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ANALYSIS OF WIND VELOCITY DATA IN THE AREA OF THE CITY OF SARAJEVO IN PERIOD FROM 2001-2010

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Abstract

A major problem in the area of the city of Sarajevo is that during the winter period there is an increase in the concentration of harmful gases in the atmosphere (primarily CO_2), as a result of the intensive use of fossil fuels. Constant growth of energy sources, then the increase in the price of electricity and the intensification of the effects of greenhouse gases is the main reason for the analysis of wind potential in the area of the city of Sarajevo. In this paper analyzes and processes wind velocity data for the period from 2001 to 2010 for the area of Sarajevo, obtained from the Federal Hydrometeorological Institute of Bosnia and Hezegovina. After analyzing and processing wind velocity, a more precise assessment of wind potential in the Sarajevo area was given and guidelines for further research.

Keywords: renewable energy sources; wind velocity; wind potential; anemograph; wind rose

1. Introduction

Renewable energy sources with increasing energy consumption and in the conditions of increasing use of non-renewable energy sources (fossil fuels) are gaining in importance due to their reproducibility and significantly less harmful effects on the environment [7]. Increasing renewable energy, reducing the use of fossil fuels and thus affecting the environment. The connection of the use of renewable energy sources with environmental protection is primarily reflected in the fight against climate change and the greenhouse effect [3]. A major problem in the area of the city of Sarajevo is that during the winter period there is an increase in the concentration of harmful gases in the atmosphere (primarily CO_2), as a result of the intensive use of fossil fuels. Constant growth of energy sources, then the increase in the price of electricity and the intensification of the effects of greenhouse gases is the main reason for the analysis of wind potential in the area of the city of Sarajevo [1]. The paper analyzes and processes wind velocity data for the period from 2001 to 2010 for the area of the city of Sarajevo, obtained from the Federal Hydrometeorological Institute of Bosnia and Herzegovina. The input data used for this analysis are: average monthly wind velocity, maximum monthly wind velocity and annual average wind velocity. After analyzing and processing data for the wind, a more accurate assessment of the wind potential in the area of the city of Sarajevo was given and gave guidelines for further research [2].

In the EU, the total installed power of 2005 wind energy was 6%, while in 2016 it increased to 16,7%. Total installed power from renewable energy sources increased from 24% (2005) to 46% (2016) [5]. The EU energy sector is increasingly determined to distance itself from oil, coal and nuclear energy, while at the same time investing more and more in renewable energy sources (wind, solar panels ...). By the end of 2016, a total of 153,7 GW wind turbines were installed in the EU with an increase of 8% compared to 2015 [4]. Germany is the leading country of all the EU countries with the largest installed capacity, followed by Spain, the United Kingdom, France and Italy. Four EU countries (Sweden, Denmark, Poland and Portugal) have more than 5 GW installed capacity [6].

The spatial distribution of the mean annual wind speeds and winds shown in Figure 1 is derived from the meteorological data of the global time model, which is applied in everyday operational meteorological practice. In the horizontal spatial dimension, the fields are displayed with a resolution of 2,5 degrees, while in the vertical dimension data are given at altitudes 50 and 500 m above the ground. In the time dimension, the step is six hours. In the southern part of Bosnia and Herzegovina in a belt about 50 km along the border with Croatia, which, according to all observed characteristics, represent the largest wind potential in the territory of Bosnia and Herzegovina [8].

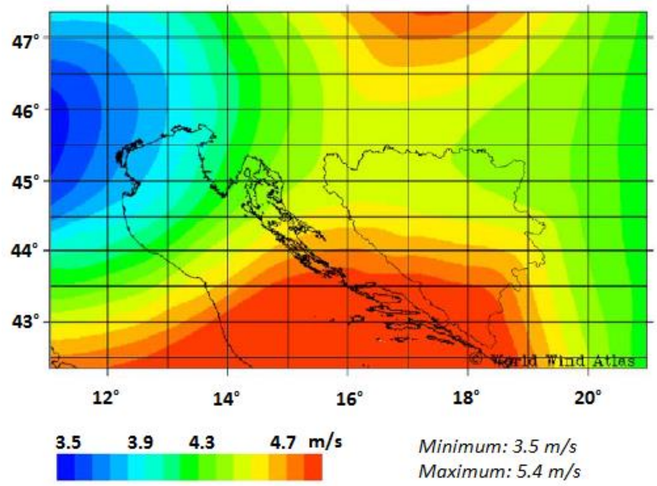

Fig. 1. Average annual wind velocity at a height of 50 m above ground for the period 1997-2006. The result of the application of the global time model. The resolution of the model is 2,5 degrees [8]

2. Measurements of wind velocities in the meteorological station Sarajevo

Within the meteorological station Sarajevo, there is a department for researching renewable energy sources. All data such as sunshine duration, wind velocity and wind direction, wind roses and wind velocities are available at any time on their web site. The meteorological annuals available from the Federal Hydrometeorological Institute of Bosnia and Herzegovina are available from 1925 to the present [2]. Data for wind velocity and wind direction within meteorological station Sarajevo are obtained from a mechanical anemograph. Anemographs are instruments for registering wind direction and wind velocity. They consist of a sensory and registration part. The sensing part in figure 2 consists of three combined parts: one for direction, the second for medium velocity, the third for the instantaneous velocity. These receivers are placed outside on a building or on a special pillar (height of 10 m) and thus exposed to the action of the wind. The impact of the wind is transmitted through specific guides to the registration section. The entire sensory part is placed on a thick iron tube - anemograph carrier. Through this line, the lines connecting sensors with the registration devices pass through [2].

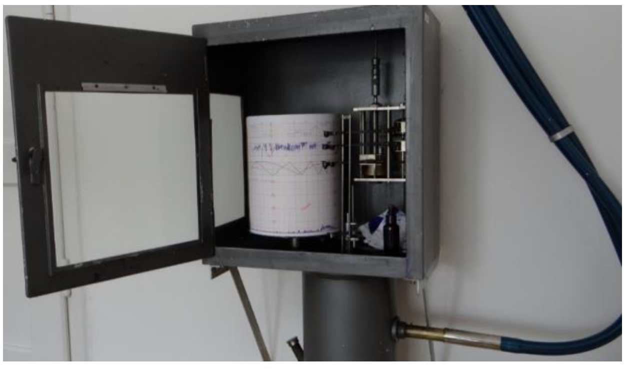

Fig. 2. The device for registering the direction and velocity of wind of mechanical Fuess anemograph [2]

3. Analysis of results

This paper analyzes and processes data obtained from the Federal Hydrometeorological Institute of Bosnia and Herzegovina related to the wind velocity in the area of the city of Sarajevo. Data obtained from the Federal Hydrometeorological Institute are the annual average wind velocity, average monthly wind velocity and maximum monthly wind velocity for the period from 2001 to 2010 [2]. The method used during the research is a linear regression method. The term linear regression refers to the method of modeling the dependence of the dependent stochastic variable on a set of independent variables in such a way that these dependences are linear. The simplest regression models use an independent meteorological variable. Basically, it is possible to construct regression models that use several meteorological variables. All regression coefficients of the forecasting model, depending on the type of regression method, are determined on the basis of statistical analysis of historical data on air movement.

It is important to note that the wind velocity must be above 3 m/s for continuous operation of wind turbines. By increasing the velocity, the amount of electricity increases to a maximum, which is achieved at a wind velocity of about 12 m/s. With a further increase in wind velocity, the amount of energy produced does not increase anymore. When the velocity rises above 25 to 30 m/s, the wind turbine is switched off because it can not withstand mechanical loads that cause such high wind velocity. From the described mode of operation of the wind turbine we can conclude that an ideal wind power production requires a wind velocity of about 12 m/s. Figure 3 shows the results of the maximum and average wind velocity for the month of January in the period from 2001-2010 in the area of the city of Sarajevo.

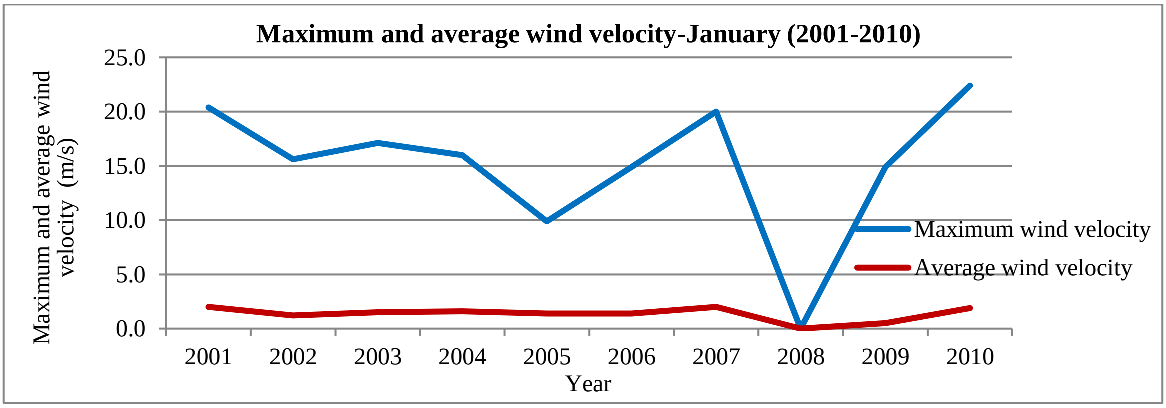

Fig. 3. Maximum and average wind velocity for the month of January in the period from 2001-2010 in the area of the city of Sarajevo [2]

The lowest average wind velocity was 0 m/s in January 2008, while the highest average wind velocity was 2 m/s in January 2001 and 2007. The lowest wind velocity was 0 m/s in January 2008, while the highest maximum wind velocity was 22,4 m/s in January 2010. In january 2008, no measurements were made in the location due to a fault at the measuring station Sarajevo. From figure 3, it can be concluded that the maximum wind velocity was range from 9,9 to 22,4 m/s on January for the period 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2009 and 2010, which sufficient condition for the operation of the wind turbine and production of the maximum amount of electricity. While the average wind velocity was range from 0 to 2 m/s in the month of January 2001-2010, which is not enough for continuous operation of the wind turbine. Figure 4 shows the results of the maximum and average wind velocity for the month of February in the period from 2001-2010 in the area of the city of Sarajevo.

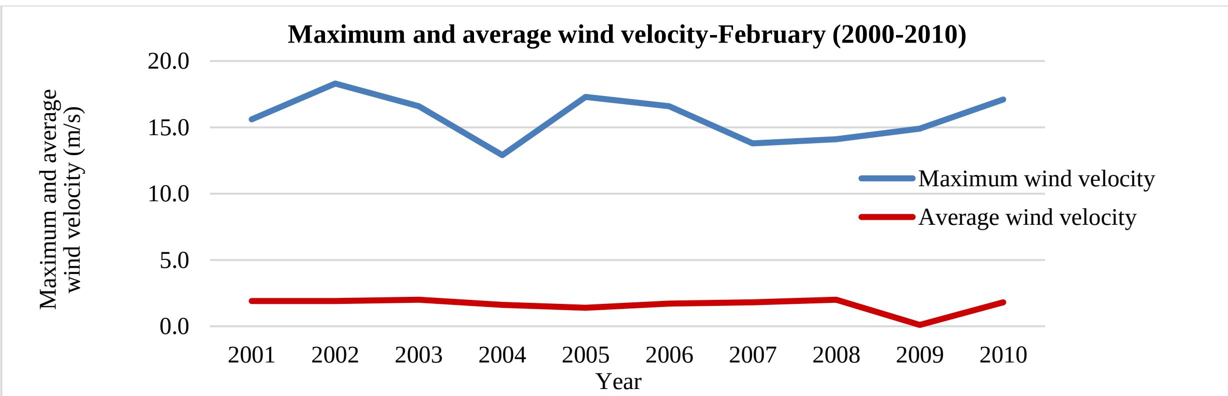

Fig. 4. Maximum and average wind velocity for the month of February in the period from 2001-2010 in the area of the city of Sarajevo [2]

The lowest average wind velocity was 0,1 m/s in February 2009, while the highest average wind velocity was 2 m/s in February 2003 and 2008. The lowest maximum wind velocity was 12,9 m/s in February 2004, while the highest maximum wind velocity was 18,3 m/s in February 2002. From Figure 4, it can be concluded that the maximum wind velocity was range from 12,9 to 18,9 m/s for the period from 2001 to 2010, which is a prerequisite for the operation of the wind turbine. However, the average wind velocity is low, so that the continuous operation of the wind turbine can not be achieved. Figure 5 shows the results of the maximum and average wind velocity for the month of March in the period from 2001-2010 in the area of the city of Sarajevo.

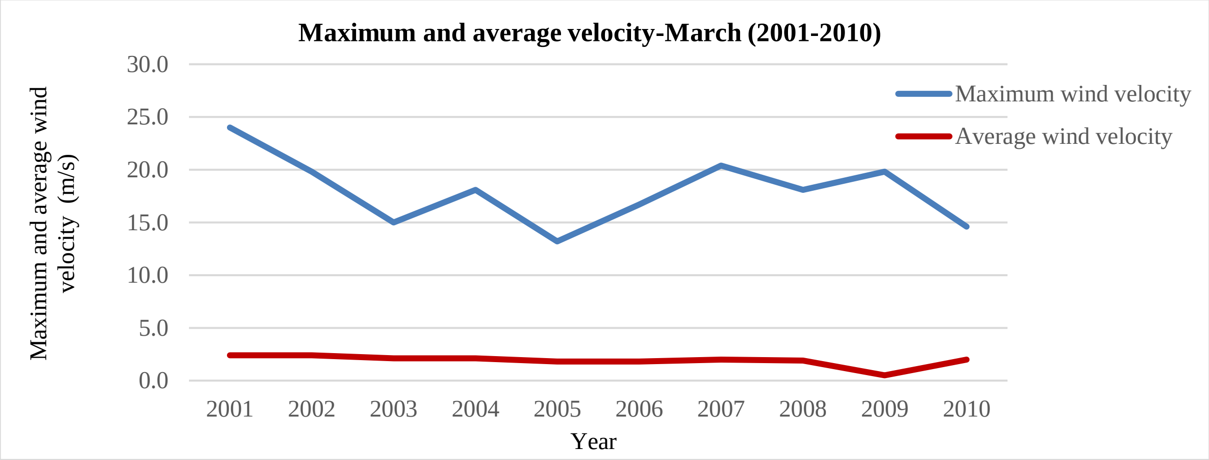

Fig. 5. Maximum and average wind velocity for the month of March in the period from 2001-2010. in the area of the city of Sarajevo [2]

The lowest average wind velocity was 0,5 m/ s in March 2009, while the highest average wind velocity was 2,4 m/s in March 2010. The lowest maximum wind velocity was 13,2 m/s in March 2005, while the highest maximum wind velocity was 24 m/s in March 2001. Based on the analysis of the results, it was concluded that there is not enough wind velocity for continuous operation, but according to the analysis of the maximum wind velocity there are high values ranging from 13,2 to 24 m/s, which are sufficient for the operation of the wind turbine. Figure 6 shows the results of maximum and average wind velocity for the month of April in the period from 2001-2010 in the area of the city of Sarajevo.

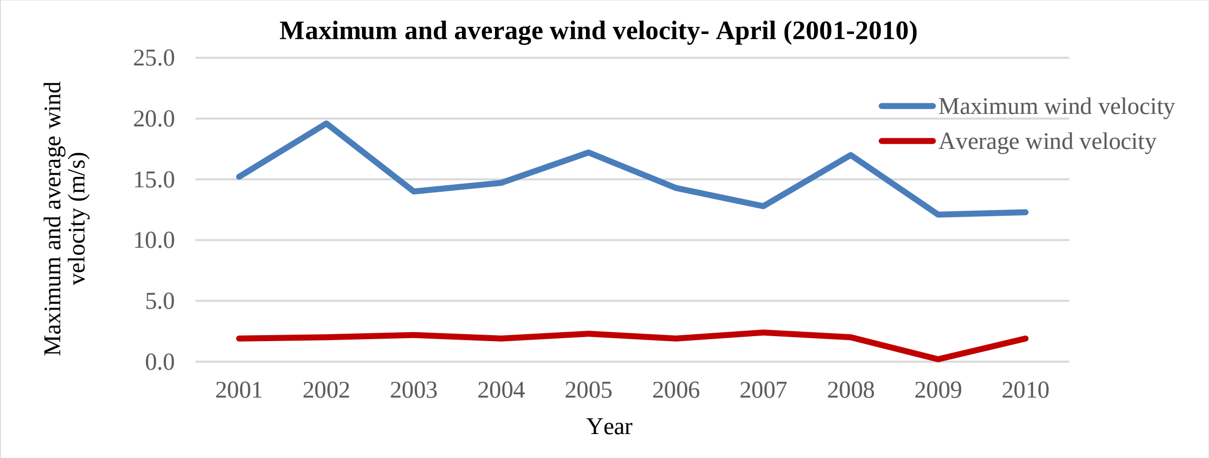

Fig. 6. Maximum and average wind velocity for the month of April in the period 2001-2010. in the area of the city of Sarajevo [2]

The lowest average wind velocity was 0,2 m/s in April 2009, while the highest average wind velocity was 2,4 m/s in April 2007. The lowest maximum wind velocity was 12,1 m/s in April 2009, while the highest maximum wind velocity was 19,6 m/s in April 2002. Based on the analysis of the results, it was concluded that there is not enough wind velocity for continuous operation, but according to the analysis of the maximum wind velocity there are high values ranging from 12,1 to 19,6 m/s, which is sufficient for the operation of the wind turbine. Figure 7 shows the results of the maximum and average wind velocity for the month of May in the period from 2001-2010 in the area of the city of Sarajevo.

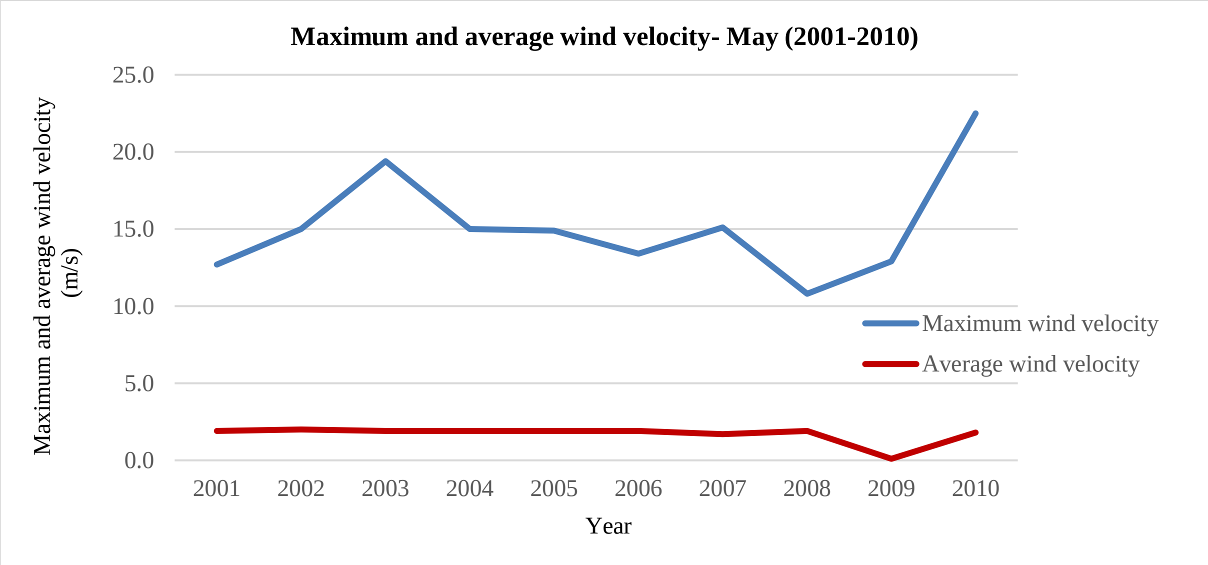

Fig. 7. Maximum and average wind velocity for the month of May in the period from 2001-2010 in the area of the city of Sarajevo [2]

The lowest average wind velocity was 0,1 m/s in May 2009, while the highest average wind velocity was 2 m/s in May 2002, from which it can be concluded that there is no enough wind velocity for continuous operation. The lowest maximum wind velocity was 10,8 m/s in May 2008, while the highest maximum wind velocity was 22,5 m/s in May 2010, which is sufficient for the operation of the wind turbine. Figure 8 shows the results of the maximum and average wind velocity for the month of June in the period from 2001-2010 in the area of the city of Sarajevo.

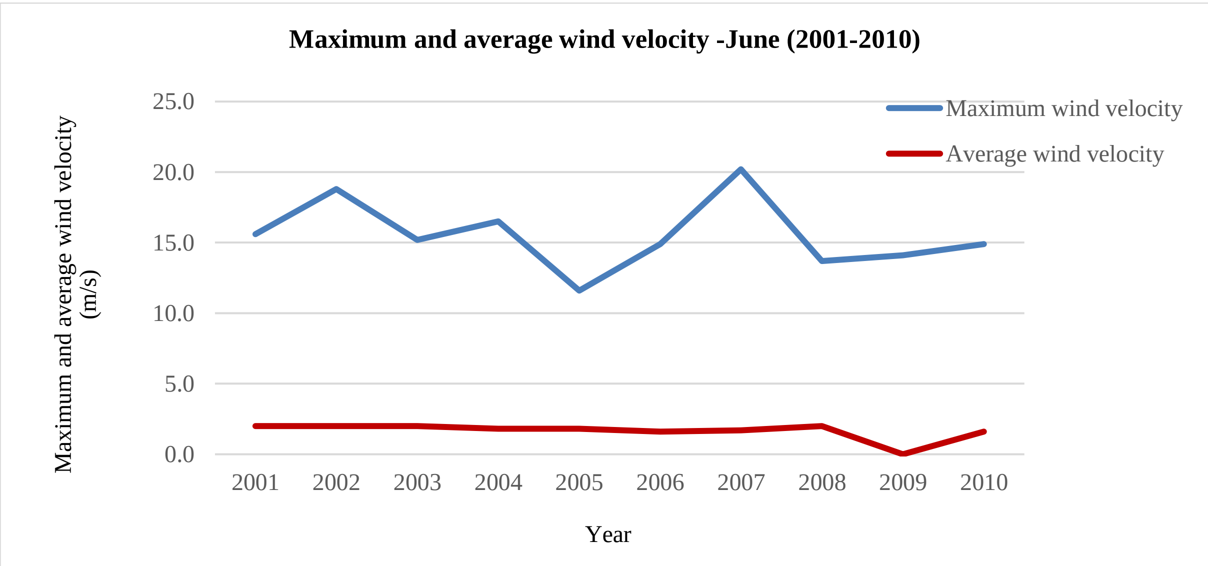

Fig. 8. Maximum and average wind velocity for the month of June in the period from 2001-2010 in the area of the city of Sarajevo [2]

The lowest maximum wind velocity was 11,6 m/s in June 2005, while the highest maximum wind velocity was 20,2 m/s in June 2007, which is sufficient for the operation of the wind turbine.

The lowest average wind velocity was 0 m/s in June 2009, while the highest average wind velocity was 2 m/s in June 2001, 2002, 2003 and 2008, from which it can be concluded that there is not enough wind velocity for continuous operation. In June 2009, no measurement were made in the location due to a fault at the measuring station Sarajevo.

Figure 9 shows the results of the maximum and average wind velocity for the month of July in the period from 2001-2010 in the area of the city of Sarajevo.

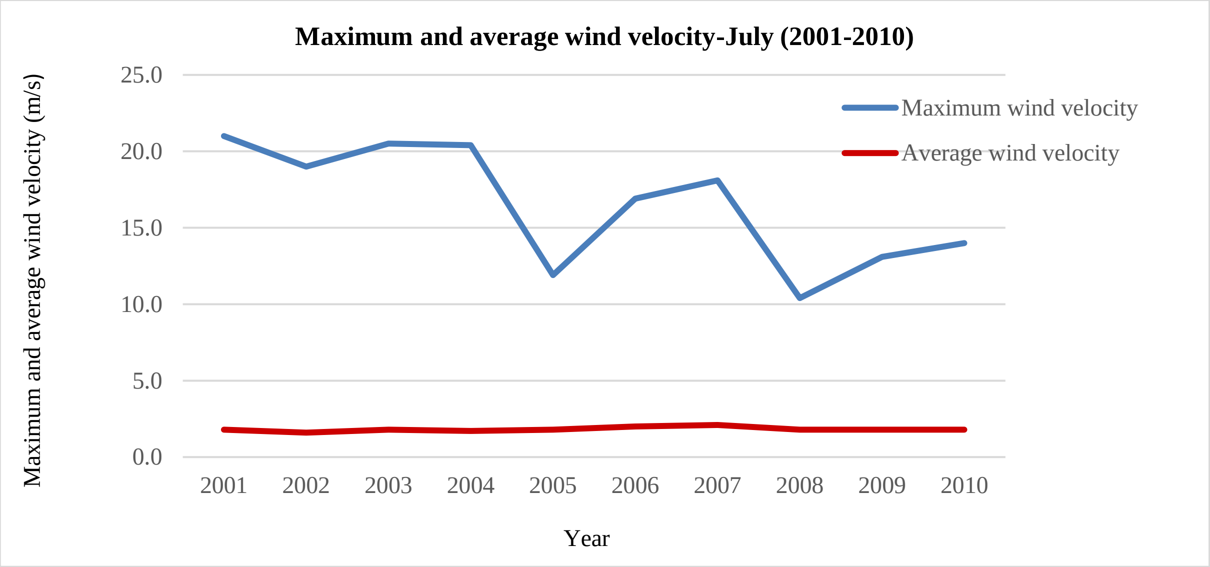

Fig. 9. Maximum and average wind velocity for the month of July in the period from 2001-2010 in the area of the city of Sarajevo [2]

The lowest maximum wind velocity was 10,4 m/s in July 2008, while the highest maximum wind velocity was 20,4 m/s in July 2004. When analyzing these obtained results, it can be concluded that the value of the maximum wind velocity ranges from 10,4 to 20,4 m/s, which is sufficient for the operation of the wind turbine. The lowest average wind velocity was 1,6 m/s in July 2002, while the highest average wind velocity for july was 2,1 m/s in July 2007, from which it can be concluded that there is not enough wind velocity for continuous operation. Figure 10 shows the results of the maximum and average wind velocity for the month of August in the period from 2001-2010 in the area of the city of Sarajevo.

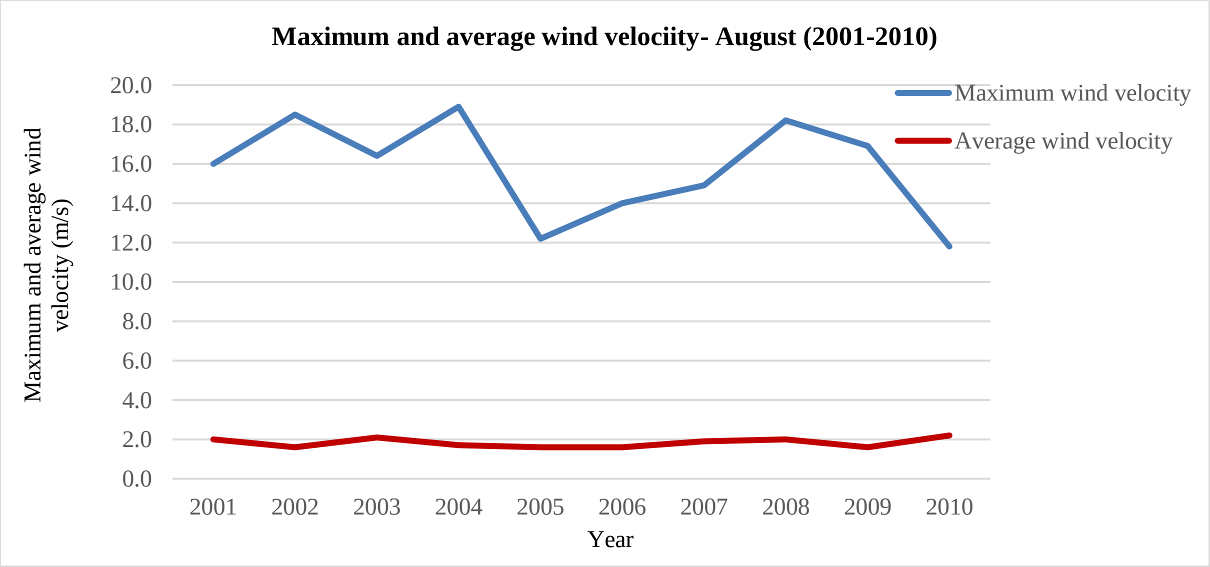

Fig. 10. Maximum and average wind velocity for the month of August in the period from 2001-2010 in the area of the city of Sarajevo [2]

The lowest maximum wind velocity was 11,8 m/s in August 2010, while the highest maximum wind velocity was 18,9 m/s in August 2004, which are sufficient for the operation of the wind turbine.

The lowest average wind velocity was 1,6 m/s in August 2002, 2005, 2006 and 2009, while the highest average wind velocity was 2,2 m/s in August 2010, from which can be concluded that there is not enough wind velocity for continuous operation.

Figure 11 shows the results of the maximum and average wind velocity for the month of September in the period from 2001-2010 in the area of the city of Sarajevo.

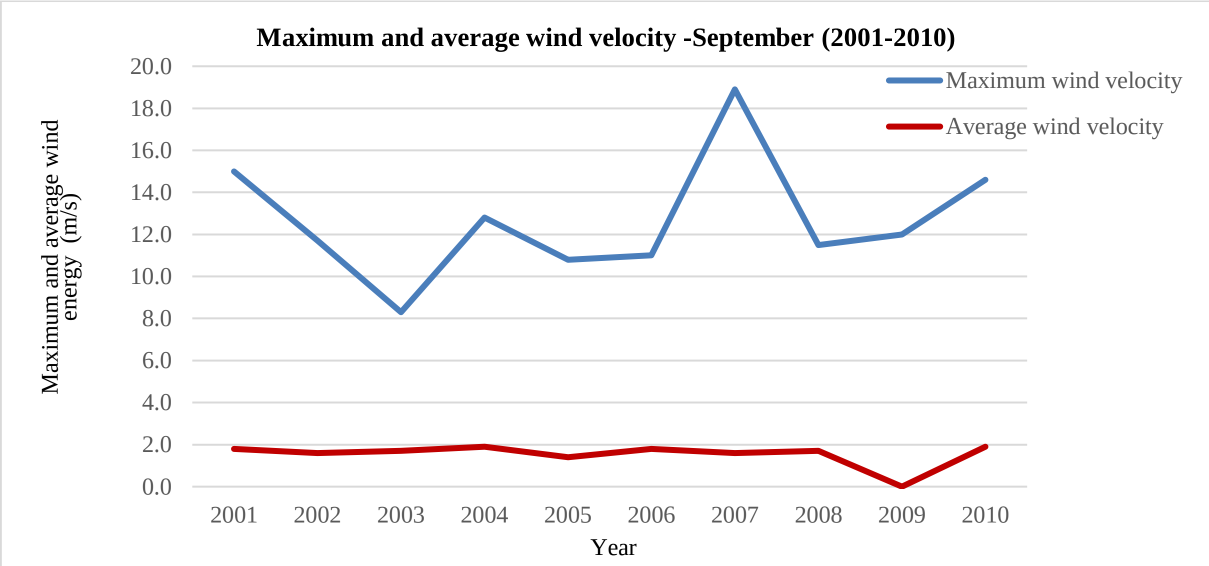

Fig. 11. Maximum and average wind velocity for the month of September in the period from 2001-2010 in the area of the city of Sarajevo [2]

The lowest maximum wind velocity was 8,3 m/s in September 2003, while the highest maximum wind velocity was 18,9 m/s in September 2007. The lowest average wind velocity was 0 m/s in September 2009, while the highest average wind velocity was 1,9 m/s in September 2004 and 2010. No measurement were made in september 2009 due to a malfunction at the measuring station Sarajevo. Figure 12 shows the results of the maximum and medium wind velocity for the month of October in the period from 2001-2010 in the area of the city of Sarajevo.

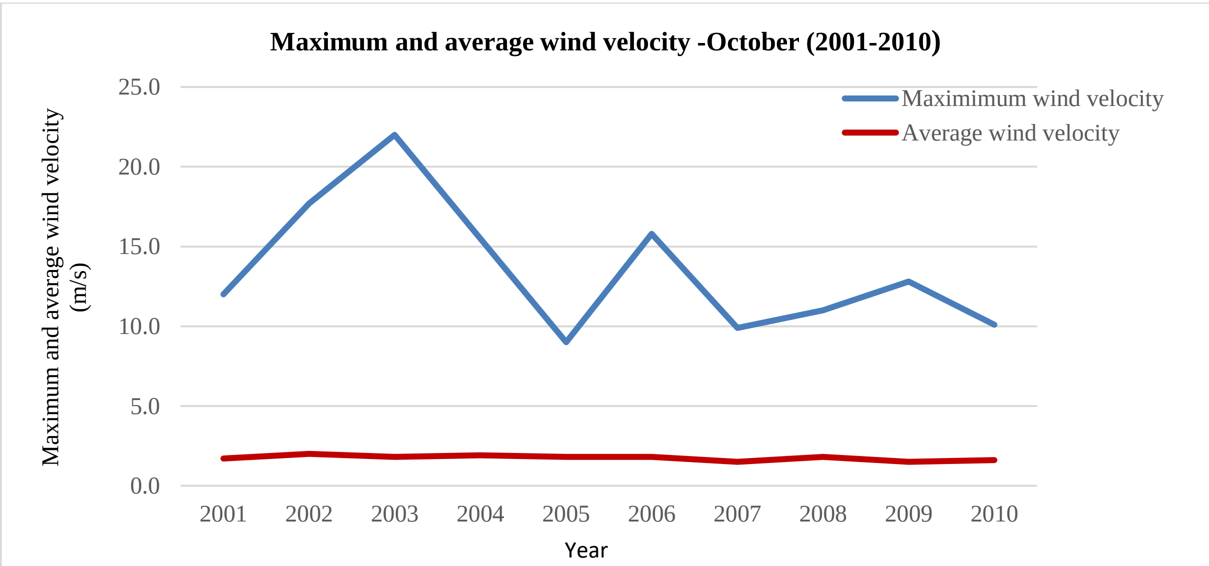

Fig. 12. Maximum and average wind velocity for the month of October in the period from 2001-2010 in the area of the city of Sarajevo [2]

The lowest average wind for october was 1,5 m/s in October 2007 and 2009, while the highest average wind velocity was 2,0 m/s in October 2002. The lowest maximum wind velocity was 9,0 m/s in October 2005, while the highest maximum wind velocity was 22 m/s in October 2003. Based on the analysis of the results, it was concluded that there is not enough wind velocity for continuous operation, but according to the analysis of the maximum wind velocity there are high values ranging from 11 to 22 m/s, which are sufficient for the operation of the wind turbine. Figure 13 shows the results of the maximum and average wind velocity for the month of November in the period from 2001-2010 in the area of the city of Sarajevo.

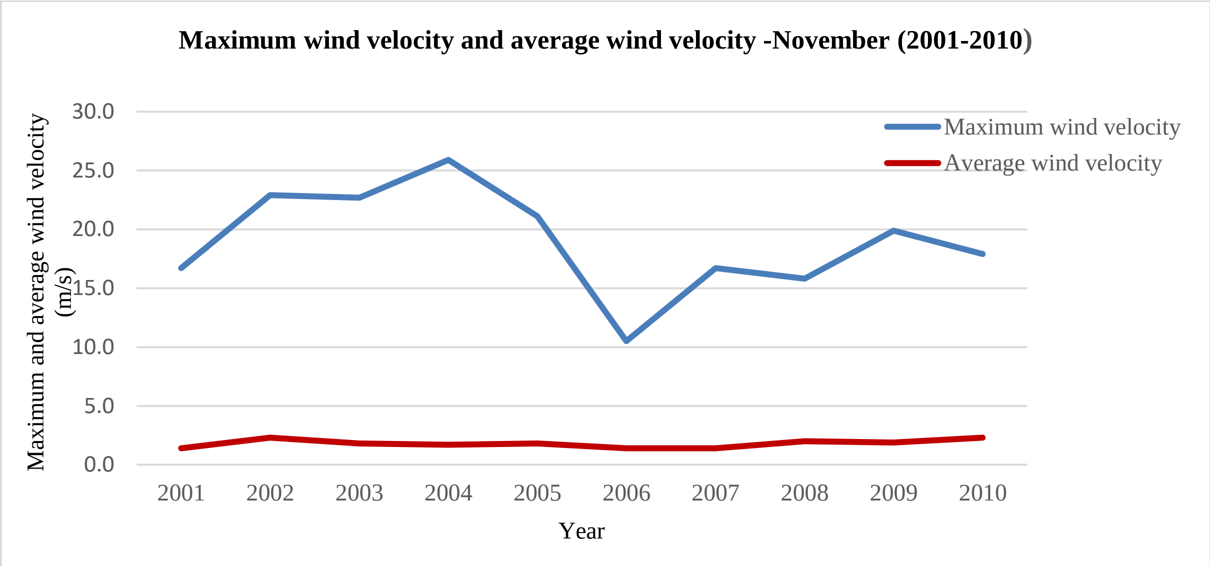

Fig. 13. Maximum and average wind velocity for the month of November in the period from 2001-2010 in the area of the city of Sarajevo [2]

The lowest maximum wind velocity was 10,5 m/s in November 2006, while the highest maximum wind velocity was 25,9 m/s in November 2004. The lowest average wind velocity was 1,4 m/s in November 2001, 2006 and 2007, while the highest average wind velocity was 2,3 m/s in November 2002 and 2010. Based on the analysis of the results, it has been concluded that there is not enough wind velocity for continuous operation, but according to the analysis of the maximum wind velocity there are high values ranging from 15,8 to 25,9 m/s, which are sufficient for the operation of the wind turbine. Figure 14 shows the results of the maximum and average wind velocity for the month of December in the period from 2001-2010. in the area of the city of Sarajevo.

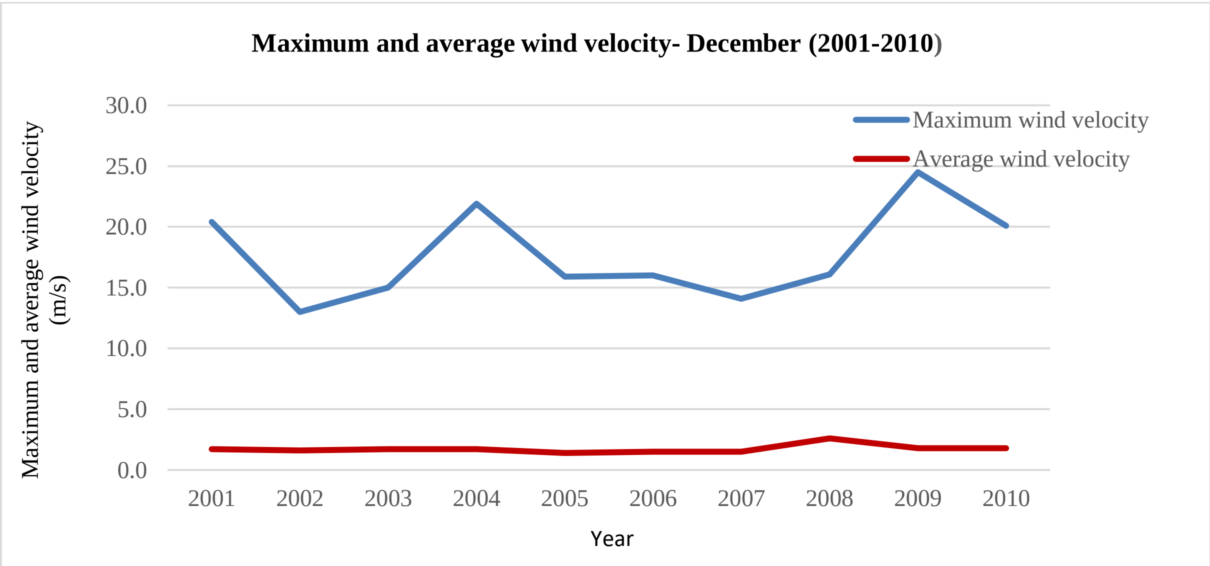

Fig. 14. Maximum and average wind velocity for the month of December in the period from 2001-2010 in the area of the city of Sarajevo [2]

The lowest maximum wind velocity was 13 m/s in December 2002, while the highest maximum wind velocity was 24,5 m/s in December 2009. The lowest average wind velocity was 1,4 m/s in December 2005, while the highest average wind velocity was 2,6 m/s in December 2008. Based on the analysis of the results, it was concluded that there is not enough wind velocity for continuous operation, but according to the analysis of the maximum wind velocity there are high values ranging from 13 to 24,5 m/s, which are sufficient for the operation of the wind turbine. Figure 15 shows the results of the annual average wind velocity in the period from 2001-2010. in the area of the city of Sarajevo.

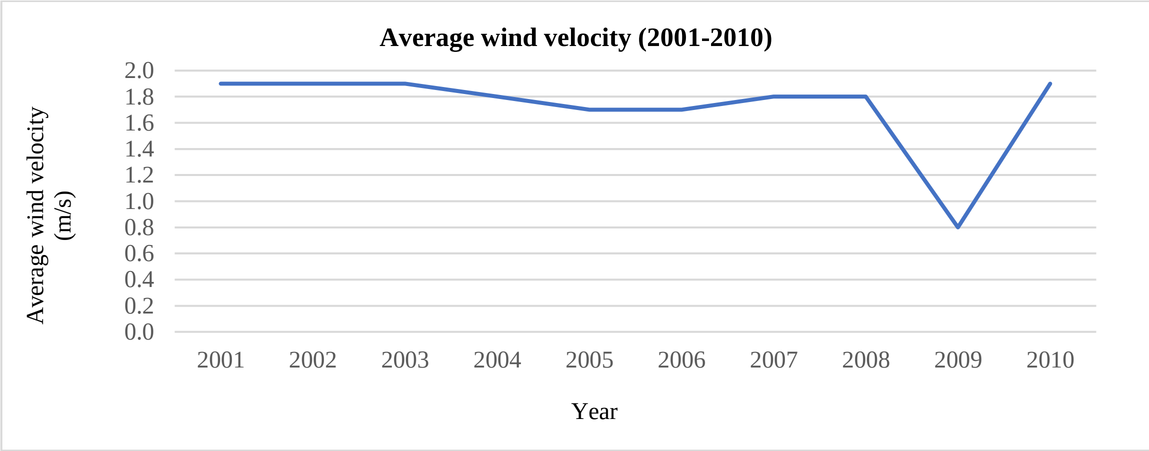

Fig. 15. Annual average wind vcelocity in the period from 2001-2010. in the area of the city of Sarajevo [2]

The lowest annual average wind velocity was 0,8 m/s in 2009, while the highest annual average wind velocity was 1,9 m/s in 2001, 2002, 2003 and 2010. From the analysis of these results the annual average wind velocity, from which it can be concluded that the wind turbine will not have continuous operation in the area of the city of Sarajevo, because for the continuous operation of the wind turbine the wind velocity must be above 3 m/s.

4. Wind rose

The wind rose for measuring station Sarajevo from 2001-2010 (figure 16) is a graphic representation of the average strength and wind velocity from certain directions. It is a polar diagram where the sides of the world are represented, which indicate the directions from which the wind blows. The winds in the Sarajevo basin are directly determined by the effects of regional atmospheric circulation and relief terrain. Under their influence, two basic types of wind are formed: with a daily period and occasional. The main local winds are the danik (valley wind) and noćnik (mountain wind). The prevailing wind blowing direction is E-W and is conditioned by the basin morphology of the terrain. From the periodic winds, the most important phenomenon, which in the area of the Sarajevo basin significantly increases the temperature and breaks the local cloudiness [2].

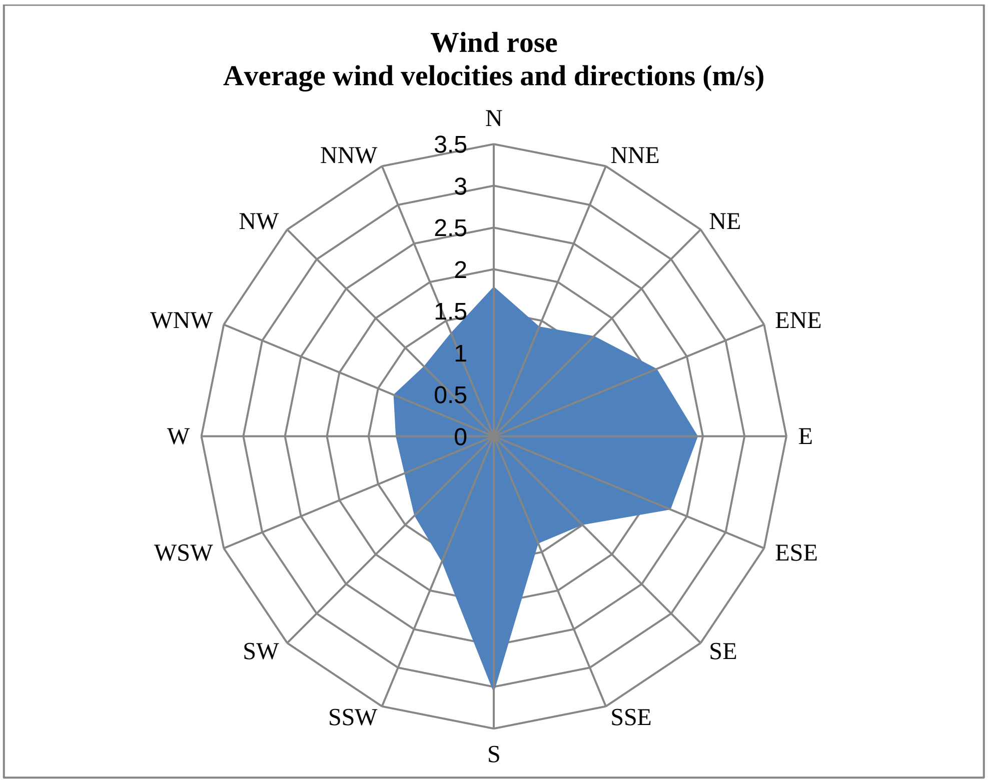

Fig. 16. Wind rose for measuring station Sarajevo from 2001-2010 in the area of the city of Sarajevo [2]

5. Conclusion

This paper analyzes and processes data obtained from the Federal Hydrometeorological Institute of Bosnia and Herzegovina related to the wind velocity in the area of the city of Sarajevo. Data obtained from the Federal Hydrometeorological Institute are the annual average wind velocity, average monthly wind velocity and maximum monthly wind velocity for the period from 2001 to 2010. The method used during the research is a linear regression method.

Regarding the analysis of data related to the maximum wind velocity for the period from 2001 to 2010, for the month of January from 9,9 to 22,4, for February, it ranges from 12,9 to 18,3 m/s, for the month of March of 13,2 m/s to 24 m/s, for the month of April from 12,1 to 19,6 m/s, for the month of May from 10,8 to 22,5 m/s, for the month June 11,6 to 20,2 m/s, for the month July 10,4 to 21 m/s, for the month of August from 11,8 to 18,9 m/s, for the month of September from 8,3 to 18,9 m/s, for the month of October from 9,9 to 22 m/s, for the month of November from 10,5 to 25,9 m/s and of the month of December from 13 to 24,5 m/s. From this analysis of the maximum wind velocity for the period from 2001 to 2010, it can be concluded that in the area of the city of Sarajevo there is a wind power potential, since the maximum wind velocity ranges from 8,3 to 25,9 m/s, and the maximum amount of electricity is achieves at a wind velocity of about 12 m/s.

Regarding the analysis of data related to the average wind velocity for the period from 2001 to 2010, for the month of January from 0 to 2 m/s, for February, it ranges from 0,1 to 2 m/s, for the month of March of 0,5 to 2,4 m/s, for the month of April from 0,2 to 2,4 m/s, for the month of May from 0,1 to 2 m/s, for the month June 0 to 2 m/s, for the month July 1,7 to 2,1 m/s, for the month of August from 1,6 to 2,1 m/s, for the month of September from 0 to 1,9 m/s, for the month of October from 1,5 to 2 m/s, for the month of November from 1,4 to 2,3 m/s and of the month of December from 1,4 to 2,6 m/s. From this data analysis of the average wind velocity, it can be determined that the wind turbine does not have continuous operation, since the values range from 0 to 2,6 m/s, and for the continuous operation of the wind turbine the average wind velocity should be above 3 m/s.

From this analysis and data processing, it can be concluded that for wind velocities there is a wind power *potential* in the city of Sarajevo, however, analyzing the average wind velocity that there is not enough wind velocity for the continuous operation of the wind turbine. In the continuation of this study, an analysis of hourly and daily wind velocities for the period 2001-2010 should be done in order to determine the exact real potential of the wind in the area of the city of Sarajevo. From this analysis it could be determined how many hours a wind turbine could work in one day.

6. Acknowledgements

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