Shashidhar Dwivedi, 11:1
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

Wind Turbines Design and Wind Pressure Optimization Using AI

Shashidhar Dwivedi, Prof. G R Kesheorey
Vindhya Institute of Technology and Science
College in Madhya Pradesh

Abstract- Nowadays the Blade Element Momentum (BEM) theory is used to determine a given element's airfoil section performance coefficient. The motivation behind this work is to improve the current method of determining the airfoil section performance coefficients and to determine these coefficients where little or no experimental data exists such as angles of attack of stall, post stall and at very low Reynolds numbers (Re). Artificial Neural Network (ANN) method is used that can supply high quality airfoil sectional lift and drag coefficients over a wide range of angle of attacks and Reynolds numbers. Two wind turbine blades are analyzed using BEM theory and Artificial Neural Network method. It is found that the predicted performance from the BEM theory and the Artificial Neural Network is very sensitive to the angle of attack and Reynolds number of the elemental airfoil sections.

Keywords- Wind turbine, Artificial Neural Network, Stall, Angle of attack, airfoils.

I. INTRODUCTION

For the purposes of this chapter, "small" wind turbines will be defined as those with a power rating of 50 kW or less (approximately 15 m rotor diameter). Small electricity-generating wind turbines have been in existence since the early 1900s, having been particularly popular for providing power for dwellings not yet connected to national electricity grids. These turbines largely disappeared as rural electrification took place, and have primarily been used for remote power until recently. The oil crisis of the 1970s led to a resurgence in small wind technology, including the new concept of grid-connected small wind technology.

There are few small wind turbine manufacturers with a track record spanning more than a decade. This can be attributed to difficult market conditions and nascent technology. However, the technology is becoming more mature, energy prices are rising and public awareness of renewable energy is increasing. There are now many small wind turbine companies around the world who are addressing the growing market for both grid-connected and remote power applications.

The design features of small wind turbines, while similar to large wind turbines, often differ in significant ways. A study on the environmental impacts of wind energy projects, Environmental Impacts of Wind Energy Projects (2007, National research council (US)), highlights some important positive factors that support the development of wind energy farms.

Wind turbines are a viable medium of energy production in that they can produce our energy requirements in place of other methods and do not have the same harmful effects on the environment. Wind turbines do not pollute our air or water with polluted or toxic bi-products of energy production. Directly, their operation only affects the wind speed directly behind the rotor blades.

Other organizations have however drawn attention to some adverse environmental effects. These include the visual effect they have on humans, the interference on the ecosystem; birds and bats – rotor blades, and the increase in transport infrastructure and power lines to the wind farm site.

II. RENEWABLE ELECTRICITY AND THE GRID

The Challenge of Variability (Godfrey, 2007) states that, "It is shown that modest amounts of input from sources such as wind pose no operational difficulties because they do not add significantly to the uncertainties in the prediction of the supply-demand balance." It also predicts that the integration of wind energy into the grid on a global scale would be around £2 per MWh with 10% wind energy, rising to £3 for 20% wind energy. Weighing up the benefits of wind energy against the incurred cost, it is evident that wind energy would be not only a sustainable alternative but also economically viable. Australia is one of the world's highest per-capita consumers of fossil fuels.

This primarily can be attributed to the vast distances between our major centres and community hubs. Along with this Australia has been identified as the developed country most vulnerable to climate change and its adverse effects on our environment and ecosystem. Energy Revolution- A sustainable Australia energy outlook, an article published by Greenpeace International draws attention to the current crossroads faced by humanity in terms of our changing climate. Since the industrial revolution our planet has warmed by 0.74° C primarily due to the burning of carbon intensive fossil fuels.

The challenge faced today is the avoidance of "runaway" climatic change. According to climate experts, if a global increase of 2° is reached it would trigger the release of even more emissions inevitably taking global warming out of our control.

1. Wind Power Energy:

Wind power energy is getting more shares in the total energy production every year, with wind turbines growing bigger and bigger at the rhythm of technology does. While we cannot expect nowadays a totally renewal energy supply in Europe, (some estimations say that it is possible for 2030) there are places where energy grid has not even arrived and has not any plans for short or midterm time. As we charge our mobile phone in any socket, there are people that has to illuminate their homes with kerosene lamps, students that cannot study when the daylight extinct, medicines that cannot be stored in a freezer.

2. Rotor Speed: Constant Or Variable:

A constant rotor speed maintains the same rotational speed while the windmill is generating energy; they don't need power electronics to adapt to grid frequency which makes them cheaper; one of their drawbacks is that their optimum efficiency is only achieved at the design airspeed. A stall-regulated wind turbine falls into this category as it maintains constant rpm once the rated rotational speed is achieved. A variable speed rotor tries to achieve the optimum rotational speed for each wind speed, maintaining constant the optimum tip speed ratio will ensure optimum efficiency at different airspeeds. From a structural point of view, letting the rotor to change its speed reduces the load supported by the wind turbine in presence of gusts or sudden starts.

III. PROPOSED METHODOLOGY

Artificial neural networks (**ANNs**), usually simply called **neural networks** (**NNs**), are computing systems inspired by the biological neural networks that constitute animal brains. Neural computing is an information processing paradigm, inspired by biological system, composed of a large number of highly interconnected processing elements(neurons) working in unison to solve specific problems. Artificial neural networks (ANNs), like people, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process. Learning in biological systems involves adjustments to the synaptic connections that exist between the neurons. This is true of ANNs as well.

An ANN is based on a collection of connected units or nodes called artificial neurons, which loosely model the neurons in a biological brain. Each connection, like the synapses in a biological brain, can transmit a signal to other neurons. An artificial neuron receives a signal then processes it and can signal neurons connected to it. The "signal" at a connection is a real number, and the output of each neuron is computed by some non-linear function of the sum of its inputs. The connections are called *edges*. Neurons and edges typically have a *weight* that adjusts as learning proceeds. The weight increases or decreases the strength of the signal at a connection. Neurons may have a threshold such that a signal is sent only if the aggregate signal crosses that threshold. Typically, neurons are aggregated into layers. Different layers may perform different transformations on their inputs. Signals travel from the first layer (the input layer), to the last layer (the output layer), possibly after traversing the layers multiple times.

The scope of this teaching package is to make a brief induction to Artificial Neural Networks (ANNs) for people who have no previous knowledge of them. We first make a brief introduction to models of networks, for then describing in general terms ANNs. As an application, we explain the back propagation algorithm, since it is widely used and many other algorithms are derived from it.

The user should know algebra and the handling of functions and vectors. Differential calculus is recommendable, but not necessary. The contents of this package should be understood by people with high school education. It would be useful for people who are just curious about what are ANNs, or for people who want to become familiar with them, so when they study them more fully, they will already have clear notions of ANNs.

Also, people who only want to apply the back propagation algorithm without a detailed and formal explanation of it will find this material useful. This work should not be seen as “Nets for dummies”, but of course it is not a treatise. Much of the formality is skipped for the sake of simplicity. Detailed explanations and demonstrations can be found in the referred readings. The included exercises complement the understanding of the theory. The on-line resources are highly recommended for extending this brief induction.

IV. ARTIFICIAL NEURON MODEL

An artificial neuron is a mathematical function conceived as a simple model of a real (biological) neuron.

- The McCulloch-Pitts Neuron This is a simplified model of real neurons, known as a Threshold Logic Unit.
- A set of input connections brings in activations from other neuron.
- A processing unit sums the inputs, and then applies a non-linear activation function (i.e. squashing/transfer/threshold function).
- An output line transmits the result to other neurons.

V. RESULT AND ANALYSIS

Mechanical design software is called CATIA. It is a parametric, feature-based design tool for solid modeling that makes use of Windows' simple-to-use graphical user interface. Fully associative 3D solid models can be produced with or without constraints, and automatic or user-defined relations can be used to record design intent.

Review the User Interface

- You can create solid 3D geometry with the Part Design workbench. You can access the Sketcher workbench from the Part Design workbench and produce 2D profiles that will eventually become 3D models.
- You can combine components on the Assembly Design workbench to build the finished product. Using techniques for developing assemblies that can help with concurrent engineering, such as Skeleton models and publishing elements, you can create parts in the context of an assembly.
- You can create surface and wireframe geometry with the Generative Shape Design workbench. You can build more intricate solid models and have more control over a model's shape by using surface and wireframe geometry.

The goal of design intent is to express a part's visual and functional characteristics by building a solid model of it. The way a solid model is constructed can have an impact on a variety of factors, including as its capacity to adapt to changes, its stability during the change process, and the amount of resources needed to compute a new result. To create an effective solid model of the part, it is crucial to consider the design objective. A parent-child relationship describes the interdependence of two features. Relationships between parents and children are crucial to upholding the part's design objective.

There are very few finished designs that only have one part. Finished designs typically have hundreds of thousands to millions of discrete pieces that distinguish them. Here, CATIA V5 Assembly Design is put to use. It enables the combination of discrete elements and smaller assemblies of parts to create larger, more comprehensive products. You acquired part creation skills in CATIA V5 Part Design and Sketcher. This class's main goal is to employ those components to construct a complicated assembly that can be used in future stress assessments,

International Journal of Science, Engineering and Technology

An Open Access Journal

kinematics, fitting simulations, and other disciplines. When working with assemblies, it's crucial to understand some of the language used by CATIA. In general, assembly design documents fall into one of three categories:

- The overall assembly,
- Sub-assemblies, and
- Individual models.

In CATIA, assemblies are referred to as "products," whereas separate models are referred to as "parts." Products can be made using parts. These items can then be used to create other items. The idea of the general structure is depicted in the diagram below.

1. Fundmentals Components:

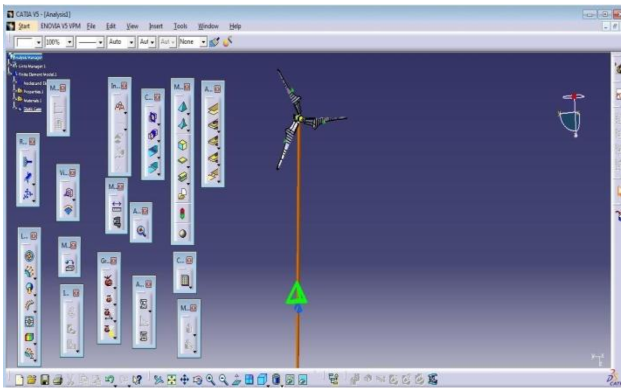

Fig 1. Wind Turbine design.

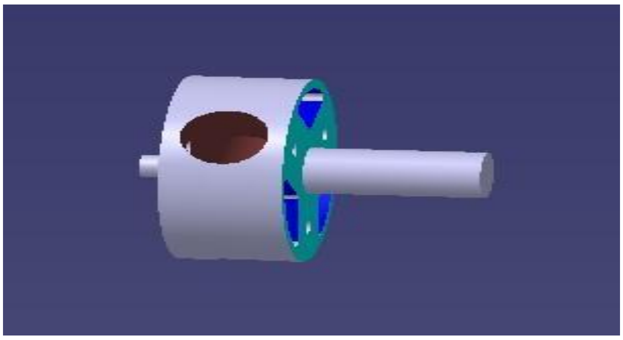

Fig 2. Connecting parts.

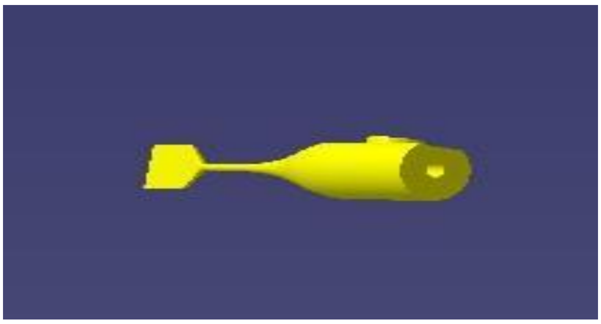

Fig 3. Turbine jumper.

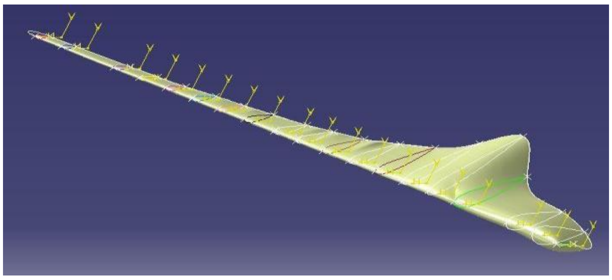

Fig 4. Blades.

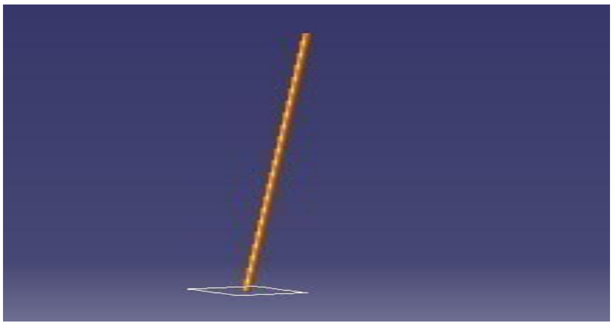

Fig 5. Base.

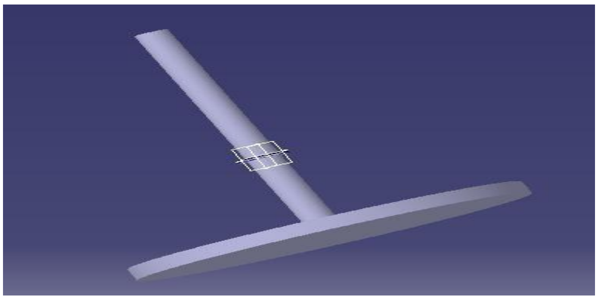

Fig 6. Base Support.

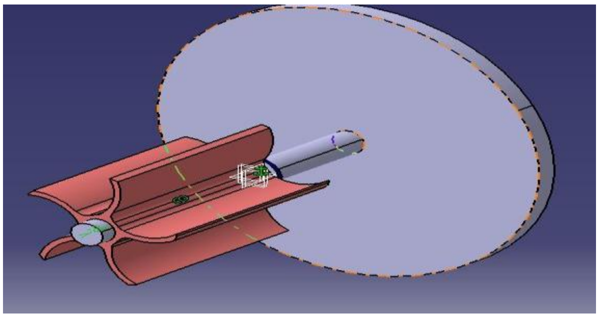

Fig 7. Rotator.

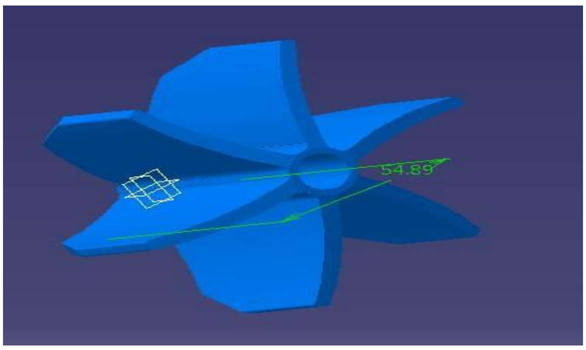

Fig 8. Blades Support.

2. Mesh Analysis:

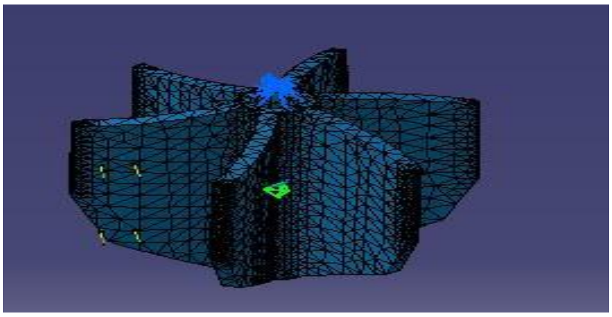

Fig 9. Mesh of Blades Support.

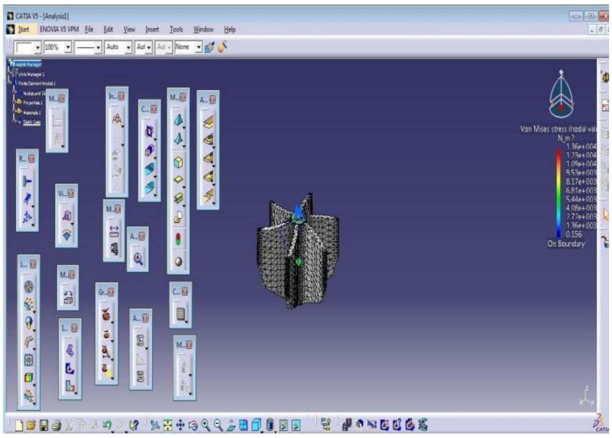

Fig 10. Stress of Blades Support.

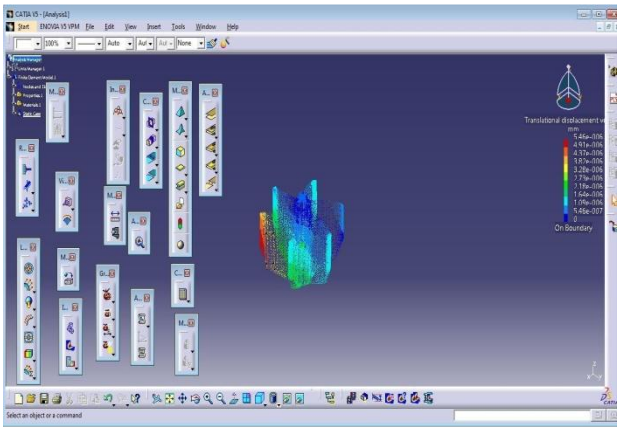

Fig 11. Deformation of Blades Support.

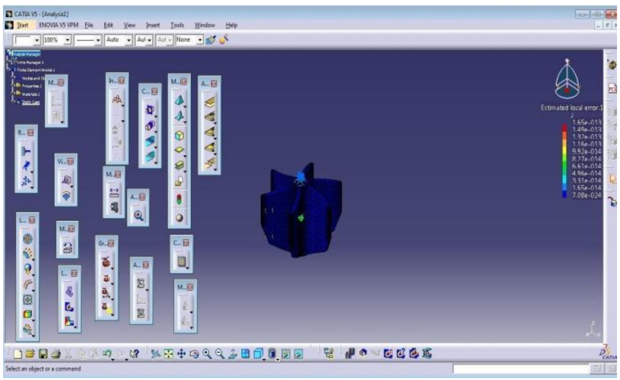

Fig 12. Torque Generation.

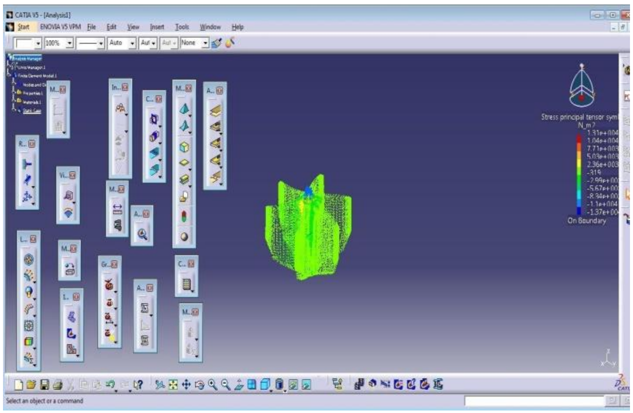

Fig 13. Minimum Stress.

Table 1. Element Quality.

Criterion	Good	Poor	Bad	Worst	Average
Stretch	18102 (99.99%)	2 (0.01%)	0 (0.00%)	0.143	0.603
Aspect Ratio	16096 (88.91%)	2008 (11.09%)	0 (0.00%)	4.666	1.994

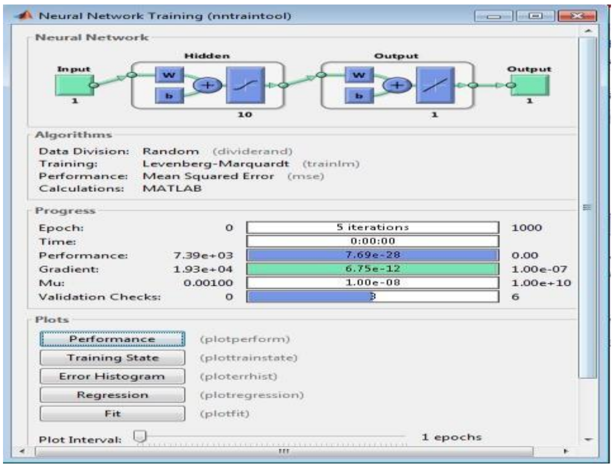

Fig 14. ANN prediction GUI.

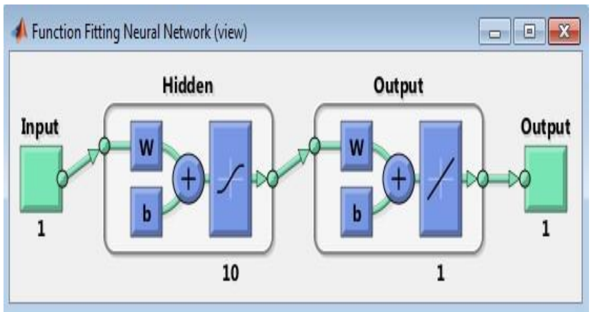

Fig 15. Networks Layers.

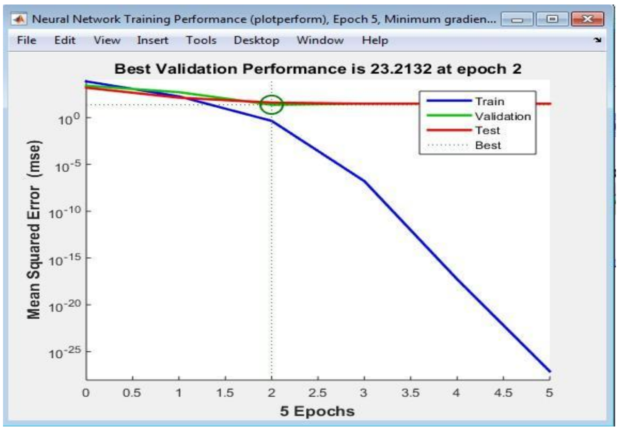

Fig 16. Optimize performance at 10p. Air pressure.

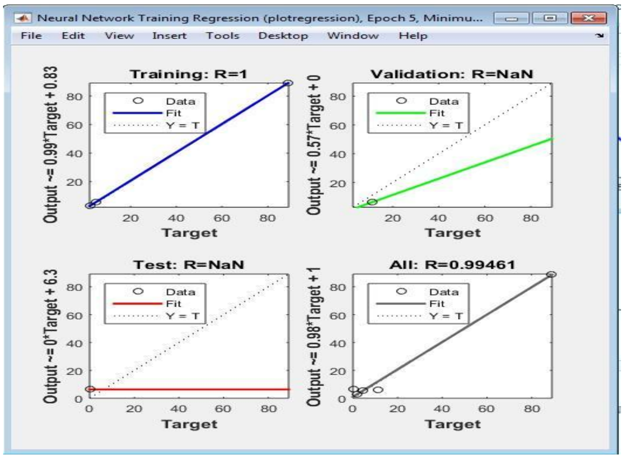

Fig 17. Predicted Sample R values.

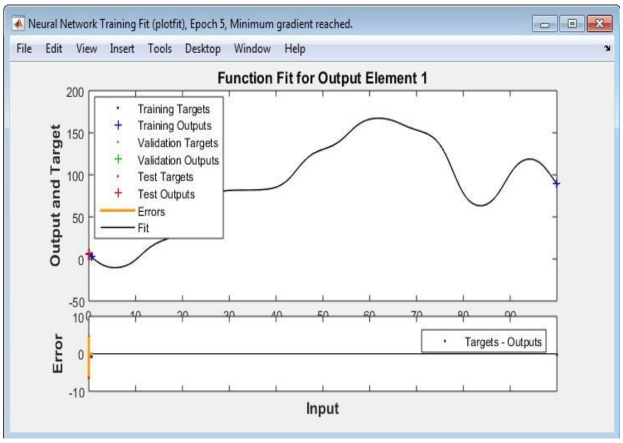

Fig 18. Outputs of Performance.

VI. CONCLUSION AND FUTURE SCOPE

The objective of this work was to propose an approach for predicting wind turbines output power using an Artificial Neural Network. The approach relies on using climatic data collected from real sites to identify the parameters of the ANN model and to analyze the influence of spatial climatic variables on the model performance.

The conducted studies have allowed identifying the parameters of the model. Then, this model was used to analyze the influence of spatial climatic variables on the model performance. Results of the spatial analysis showed that the performance of the model is different from one site to another. The difference was significantly related to sites characteristics and to the operating mode of the wind turbine. A study was also conducted to analyze the influence of the climatic variables on the performance of the model using the data collected on the site of Sendou.

The results of this study allowed observing that the climatic variables have a significant influence on the performance of the model. That influence can range from 0.1% when considering two climatic variables as input (wind speed with temperature, wind speed with relative humidity or wind speed with solar radiation) to 0.3% when considering all climatic variables (wind speed, temperature, relative humidity and solar radiation). The influence analysis of the wind direction on the performance of the model has shown a significant improvement considering as model input both wind speed and wind direction. Results showed that the fitting rate increases from 98.33% when the wind speed is the only input variable of the model to 98.56% when both the wind speed and the wind direction are considered as the model input.

REFERENCES

[1] Gupta R, Biplab K D and Ranjan D 2009 CFD analysis of two-bucket Savonius rotor using fluent package European Wind Energy Conference and Exhibition.

[2] Tian W, Mao Z, Zhang B and Li Y 2017 Shape Optimization of a Savonius Wind Rotor with Different Convex and Concave Sides Renew. Energy.

[3] Sargolzaei J and Kianifar A 2009 Modeling and simulation of wind turbine Savonius rotors using artificial neural networks for estimation of the power ratio and torque Simulation Modelling Practice and Theory 17 1290–1298

[4] Biplab Kumar Debnath1, and Ranjan Das 2010 Prediction of performance coefficients of a three bucket Savonius rotor using artificial neural network Journal of Renewable and Sustainable Energy 2 043107.

[5] Mohamed M H, Janiga G, Pap E and Thévenin D 2010 Optimization of Savonius turbines using an

obstacle shielding the returning blade Renewable Energy 35 2618-2626.

[6] Gad H E, AAbd El-Hamid A A, El-Askary W E and Nasef M H 2014 A New Design of Savonius Wind Turbine: Numerical Study CFD Letters Vol. 6(4) .

[7] Sukanta R, Ranjan D and Ujjwal K S 2018 An inverse method for optimization of geometric parameters of a Savonius-style wind turbine Energy Conversion and Management 155 116–127.

[8] Ramadan A, Yousef K, Said M, Mohamed M H 2018 Shape Optimization and Experimental Validation of a Drag Vertical Axis Wind Turbine Energy.

[9] Chan C M, Bai H L, He D Q 2018 Blade shape optimization of the Savonius wind turbine using a genetic Algorithm Applied Energy 213 148–157.

[10] Nur Alom 2018 Examining the Aerodynamic Drag And Lift Characteristics of A Newly Developed Elliptical-Bladed Savonius Rotor Journal of Energy Resources Technology. Received April 15.