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Evaluation of the wind conditions for the acquisition of energy from renewable sources on the base of Sosnowiec city

KEY WORDS:
wind,
renewable energy,
Sosnowiec.

ABSTRACT

Inherent in the continuous development of civilization is a constant increase in demand for electricity. The result of this situation could be a threat to cover domestic demand for electricity generated from domestic sources. It is significant therefore, to increase the energy security of the country, as well as to generate a positive impact on the development and dynamics of social and economic processes which is carried by the development of renewable energy sources. A crucial argument for the need to implement new sustainable solutions is growing environmental degradation and pollution resulting from the acquisition and use of non-renewable energy resources.

Renewable energy resource for interest of this analysis is the wind. A crucial feature of the wind is its high volatility. Wind speed

is characterized by diurnal, seasonal and long-term variation.

The study area is Sosnowiec city. The analysis covers the data from the period 2002 – 2011 obtained using a meteorological station located in the Department of Earth Sciences, University of Silesia in Sosnowiec. Analyzed data are observations of wind speed measured at the height of 10m above the ground – average values of 10 minutes. The mean and maximum daily, monthly and annual values of wind speed have been calculated, and on their basis, a relevant analysis have been made. Average wind speed value for the analyzed area of the analyzed period (2002 – 2011) is 1,70m/s, while the maximum wind speed value is 3,78m/s. Sosnowiec is located in zone IV – unfavorable for the use of wind energy.

Introduction

We can obtain the energy in two ways: through the use of non-renewable energy sources such as coal, lignite, petroleum, natural gas or through the use of renewable energy sources, also known as non-conventional¹ sources of energy, with which the so-called clean energy or green energy is produced. Renewable energy sources cover a wide range of self-renewing energy sources: solar radiation, wind, water flow (energy in drop, tidal energy), the internal heat of the Earth and biomass and biogas. Their use can provide both electricity and thermal energy.

Due to the fact that the conventional resources are at risk of running out, an intensive work is carried out in the world on increase the use of renewable energy sources. A crucial argument for the need for the implementation of new sustainable solutions is growing environmental degradation and pollution resulting from the acquisition and use of non-renewable energy resources. It results in the destruction of the landscape, environmental imbalances, as well as pollution of its individual components: the atmosphere, soil and water by placing compounds with high harmfulness to them. The most detrimental effect is emission of combustion products in the form of harmful materials compounds such as: carbon dioxide (CO₂), methane (CH₄), sulfur fluoride (SF₆), nitrogen oxides (NO_x), sulfur dioxide (SO₂), carbon monoxide (CO), dust and heavy metals. Harmfulness of such gases is due to the fact that they belong to the so-called greenhouse gases, which trap part of the heat emitted by the Earth, causing the greenhouse effect, and thus climate changes and its consequences, such as heavy rains, floods or droughts and other adverse

effects such as ozone depletion, acid rains and smog. Progressive environmental pollution is the cause of the rising incidences of diseases and genetic disorders in population, as well as damage to flora and fauna. There is also an increased negative impact on buildings, which results in the destruction of cultural heritage.

Inherent in the continuous development of civilization is a constant increase in demand for electricity. Intensification of electricity consumption is due to the increase in the number of electricity consumers in all sectors of the economy. The result of this situation could be a threat to cover domestic demand for electricity generated from domestic sources. It is significant, therefore to increase the energy security of the country, as well as to generate a positive impact on the development and dynamics of social and economic processes which is carried by the development of renewable energy sources.

Renewable energy resource of interest for this analysis is the wind. Wind is the movement of air caused by the force of the horizontal pressure gradient, subject to the Coriolis force, centrifugal force and friction. Pressure gradient is a result of the density difference between unevenly heated air masses – the natural tendency of the masses to equalize the pressure causes the movement of air masses, that is the formation of the wind. Wind energy is one of the first human explored renewable energy sources. Production of electricity using wind is considered to be ecologically clean because, apart from the construction of a wind power plant, the production of this energy does not involve emissions resulting from the combustion of fossil fuels.

¹ The term 'non-conventional/unconventional' sources of energy, as well as 'alternative' sources of energy, acts as a common name for renewable energy sources to the energy sector, because it is not an innovative solution, but it is already fully implemented.

Study area

Sosnowiec is a city with county rights located in the south of Poland in eastern part of Silesia voivodeship at the confluence of Brynica, Black and Small Przemsza rivers belonging to the basin of the Vistula. Neighboring towns are from the southwest: Katowice, north west Czeladź, north Będzin and Dąbrowa Górnicza, south Jaworzno and Myslowice, south east Sławków.

Urban area is more than 91km² and is inhabited by over than 219 thousand residents. According to the physical – geographical Kondracki distribution, Sosnowiec lies within the Province of Silesian – Cracow Upland,

Silesian Upland macroregion, mesoregions: Katowice Upland, Jaworznickie Hills and in a small portion, Tarnogórski Hummock. In terms of topography town is located on the border of Katowice Upland several regions, they are: Bytomsko – Katowicki Plateau – occupying the northern, western and central parts of the Highland, Dąbrowska Upland and Mysłowicka Basin – located to the east. Over the years, Sosnowiec transformed from a mining center associated with the operations of the coal, steel industry and engineering to the shopping – service – processing center.

Materials and methods

The analysis covers the data from the period 2002 – 2011 obtained using a meteorological station located in the Department of Earth Sciences, University of Silesia in Sosnowiec. This station is characterized by its location on built-up area, which is a unique solution and also desirable from the point of view of the objective which is to assess the actual resource of wind energy in the area covered by dense urban development, which is a destination for the use of a potential energy.

Data are observations of wind speed measured at the height of 10m above the ground – the average values from 10 minutes.

The mean and maximum daily, monthly and annual values of wind speed have been calculated, and on their basis, a relevant analysis have been made.

The obtained data were characterized by a lack of continuity. Gaps in the data resulted from the anemometer failure during the period of wind speed data recording.

Results

Average wind speed value for the analyzed area of the analyzed period (2002 – 2011) is 1,70m/s, while the maximum wind speed value is 3,78m/s.

The chart below (Fig. 1) shows the average and maximum annual values of wind speed during analyzed period. Comparing the values recorded for each year of the period, it can be concluded that they are similar. The course of averages and maximum values is the same. The average annual wind speeds do not exceed value of 2m/s. The highest annual average wind speed value was observed in 2007 and amounted to 1,91m/s, while the lowest annual average wind speed value characterized year 2003 and the value was at 1,40m/s. Annual maximum wind speed values fluctuated around value 4m/s exceeding it in only two of the ten analyzed years – in 2002 (4,13m/s) and in 2007 (4,15m/s).

The chart below (Fig. 2) shows the average and maximum values of wind speed for each month in the analyzed period. Their reciprocal course appears in the same way. The average values of wind speed do not exceed 2m/s, apart from the month of March. As shown on the graph, in average, the maximum wind speed values were recorded for the month of March (2,03m/s) while the lowest for the month of September (1,44m/s). The maximum values of wind speed in the first half of the year and in the end oscillated around the value of 4m/s, and in the months of August – October were closer to the value of 3m/s.

The month, which marked the highest average wind speed value in the years 2002-2011 was February 2002 – 3,18m/s, while month, in which the lowest average wind speed value recorded was February 2003 – 0,33m/s.

Evaluation of the wind conditions for the acquisition of energy from renewable sources on the base of Sosnowiec city

Fig.1 The average and maximum annual values of wind speed in the 2001 – 2011

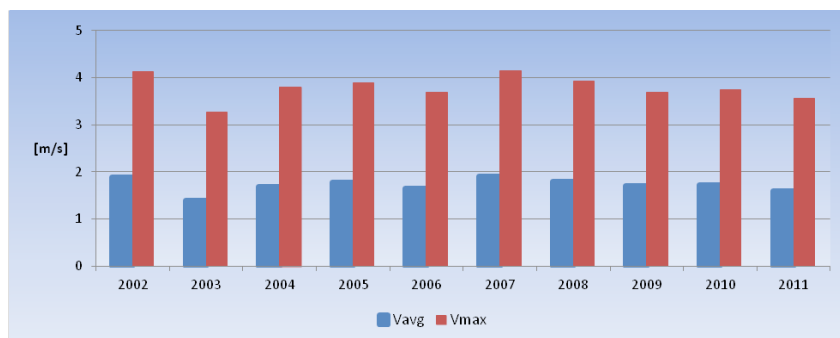
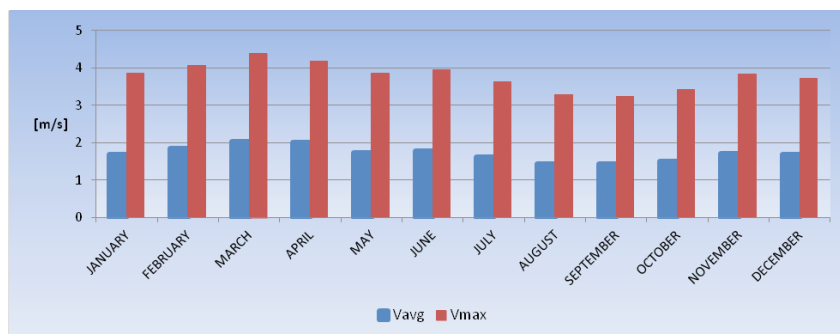


Fig.2 The average and maximum wind speed values for each month in the period 2001 – 2011



The chart below (Fig. 3) shows the course of the average and maximum daily values of wind speed for the year 2007. The year 2007 was chosen for the presentation of the annual wind speed value course from the years 2002 – 2011, due to the fact that it was characterized by the complete set of data. The diagram looks analogical to the analysis for the remaining years.

The course of the average and maximum daily wind speed values curves is very similar. On the basis of the following example it can be concluded that daily average wind speed values observed at the height of 10m above the ground on each day of the year is unlikely to exceed the 6m/s and essentially fluctuate around the value 2m/s. The highest wind speed values occur in the initial and final part of the year, i.e. during the winter months, while during the summer months they remain at a slightly lower level. The maximum daily values of wind speed exceeded the value of 12 m/s only twice during the year, and

generally revolve around the 4m/s.

In the analyzed period, the day on which the highest daily average wind speed average was recorded was 28 October 2002, and this value was at 6,26m/s. The following graph (Fig. 4) shows the daily course of wind speed values at the height of 10m above the ground on this day. Average values of wind speed ranged from 2,7 – 10,3m/s. The highest values of wind speed occurred in the early morning hours (3:00) till the afternoon (15:00), while the lowest in the late afternoon hours until late at night (2:00). The maximum values of wind speed varied in the range of 6,7 – 21,4m/s. The course of both curves is similar. The following table (Table 1) shows the percentage of the daily average values of wind speed in settled ranges in the analyzed period 2001 – 2011. The largest share has the wind speed values between 1-2m/s – 48,60%. Percentage of daily average wind speed values exceeding the value of 4m/s is 1,42%.

Fig.3 The course of average and maximum daily values of wind speed in 2007

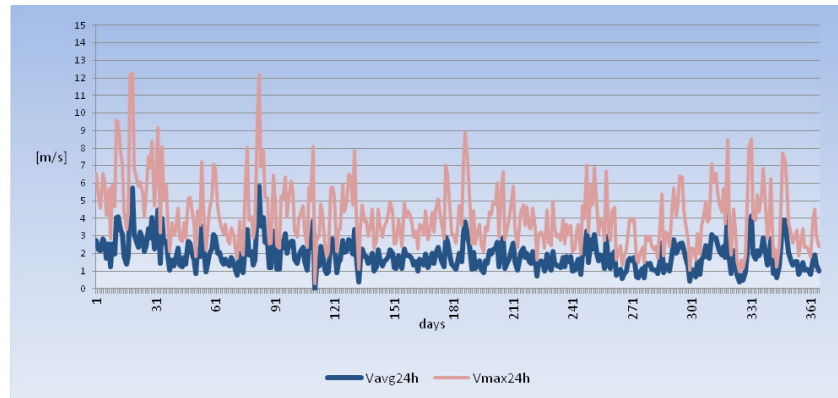


Fig.4 Daily course of wind speed

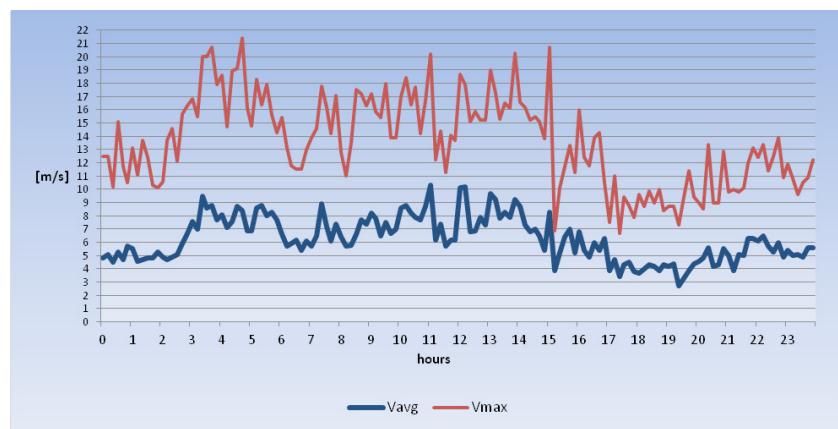


Table 1 The percentage of the daily average values of wind speed in settled ranges in the analyzed period 2001 – 2011

WIND SPEED [m/s]	PERCENTAGE
0 - 1	22,84%
1 - 2	48,60%
2 - 3	21,44%
3 - 4	5,70%
4 - 5	1,12%
5 - 6	0,27%
6 - 7	0,03%

Discussion

A crucial feature of the wind is its high volatility. Variability is manifested both in geographical space and in time. Wind speed is characterized by diurnal, seasonal and long-term variation. In the course of diurnal periodicity cyclical changes in wind speed are observed, which are related to the local thermal phenomena resulting from the heating of the Earth's surface during the day

and cooling at night. The resulting movement of air masses causes the increase of the wind speed during the day and decrease during the night. In the annual course the wind speed at the Polish area varies cyclically with the seasons. The highest values are observed in the autumn – winter season from December to February, and lower in summer. Variability of wind in space

Evaluation of the wind conditions for the acquisition of energy from renewable sources on the base of Sosnowiec city

depends on among others, the height above the ground. Average wind speed value increases with height to the surface of the Earth. The higher the wind becomes more stable in nature (less turbulence caused by the topography of the land).

Wind speed is continuously variable, meaning that, at any period of time it can take infinitely many values and hence, it is not possible to allocate the individual values of velocity to specific probability values. Therefore the probability density is determined which means the likelihood that the specific wind speed values belong to a given range.

Polish territory can be divided into six zones, for the potential use of wind power as an energy source. Three of them, representing two thirds of the country area, are in regions I–III and are areas characterized by favorable conditions for the development of wind power industry (I – highly favorable,

II – very favorable/favorable and III – favorable/somewhat favorable), favoring the construction of wind power plants – the area of Pomerania and Suwałki, where the annual average wind speed value is at least at 4m/s.² The following two areas are characterized by unfavorable weather conditions (IV – little favorable/unfavorable and V – unfavorable/highly unfavorable) that are not conducive to using them for the construction of wind turbines. One of the zones is not suitable at all for the constructions of wind turbines (VI – areas off) – high-altitude and mountain areas. Despite the presence of areas with very low potential of wind energy in Poland the wind energy in Poland is used much less than the potential of existing opportunities.

² For the purpose of power plants can be used wind speed in the range of about 4m/s – 30m/s. For the purposes of the small power plants wind area increases significantly as small wind turbines take off at lower wind speeds – even 2m/s.

Conclusions

Conducted analyzes of the weather data presenting wind conditions for the city of Sosnowiec confirm the fact of the volatility of the wind speed over time and the observed regularities do not differ from those generally accepted and shown in the analyzed literature. The examples presented in the article clearly show diurnal, seasonal and long-term variations of the wind speed in the analyzed period in the study area. In the course of daily mean values of wind speed, the highest values are observed from the early hours of the morning to the afternoon and the lowest from the late afternoon until late at night. In the annual course of the mean wind speed values highest values were observed at the beginning and end of the year in the autumn and winter months while the lowest in the summer months. The

mileage of annual average wind speed values of several years shows little variation. Average wind speed values are in the range between 1,40m/s and 1,91m/s and the maximum mean wind speed values are around the value of 4m/s.

The analysis of the probability density of the mean wind speed values shows that most of the time daily average wind speed values are in the range 1-2m/s and constitute 48,60% of the share.

The average wind speed, obtained as a result of the conducted analyzes in the study area during the analyzed period, at the level of 1,70m/s and the fact that only 1,42% of the reported daily average values of wind speed exceeds 4m/s, confirm that Sosnowiec is located in zone IV – unfavorable in the use for wind energy.

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