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Original Research Article

Estimation of operational parameters of the counter-rotating wind turbine with artificial neural networks

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ABSTRACT

The article presents the possibility of using artificial neural networks to model the operating parameters of a counter-rotation mini wind turbine. The work is based on data from wind turbine research results conducted in an aerodynamic tunnel in the Institute of Agricultural Engineering at the University of Environmental and Life Sciences in Wrocław. The correlation between the depended variable (generated power P) and independent variables (average velocity of the air stream v, wedge angle of the first rotor blades, wedge angle of the second rotor blades, distance between rotors) was examined. The quality of the network was verified based on the mean-square error. The construction of the turbine allows to steplessly change of the blades wedge angle and the distance between rotors. Hence in the future the constructed network model can be used for programming the controller allowing to optimize the operating parameters of the wind turbine to maximize the generated power.

1. Introduction

1.1. Introduction and the goal of the research

Over the last fifteen years wind power technology, along with solar power technology, has been one of the fastest developing areas of the renewable energy sources. The authors' interests encompass, among others, horizontal axis wind turbines, whose power does not exceed 1 kW. They are used whenever the power of about several dozen or a few hundred watts is sufficient to power up the electrical equipment and simultaneously there is no electrical grid nearby. An example of such small power receivers can be agricultural installations located long distances away from households, hydrological and

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meteorological stations, roads and motorways control stations, signposts illumination as well as all sorts of monitoring (in forests, on yachts and sailboats), etc.

In the case of large wind turbines the increase in generated power is obtained mainly by increasing the rotor diameter. In the case of small wind turbines this simplest solution is not taken into account because increasing dimensions would mean that such structures would be no longer classified as mini structures and in consequence they could not be used in numerous solutions (street lights, yachts, etc.). This is why other ways of achieving the same goal are searched for. A good example can be locating a turbine in a pipe casing equipped with a diffusor or a confuser, improving rotor blades profiles or using a larger number of rotors.

To increase the power output by improving the shape of rotor blades, the blades are constructed in a way which allows to change not only their cross-section but also the profile along with the increase of the length. In large wind turbines rotor blades are several dozen metres long and usually 2–3 different profiles are registered at their longitudinal section. The type of profile selected for a particular blade length influences the shape of the blade and its aerodynamic properties, because each profile is adjusted to the air stream velocity which changes with the length of the rotating blade. In the case of mini wind turbines the length of blades is usually about several centimetres. Velocity change along the blade is very small, which results in difficulties in the selection of the appropriate profiles. More information regarding this issue can be found in [1,2].

The development of modern information tools, including artificial intelligence methods, causes that they are increasingly being used in various fields of science and technology. Also in the area of energy technology, these tools allow to solve new issues, and for those that are recognized as a fundamental. Progressing development of information technologies that allow for a significant increase of computing power greatly affects the new possibilities of numerical methods [3].

Neural networks are numerical modelling technique, that is capable to mapping of complex functions. Modern neural networks have a non-linear character. It allows user to freely and easily creating models that describe the features of the modelled objects. The advantage of neural networks is the fact that they allow us to look for numerical models for poorly known phenomena and processes. The user also does not need to declare a predetermined forms of searched model, and does not even have to be sure that even a mathematical relationship exists. A characteristic feature of neural networks is the possibility of learning by the so-called learning algorithms that enable adaptation of the network parameters to the specific the problem being solved. The complexity of the neural network and the efficiency of learning characterized by learning algorithms [4].

Note that the main goal of this research is neither presentation of the details of ANN arrangement nor description of the algorithm of the ANN training procedure. The details on both issues can be found in [4,5]. The main objective of the paper is demonstration that the existing ANN, described in detail in the cited works, can be applied to fitting the operational parameters of the counter-rotating wind turbines, and presentation of the conditions necessary for application of the ANN for this purpose.

The article presents a possibility of using artificial neural networks to correlate the operation parameters of a mini wind turbine with two rotors. Correlation refers to the parameter values of input and output (power turbine), i.e.:

- interaction between the velocity of the air stream and the power generated by the twin rotor wind turbine power;
- interaction between the wedge angle of the blades in the first (and the second) rotor and the power generated by the twin rotor wind turbine power;
- interaction between the distance of the rotors and the power generated by the twin rotor wind turbine power (more in the section Results and discussion).

To show differences in the essence of the operation of a single- and counter-rotation wind turbine, Fig. 1 presents schemes of both constructions. In the classical construction the propeller (rotor-propeller) drives the power generator rotor and the electric power is generated in a stator. In a counter-rotation construction, apart from a rotating generator rotor there is also a stator rotating in the opposite direction. It is driven by the other propeller. Because after going through the first propeller the air stream still has defined kinetic energy, it can propel also the other propeller of a wind turbine. Theoretical considerations [6] show that the maximum value of the coefficient of wind power usage for a counter-rotation wind turbine is 0.64, while the maximum value of wind stream usage calculated by Betz for a single-rotor turbine is 0.59 [7].

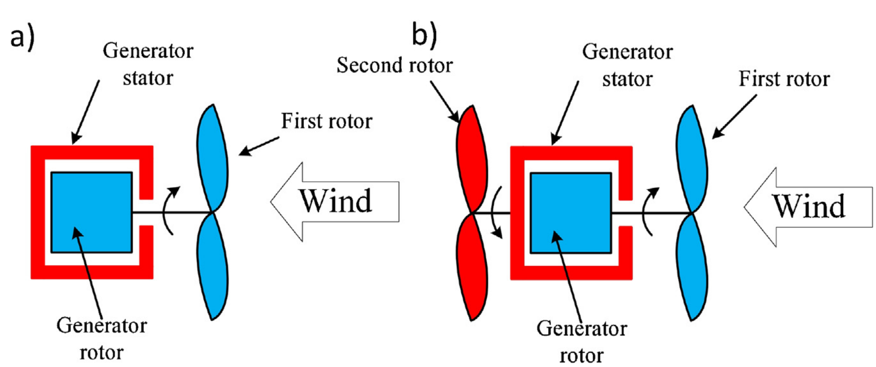

Fig. 1 – The scheme of wind turbine operation: a – single-rotor, b – twin rotor.