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Academic @ Paper
International Journal of Energy Applications and Technologies
Vol. 3, Issue 2, pp. 72 – 76, 2016
www.academicpaper.org/index.php/IJEAT

Research Article

A WIND POWER PLANT FEASIBILITY STUDY FOR BURSA, GEMLIK REGION IN TURKEY BY WINDSIM SOFTWARE

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Received 24th November 2016, Accepted 9th December 2016

Abstract

Development of technology and industry has been causing a remarkable energy demand all around the world. In order to meet this huge energy demand, conventional energy sources are being used a lot and this issue brings along a serious environmental pollution. Especially, last decades many countries have signed the agreements to prevent environmental pollution. In conjunction with these events, renewable energy sources have become important. In this context, most of countries have been increasing the incentives to the clean energy systems. Also, Turkey has been increasing the incentives to renewable energy investments; therefore renewable energy usage is increasing day by day. In 2015, Turkey's total installed capacity has reached 72146.7 MW and 42.7% of this amount is met by renewable energy sources. In Turkey most commonly used renewable energy sources are hydroelectric energy, wind energy, solar energy and geothermal energy respectively. In 2013, installed wind energy capacity of Turkey was 2759.6 MW and this capacity reached 4503.2 MW in 2015. It can be deduced from this data, wind power investment in Turkey has been expanding dramatically. In this study, a wind power plant (WPP) feasibility study for Gemlik region in Bursa Province is released by using 5 number of Vestas V90 commercial wind turbines. Also, climatology data obtained from Turkish State Meteorological Service are used for this study and by applying these date to the Windsim software; annual energy production (AEP) and capacity factor of the WPP are calculated. The study shows that, establishment of a WPP which has 30.6 GWh/y AEP and 34.9% capacity factor is feasible.

Keywords- *Gemlik, Renewable Energy, Wind Energy, Windsim, Wind Power Plant.*

1. Introduction

Energy demand has been increasing all around the world day by day due to the fact that technology and industry have been growing rapidly. As a result, significant environmental pollution issues and problems have been emerging. In recent years, most of agreements have being signed by many countries in order to prevent environmental pollution such as Kyoto Protocol [1]. The main objective of the Kyoto Protocol is that controlling greenhouse gases emission and struggling for reducing hazardous effects of these gases [2]. In parallel with these agreements, clean energy technologies, sustainability and energy efficiency has become important subject matters.

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Note: This paper has been presented at the International Conference on Advanced Technology & Sciences (ICAT'16) held in Konya (Turkey).

Therefore, the developing countries have been increasing incentives and investments to the clean energy technologies. In addition to that, Turkey as a developing country, has been noticed the importance of the renewable energy technologies and it has been raising the investments to this field [3]. The population of Turkey is about 74 million inhabitants and it is estimated that 75.5% of this remarkable population lives in urban centres [4]. Also, this important population is increasing in conjunction with the technological improvement and as natural consequence of this situation; Turkey's energy demand is increasing each passing day and it causes huge energy demand in the country. Turkey is a foreign dependent country because domestic fossil reserves are limited and inadequate. In order to decrease foreign dependency, Turkey needs to benefit from renewable energy sources such as wind, solar, hydropower, biodiesel etc. [5]. Wind energy as a renewable energy source has shown a great

development across the world since it is clean, sustainable and efficient energy source. In this context, thanks to Turkey's geographical position Turkey is a rich country in terms of wind energy. According to Turkish Wind Energy Association (TWEA) installed wind energy capacity has reached 4718 MW by the year of 2015 [6]. As shown in Fig.1, amount of wind power plant and naturally wind energy production has been increasing each passing year [7]. According to Turkey's development plan, Turkey wants to increase the share of renewable energy source usage to at least 30% [8].

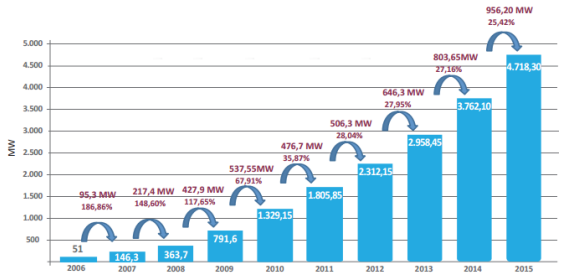

Fig. 1. Cumulative wind energy production by years in Turkey [7].

In this study, wind power potential of Bursa Province in Turkey is evaluated. A WPP feasibility study is revealed for Gemlik region in Bursa Province and total energy production of the designed WPP is calculated. The main objective of this study is providing inputs to researchers and encouraging the investors for harvesting wind potential of the region.

2. Materials and Methods

The amount of wind power potential is depend on following factors; structure of terrain, wind speed and the distance to the energy transmission lines (ETL). In the first part of this study, wind power potential in Turkey is evaluated Secondly, Gemlik region in Bursa Province is selected for a wind power plant investment and the wind power potential of the region is evaluated by considering related parameters. In this context, Turkey wind energy potential atlas created by Turkish Electric Affairs Etude Administration is used. Finally, roughness formation and distance to energy transmission lines and transformer stations are analyzed in order to determine whether wind power plant investment is feasible or not.

Assessment of Wind Power Potential in Turkey

Thanks to its geographical position, Turkey has a significant wind power potential. The leading regions in terms of wind power potential investment are Marmara and Aegean region in Turkey. According to TWEA report published in 2016, %49.94 of total number of WPP is in Marmara region and 24.82% of this amount is in Aegean region [7]. The wind atlases given by Fig.2 and Fig.3 were used to estimate the wind power potential for 50 meter and 100 meter elevation respectively. According to wind atlases, average wind speed at 50 meter elevation is approximately 6.5-7.0 m/s through out of the country and this value is nearly 7.5 m/s for 100 meter elevation. In Marmara region this parameter changes between 7.0 and 7.5 m/s at 50 meter elevation and this value is pretty sufficient for the WPP investments.

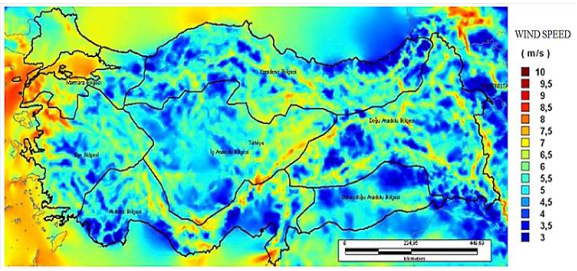

Fig. 2. Average wind speed distribution at 50 meter elevation [9].

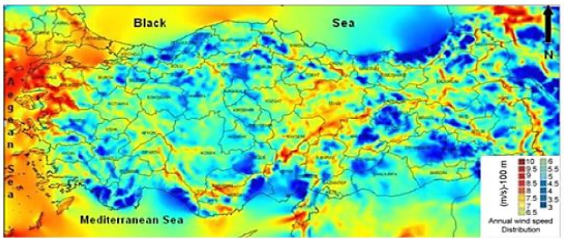

Fig.3. Average wind speed distribution at 100 meter elevation [10].

In order to provide an economical WPP investment, average wind capacity factor must be %35 and more [11]. As shown in Fig.4, Aegean, Marmara and East Mediterranean regions have more than 35 % capacity factor and so these regions attract the attention for WPP investments.

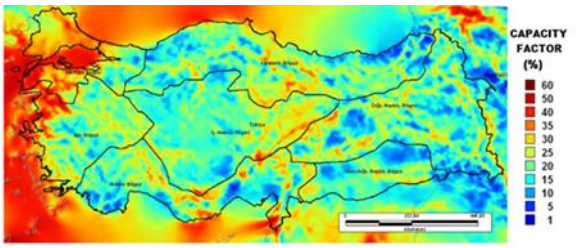

Fig. 4. Average wind capacity factor in Turkey at 50 meter elevation [9].

The WPP which have 5 MW capacity or more can be installed in the fields where have 7.5 m/s or more wind speed at 50 meter above ground level [12]. When considered from this aspect, Marmara and Aegean regions are the pretty suitable region for WPP investments.

Assessment of Wind Power Potential in Bursa Province

Bursa Province is located between 40 degrees longitude, 28-30 degrees latitude and located in North-western Anatolia, within the Marmara Region. It is the fourth most populous city in Turkey and it is one of the most industrialized metropolitan cities [13].
Wind power potential of Bursa Province was analyzed by using Wind atlases created by Turkish Electric

Affairs Etude Administration. As illustrated in Fig. 6 and Fig. 7, average wind speed at 50 meter elevation is 7.0- 7.5 m/s in Bursa Province. In addition to that, average wind capacity factor is 30%-35% for the city.

Fig.5. Location of Bursa Province in Turkey map.

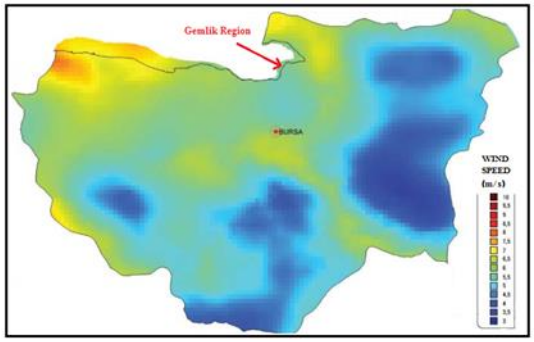

Fig. 6. Average wind speed distribution in Bursa Province [14].

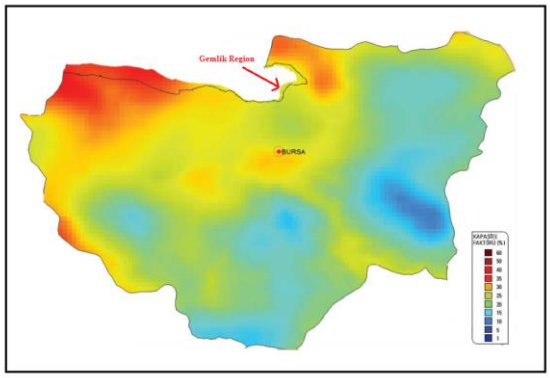

Fig. 7. Average wind capacity factor distribution in Bursa [14].

According to Fig. 6 and Fig. 7, coastal areas of Bursa Province have notable wind speed and wind capacity factor. Especially, Gemlik region where located in coastal area of Bursa Province has average 7.0-7.5 m/s wind speed and nearly 35% capacity factor at 50 meter elevation. In the light of these informations, it can be said that Gemlik region is a suitable field for a WPP investment.

3. Wind Power Plant Feasibility Study

In this section firstly, Windsim software is introduced. Secondly, wind farm layout design is realised by considering roughness formation and distance to ETL and transformer stations in Gemlik region. Finally, annual energy production and capacity factor of the designed wind farm are calculated.

Windsim Software

Windsim is one of the popular wind farm design tools which developed by a Norway company named Windsim AS [15]. The software is based on the Reynolds Averaged Navier-Stokes equations of the Atmospheric Boundary Layer and by solving these equations; the correlation is provided [16]. The calculation steps of Windsim software is shown in Fig. 8. Three inputs; terrain data, roughness map and meteorological data are defined to the software as inputs. Then, solutions are obtained by using computational fluid dynamics (CFD) method.

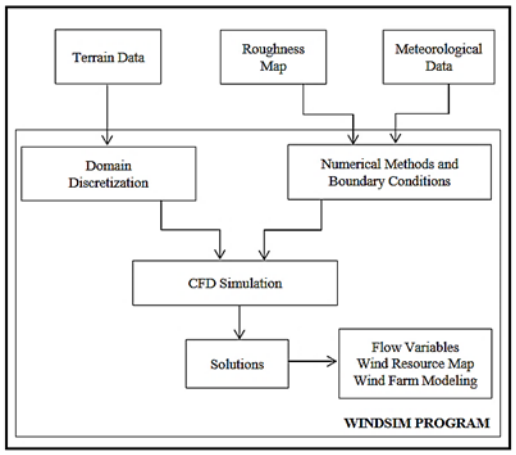

Fig. 8. Basic flowchart of wind resource assessment by Windsim [17].

Wind Farm Layout Design

Wind farm site selection is carried out by considering roughness formation and distance to ETL in Gemlik region. For this purpose, the roughness map of Bursa Province was used as shown in Fig. 9. According to Fig. 9, most part of Bursa Province containing Gemlik region is feasible for the WPP investments.

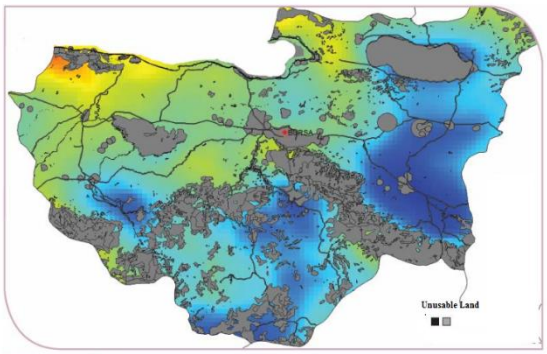

Fig. 9. Unusable lands for WPP in Bursa Province [14].

Energy transmission lines and transformer stations in Bursa Province is given in Fig. 10. As shown in Fig. 10, there is a transformer station which is rather close to Gemlik region and it is vital parameter for an economical WPP investment due to the fact that it will reduce the initial investment cost.

After analyzing of the roughness formation and distance to ETL and transformer stations in Gemlik

region, a wind farm site selection for WPP investment was realised. As shown in Fig. 11, hillside of Gemlik region was chosen for a WPP feasibility study.
5 Vestas V90 commercial wind turbines were installed in the selected region for numerical analysis. The locations of the installed wind turbines are given in Fig. 12.

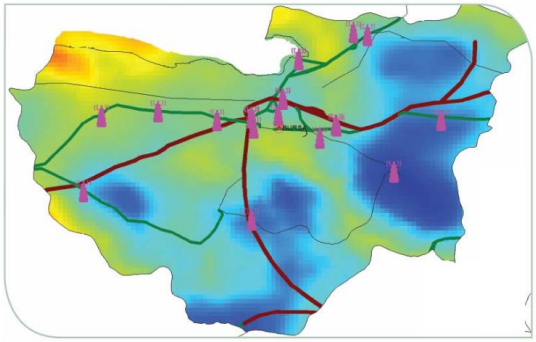

Fig. 10. ETL and transformer stations in Bursa Province [14].

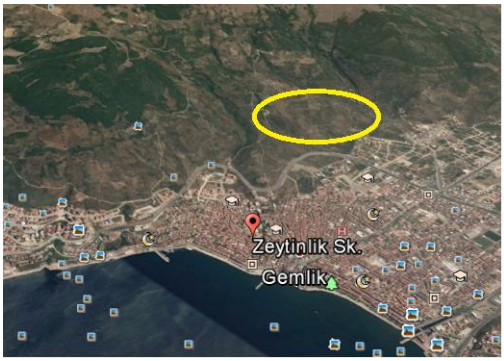

Fig. 11. Wind farm site selection.

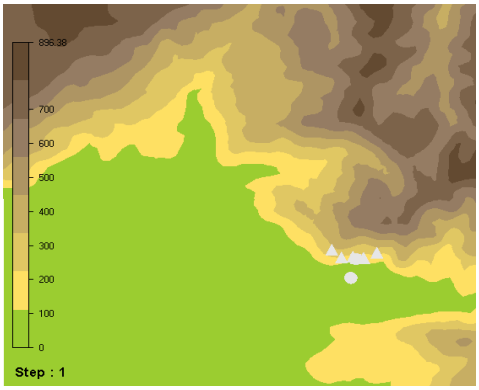

Fig. 12. Wind turbine locations.

Wind turbine layout design was carried out by considering wake affect which decrease the energy efficiency of the wind turbines. Turbine layout was performed by considering wind turbine layout proposal as shown in Fig. 13 in order to decrease wake effect.

Energy Analysis

According to CFD analyses results performed by using Windsim software as shown in Fig. 14, average wind speed in the selected region was found as nearly 7.5 m/s at 90 meter elevation. When the wind resource map is compared with the wind atlas, it can be deduced that the wind speed data match well.

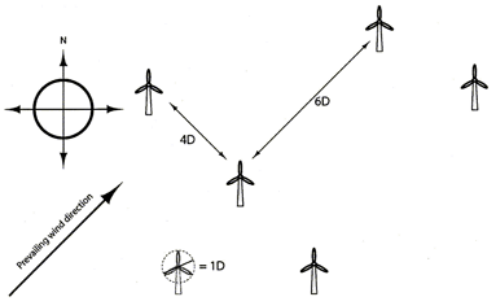

Fig. 13. Wind turbine layout proposal [18].

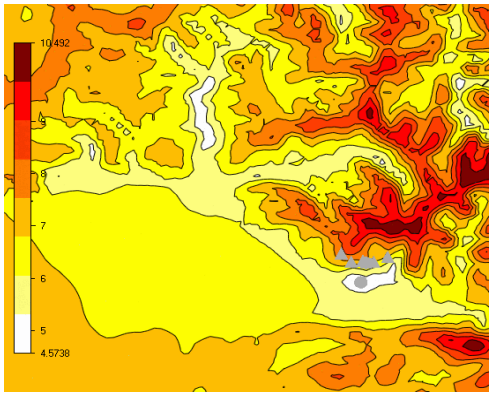

Fig. 14. The wind resource map with average wind speed (m/s) at a hub height of 90 meters.

In addition to the wake affect, energy analysis of the designed wind farm was implemented by considering the air density change with elevation. Energy analysis results of the WPP were obtained as given in Table I. According to Table I, annual energy production (AEP) and capacity factor of the designed WPP were calculated as 30.6 GWh/y and 34.9% respectively. Also, wake loss of the wind farm is 2.301% and it is a satisfactory value for the energy efficiency.

Table 1. Energy analysis results

AEP (GWh/y)	Full load hours	Capacity Factor (%)	Wake loss (%)
30.6	3055	34.9	2.301

4. Conclusions

Turkey's economy has been growing very fast, and this important growth causes a huge energy demand in the country. Turkey as a developing country has noticed the important of the energy to provide the continuity of the production and combat with the other countries. That is why Turkey has been increasing the incentives and the investments towards to the renewable energy systems. Wind energy as a renewable energy sources has a vital importance for Turkey's future since Turkey has a remarkable wind power potential thanks to its geographical position. If the country benefit efficiently from this remarkable source, it will be able to reach the energy management objectives and goals.

In this study, a WPP feasibility study for Gemlik region in Bursa was realised. According to feasibility study, investment of a WPP which has 30.6 GWh/y AEP and 34.9% capacity factor is feasible by 5 number of commercial Vestas V90 wind turbine. However, cost analysis of the designed WPP was not considered in this study. Also, only one analysis was performed to estimate the economical aspect of the WPP. If the cost analysis is done and the numbers of analyses are increased, more reliable results can be obtained.

Acknowledgement

The authors would like to thank Turkish State Meteorological Service for their support given to this work.

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