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SELECTED ASPECTS OF WIND ENERGY USAGE IN THE BIAŁYSTOK REGION

Summary. This paper deals with problems relating to the impact of wind power plants on the landscape and their acceptance by society. The advantages and disadvantages of wind power energy produced by such energy plants are discussed. It is observed that most of the disadvantages of classic windmills can be avoided with the application of wind turbines with vertical spin axes. These turbines are designed for consumers who need power sources up to 1.5 kW. This paper also presents new and original construction solutions for these types of turbine masts, which are defined as types "F," "2F" and "F/2F". It is concluded that the presented solutions are easily integrated with the landscape, architecture and infrastructure of the region. The work also introduces research results concerning wind speed in the Białystok region (Nowosiółki, near Krypno). As the range of wind speed changes over time is relatively wide, this influences the value

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of momentary turbine power. The research results indicate that from October to March, wind speeds are significantly greater than during the remaining months.
Keywords: wind energy; wind turbines; environment

1. INTRODUCTION

The primary method of increasing electrical energy production involves the usage of renewable energy sources. The wind energy industry enjoys great popularity, especially in Eastern Europe. Apart from its main advantage, which is the lack of air pollution emissions (so-called clear energy), wind energy production is associated with a number of ecological and sociological issues. Sociological aspects of this kind of energy are related to the location of the plants near to areas inhabited by local communities. The significant size of the wind turbines also causes substantial architectural changes to the landscape. The concerns among people living near wind energy plants are often associated with the safety of such constructions. The noise produced during their operation is also a challenge. To date, observations of wind energy functioning have revealed a great daily power fluctuation. Therefore, it should not be used as a main source of electrical energy in the given region. Rather, it should be used as an additional element supporting the traditional energy industry. All these aspects explain why the wind energy industry has both numerous followers and opponents.

2. ADVANTAGES AND DISADVANTAGES OF THE WIND ENERGY INDUSTRY

2.1. Barriers of wind energy usage

At present, the dominant issues concerning wind energy relate to applied construction solutions. Obtaining high levels of nominal power, as well as wind turbine productivity, requires various procedures, which include increasing the external diameter of the propeller. Currently, a standard diameter measures 112 m. Constant increases in turbine size involve not only construction issues, but also new challenges connected with the logistics, transportation and installation of a device at its final destination. It is important to mention that these difficulties have an essential influence on wind energy plant usage; nevertheless, it is possible to overcome these issues. Current technical developments have improved the efficiency of constructing and installing these devices, which involving the use of specialized cranes mounted on semi-trailers. All of these aspects have led to an increase in construction expenses and the time needed to build a wind energy plant [1].

Safety aspects are also critical with respect to local communities that live near to the site of a wind energy plant. It is necessary to emphasize that current wind energy constructions are characterized by high safety indices. High construction standards are applied, starting with the design phase, while rigorous tests determine whether these standards are met. Meanwhile, research conducted by ecologists on the impact of power plants on the safe movement of birds has demonstrated that collisions happen sporadically, even when birds are moving in massive groups. As stated in [2], greater threats to the birds' safety are present in urban areas, especially in the vast agglomeration regions. The additional threats take the form of the overhead power lines.

2.2. The influence of the wind power energy on the environment

In spite of its many advantages, there are also numerous disadvantages associated with the wind energy industry, which negatively affect the natural environment. They include two types of influences. The first is sound pollution created by the aerodynamics of the rotor and propulsion mechanisms. The sources of the noise produced by wind turbines are very difficult to localize; therefore, their elimination is challenging. Furthermore, atmospheric turbulence, whirlwinds and wind patterns can also significantly influence noise production. In major wind electric plants, in which the diameter of the blade equals 112 m, the tangential velocity of the tip of their blades can reach the speed of sound. In smaller wind energy plants, the noise level is relatively low. The mechanical noise generated by turbines is being gradually decreased due to the application of new technologies to drive system designs. The maximal sound intensity level measured at the base of the wind turbine mast is around 104 dB. This level significantly decreases along with increasing distance; for this reason, wind energy plants are situated far away from areas of human habitat. For example, noise at a distance of 100 m is around 100 dB, while, at a distance of 500 m, it is only 45 dB; therefore, the noise is compatible with living conditions. The local community's stance regarding noise production depends on their attitude towards wind energy plants. The Technical University of Denmark has proven that the ability to notice noise is determined by an individual's view of the wind energy industry. It is necessary to state that overexposure to sound waves, along with constant intensity, negatively influences people's feelings and emotions [3, 4, 5].

The second elemental aspect regarding the wind energy industry's effect on the environment is the aesthetics of wind energy plants and how they are subjectively perceived by society. As stated by the European Commission, these judgements are determined by individuals' attitude towards wind turbines. For some, energy plants are viewed in negative terms as they affect the landscape, while others consider them to be regional tourist attractions, given their ecological dimension [6]. It is undeniable that clearly visible wind energy plants attract tourists' attention, which leads to the development of the region in question and, to some degree, tourism growth [3, 4, 5].

It has been noted that, even though some communities believe that turbines symbolize pure energy, they may strongly oppose the installation of individual wind turbines, especially vast wind energy farms. In the past, similar issues were noticed when cellular networks were being installed. While the installation of cellular network transmitters also led to strong objections, they were generally accepted by society, even though electromagnetic waves emitted by these towers had much higher health and safety risks than wind energy plants. Therefore, the present reaction to wind turbine installations, which change the landscape, can be said to be similar to the context of more stable and accepted technologies. Furthermore, it can be related to the controversial Eiffel Tower construction in Paris in 1889. During its period of construction, many objections were raised against the possible disturbance of the architectural aestheticism of Paris. There were even numerous protest committees set up at the time. Indeed, the Eiffel Tower was almost demolished in 1909, but was saved when radio transmitters were installed on it [2].

3. INTEGRATING WIND TURBINES WITH VERTICAL SPIN AXES INTO THE LANDSCAPE

3.1. New mast constructions of wind turbines with vertical spin axes

The increase in the popularity of wind energy industry has led to a series of attempts to improve wind turbines' construction. As a result of these works, small wind turbines with a vertical spin axis have been developed. In comparison to traditional wind energy plants, these small turbines offer various advantages, of which the most significant are their simple structure, a lack of an "into the wind" system and a more effective utilization of wind energy in urban territories. The essential quality of these wind turbines, in comparison to conventional windmills, is the possibility of installing them on the rooftops of single- and multi-family houses. Their capacity to work with relatively low wind speed is not without significance.

Meanwhile, designers have come up with various solutions to improve the aesthetic presence of wind turbines. According to the authors of the article, special attention should be given to the structure when the arm is designed as a monolithic pipe construction with a screw-on mast. This provides the turbine with additional universality and the possibility of facilitating installation on the roof truss (without the mast). This type of construction allows for easy transportation and mobility. In Fig. 1, three original construction solutions are presented for wind tribune masts, which have been designed for a rotor with a diameter of 1 m and a height of 2 m. For a single rotor, the proposed shape is referred to as "F" (Fig. 1a), which has a shifted mast to counterbalance the mass powers in the construction. The aim of the construction labelled as "2F" (Fig. 1b) is to increase the power produced by the turbine, as well as counterbalance the mass.

This article presents a new and original solution for masts with vertical spin axis turbine rotors, that is, of type "F/2F" (Fig. 1c), which represent the universal and compromised solution between types "F" and "2F". When comparing the aesthetics and harmony of construction of the frame shapes, it is visible that the "2F" shape frame is symmetrical. It also has an aesthetically symmetrical presence and a visual phenomenon of two rotors spinning in two different directions.

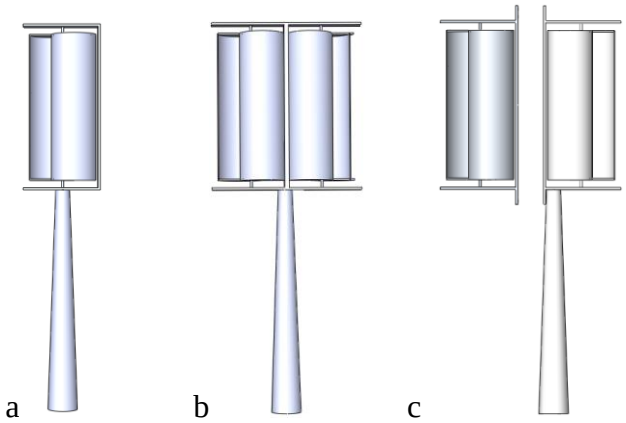

Fig. 1. Three mast designs of a wind turbine with vertical spin axes of the rotors
1) rotor; 2) main frame; 3) mast; 4) disassembled rotor assembly;
a) "F" type; b) "2F" type; c) "F/2F" type"

3.2. Natural conditions of the wind energy industry in the Białystok region

Wind turbines with vertical spin axes can be used wherever there is a need for low-level electrical energy production involving the use of unnecessarily high wind speed. Their construction can be transportable and installed in difficult-to-access areas, such as on yachts or boats, in order to illuminate a licence plate during the night. Not only are small wind turbines, especially those with vertical spinning axes, easy to incorporate into the environment, they can also be used for decorative purposes. In Fig. 2, the shape of the "F" type is presented when integrated into farm buildings.

Fig. 2. An example of the integration of a wind turbine with a vertical spin axis into farm buildings

In order to determine usage possibilities of wind turbines with vertical spin axes in the Białystok region, research was conducted on wind speed in Nowosiółki, near Krypno. The research was carried out at a height of 6 m, in an area that is 1.5 on the so-called roughness scale (cultivated areas with a few buildings), over the duration of one year. In the research, the weather station (weather gauge) WS-3600 was used, along with a personal computer. Brief speed values were registered every 10 min. Fig. 3 presents the measurement results of wind speed. It is visible from the chart that there is a wide range of speed changes during the day and throughout the month.

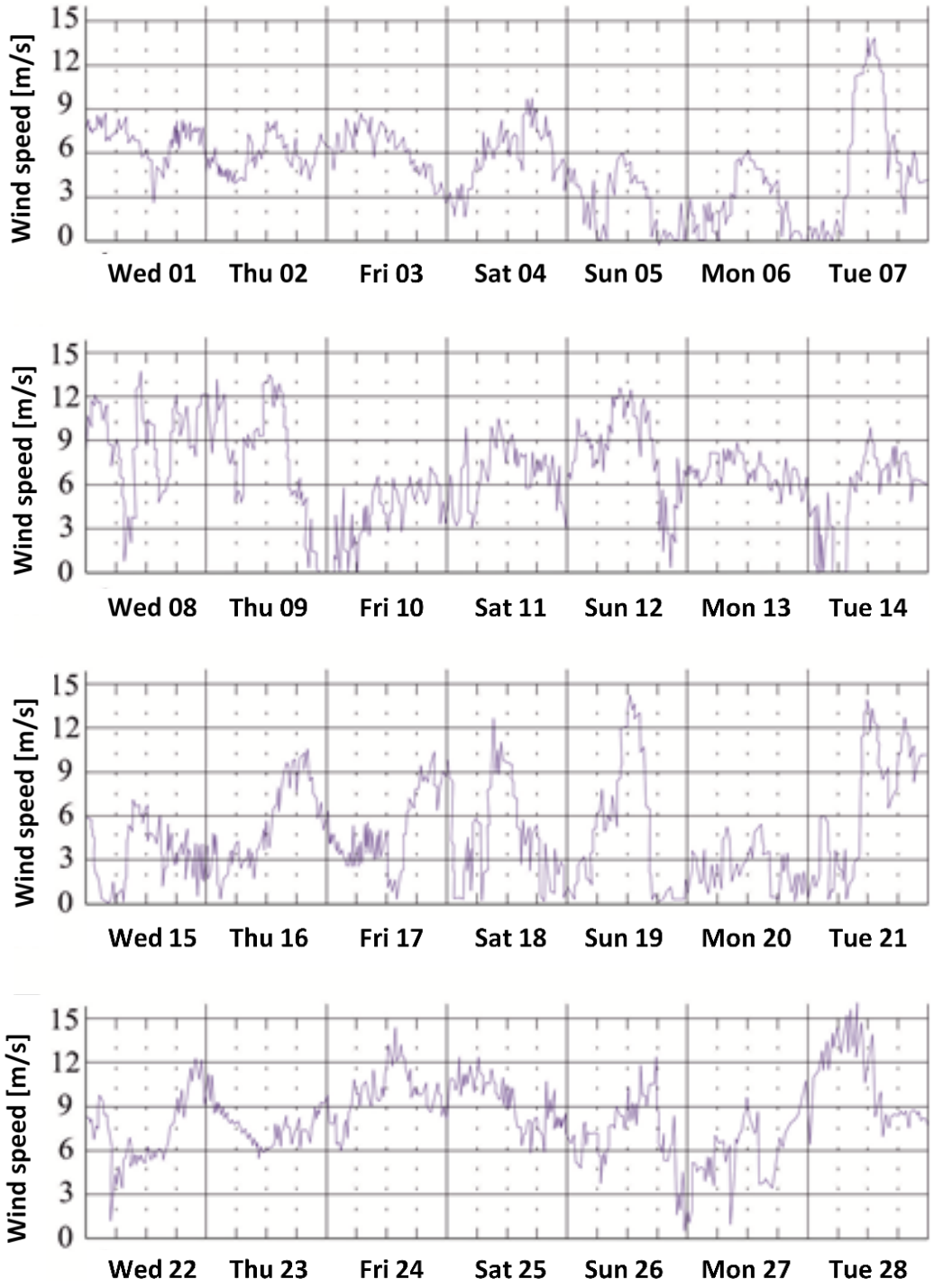

Fig. 3. Wind speed in the Białystok area

The results of the conducted research enabled the estimation of the annual average wind speed in the Białystok area, namely, 4.7 m/s. Average monthly wind speeds are presented in Fig. 4. The analysis of the data reveals significant speed differences between the individual months. The highest values are noted during the autumn and winter, while the lowest occurred during the summer. These greatly influenced the amount of power produced by the turbine.

According to Fig. 4, the most effective opportunities for using wind energy are in the period between October and March. It can be stated that, as previously mentioned, wind energy can be used as an additional energy source, supporting the conventional one.

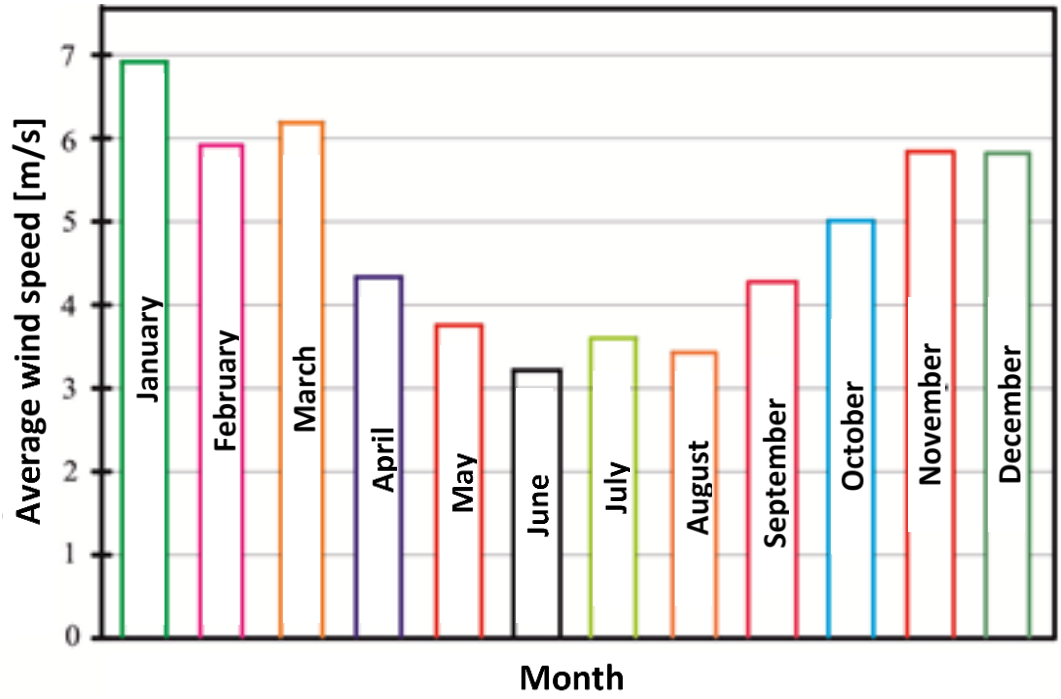

Fig. 4. The average monthly wind speed in the Białystok area

The results presented in Fig. 5 demonstrate that, in the analysed time period, there are significant 24-h wind speed changes. The increase in speed was often observed during the morning hours, while maximum speed occurred at midday, before decreasing in the afternoon. In order to thoroughly analyse this phenomenon, the average daily wind speed for the specific time of day was computed using the following formula:

$$\bar{v} = \frac{1}{\Delta t \cdot d} \sum_{\substack{i=1 \\ j=1}}^{\substack{i=p \\ j=d}} \int_{t=0}^{\Delta t} V dt \tag{1}$$

where:
Δt – unit of time
d – number of days analysed
p – number of the time lag received over 24 hours (p=24/Δt)
$\bar{v}$ – average wind speed
i – number of the time lag
j – number of the analysed day

The results of the analysis, which are presented in Fig. 5, indicates that, in the morning, the average wind speed increases, reaching 7 m/s by noon. The speed then decreases, such that, at night, it is below 4 m/s.

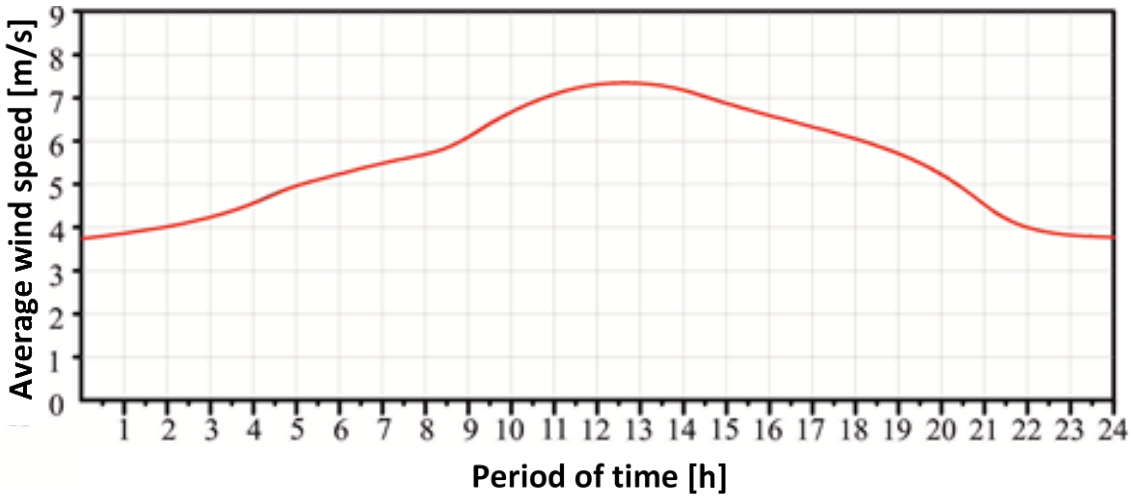

Fig. 5. Overview of the average 24-h wind speed changes registered in the Białystok region

4. CONCLUSION

This paper deals with problems relating to the impact of wind power plants on a landscape and their acceptance by society. The advantages and disadvantages of wind power engineering were discussed, along with the development opportunities of wind turbines with vertical spin axes. Such turbines are appropriate for small energy receivers of about 1.5 kW. The authors suggest new solutions for the construction of masts (i.e., of the "F", "2F" and "F/2F" types), which are suitable for fixing the runners of wind turbines. It was further emphasized that these constructions can integrate well with the landscape and architecture of the local territory. The paper also presented the results of wind speed research in the Białystok region (in Nowosiółki, near Krypno). It was found that speed changes are relatively large during the day, as well as across the year. This phenomenon strongly influences the possible transitory power of the turbine. From October to March, wind speeds are significantly greater than during the remaining months.

The conducted research allows us to make the following conclusions:

1. The frame constructions of wind turbines with vertical spin axes, which are proposed in this work, are characterized by their aestheticism; therefore, they can be effectively integrated into the environment.
2. The "F/2F" construction solution is characterized by its universality, as it combines the advantages of the "F" and "2F" frame types, which allows for the power generated by the turbine to be easily increased.
3. The results of the conducted research indicate that there are significant 24-h, as well as annual, wind speed fluctuations. It is, therefore, advisable to use wind energy in the Białystok area as an additional energy source, in support of the traditional energy industry.

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