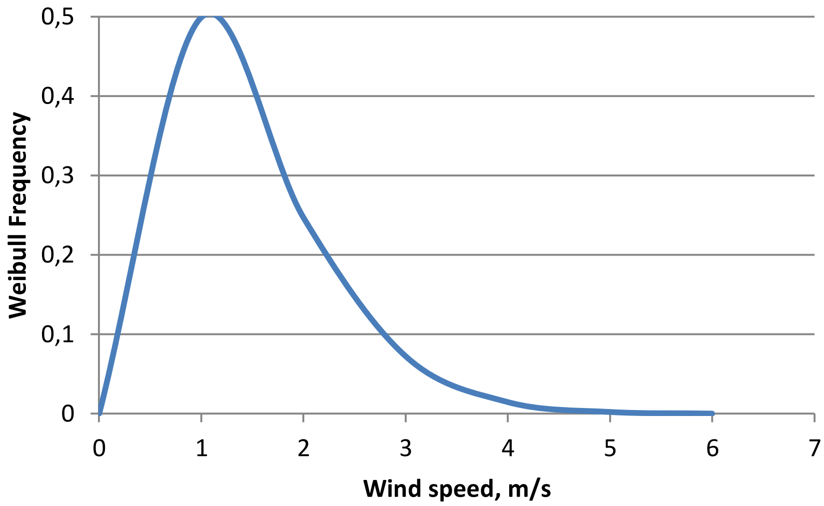

Fig. 5. Weibull frequency distribution

3. Determination of the suitable wind turbine

After implementing the first step known as "determination of the regional wind characteristics", the next step known as the selection of reasonable and suitable wind turbine for the interested location is carefully taken. Eventually, the most suitable wind turbine is determined in accordance with Fig. 6.

According to this study, this location appears sufficient to install a small scaled wind turbine instead of a large wind turbine because its wind energy potential is enough for only a house with a small electricity demand. In Fig. 6, the relationship between rotor power coefficient and wind speed is shown [11].

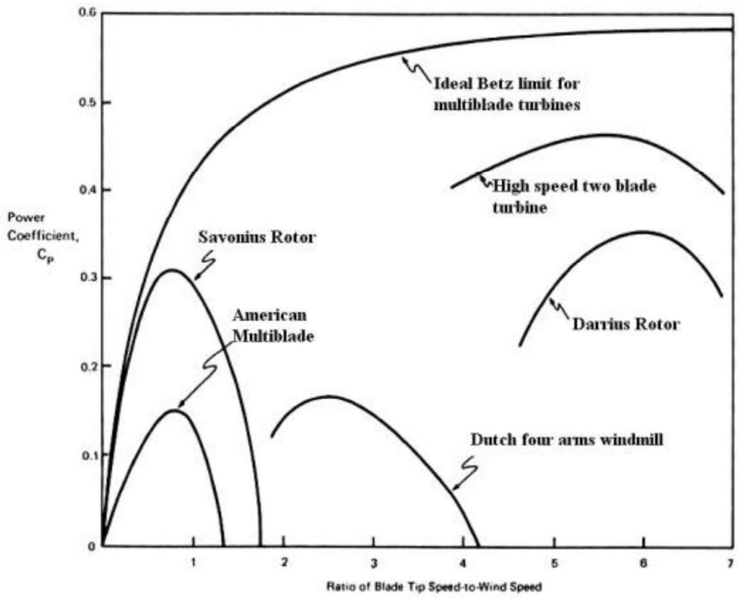

Fig. 6. Rotor power coefficient versus wind speed graph

Because the location has the lower average wind speed value less than 2m/s, Savonius and American multi-blade type wind generators are selected and can be utilized in the small-scaled electricity generation applications here. These wind turbines can generate electricity at wind speeds less than 3m/s while three bladed wind turbines can generate at wind speeds greater than 3m/s. Furthermore, power coefficients of these wind turbines are max. 30% (it is max. 15% for Savonius, and max. 30% for American type wind turbines), while it is max. 40% for three bladed wind turbines. It means that efficiency values of these wind turbines are lower than traditional ones.

4. Conclusion

Turkey has the rich renewable energy potentials. Therefore, Turkey should trust on its renewable energy potentials, especially wind energy to reduce its current energy dependency. The following wind characteristics for the location were obtained in this study.

- Average wind speed of the location is obtained as 1.30m/s considering the wind data measured at 10m height.
- Dominant wind direction is determined as NW.
- Its power density value is about 3.6 W/m^2.
- This location in Yalova is not sufficient for big wind energy projects because of its low wind power density.
- It is can be assessed for a small house in a remote place by using Savonius and American type wind generators.

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