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PI-ANFIS Controller for Grid Connected SPMSG Based WECS

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Abstract: In this research paper, ANFIS modeling of 5 kW wind turbine is performed. The turbine modeling is performed by deriving the non-linear dynamic equations of different subsystems. Then, the model parameters are identified to match the actual response. ANFIS is an artificial intelligent technique which creates a fuzzy inference system based on input and output information of the model. In this research, the ANFIS algorithm combines neural network and fuzzy logic with 5 layers which utilize different node functions for learning and setting fuzzy inference system parameters. After learning, by assuming constant parameters, a hybrid method is used to update the results. Employing the proposed method, computation time and complexity are remarkably reduced. Results of the proposed method are then compared and it is shown and concluded that the proposed model performs favorably well.

Index Terms: **(ANFIS) Adaptive Neuro Fuzzy Interface System, Maximum Power Point Tracking (MPPT), Proportional Integral (PI) Controller, Power System Stability, Six Phase Permanent Magnet Synchronous Generator (SPMSG).**

1. INTRODUCTION

Wind turbine technology because of the environmental, social and economic benefits has become the fastest-growing green energy against other energy resources considering the installed capacity per year [1]. Unlike the other alternative sources, wind turbines industry has attained full-grown commercial stage. In spite of that, wind turbines are ceaselessly increasing size and rated power capacity in order to achieve more competitive cost of energy compared to fossil fuel sources. Wind turbines divided into fixed and variable turbines are widely used nowadays. Variable-speed of the wind and the increased extracted energy from wind reduce loads on the structure [1-4]. Modeling is a basic tool for analysis that requires experience, repetition and enough accuracy of the system modeler. Almost in all branches of engineering, much effort is being done to gain information about different aspects of a system, which is known as system analysis. System analysis is performed through inputting test signals and observing responses.

However, this method is not always possible because the changing range of physical system parameters is limited. Thus, there is a limitation of the range of inputs. A simplified representation of the system is the solution which is called system model.

A plethora of methods has been used to model variable speed wind turbines. Velastimir et al. [5] utilized a model combined with a stochastic wind model for simulation purposes. Aamer and Xiaodong [6] proposed a hybrid intelligent learning based adaptive neuro-fuzzy inference system (ANFIS) for online estimation of effective wind speed from instantaneous values of wind turbine tip speed ratio (TSR), rotor speed and mechanical power. Singh [7] presented manufacturer-specific models of wind turbines for use in wind power interconnection studies. While they are detailed and accurate, their usage is limited to the terms of the non-disclosure agreement, thus stifling model sharing. The primary objective of the work proposed was to develop universal manufacturer-independent wind power plant models that can be shared, used, and improved without any restrictions by project developers, manufacturers, and engineers. Sahasakkul [8] focused on three important topics: (i) development of the combined offshore wind turbine system model with the 13.2 MW wind turbine, a floating semi-submersible platform, and a mooring system; (ii) the entire procedure involved in modeling and analyzing firstorder hydrodynamics using two codes, Multi Surf and WAMIT; and (iii) assembling of the integrated aero-hydro-servo-elastic model considering hydrodynamics in order to verify the steady-state and stochastic response of the integrated wind turbine system.

Manyonge et al. [9] proposed a mathematical model of wind turbine. A mathematical model is essential in understanding the behavior of the wind turbine over its region of operation because it allows for the development of comprehensive control algorithms that aid in optimal operation of a wind turbine. Modeling enables control of wind turbine's performance. This paper attempts to address part or whole of these general objectives of wind turbine modeling through examination of power coefficient parameter. Rolan et al. [10] analyzed a typical configuration of a Wind Turbine Generator System (WTGS) equipped with a Variable Speed Generator. Moreover, the concept of the Maximum Power Point Tracking (MPPT) has been presented in terms of the adjustment of the generator rotor speed according to instantaneous wind speed. Junyent-Ferré et al. [11] presented the modeling of wind turbine generator systems and the model of a doubly fed induction generator, along with the corresponding converter, crow bar protection electrical grid is described. Sanchez and Medina [12] represented three principal parts (blades, gearbox, and generator) by using the bond-graph methodology. Then, they are combined together in order to simulate the complete system. The complete aerodynamic model is simulated and validated using real data provided in the open literature (blade profile and gearbox parameters for a 750 kW wind turbine).

As mentioned above, ANFIS modeling of 5 kW wind turbine is done. ANFIS has a combination of fuzzy systems and neural networks advantages which uses fuzzy theory for presenting knowledge and employs the capability of learning from a neural network to optimize the parameters [13-19].

The structure of this paper is as follows. In section 2, the wind turbine performance is discussed. In section 3, a model of the wind turbine is presented. Model validation with actual data is done in section 4. ANFIS modeling is discussed in section 5. Finally, the last section shows the conclusion.

2. ANFIS MODELING

ANFIS system is an artificial intelligent technique which creates a fuzzy inference system based on input and output information of the model. This system combines neural network and fuzzy system. ANFIS can be used in a wide range of applications in modeling, decision making, and signal processing and control. This system is a class of adaptive networks which is a function of fuzzy inference system.

ANFIS algorithm is consisted of combining neural network and fuzzy logic with 5 layers which utilize different node functions for learning and setting fuzzy inference system parameters. After learning, considering the parameters are constant, least square estimation method is used to update results [30].

ANFIS has 5 layers. First and fourth layers are constructed from adaptive (settable) nodes and the other three layers are constructed from constant (non-settable) nodes.

First layer, fuzzification: each node in this layer is adaptive. The output of this layer is the degree of membership of inputs.

Second layer is rules layer: each node in this layer is a constant node and non-adaptive and shown with circle. The output of each layer is equal to the multiplication of its inputs. In this layer, instead of multiplier operator, any fuzzy operator that can satisfy AND can be used.

Third layer: each node in this layer is constant. The output of i^{th} node is equal to the i^{th} firing strength divided by the total firing strength of all rules. Outputs of this layer are known as normalized firing strength.

Fourth layer is the defuzzification layer: each node in this layer is adaptive. Fifth layer is the summation neuron: the sole node in this layer is constant in which the final output is from the summation of all outputs from the fourth layer.

It worth to mention that second, third and fifth layers are constant, while the first and fourth layers are adaptive. In other words, learning of the network is changing the parameters of these two layers to reach desired results. ANFIS structure is learned automatically by least square method and backpropagation algorithm, or hybrid learning.

3. SIMULATION RESULTS

The intermittency of wind speed poses challenges to obtaining reliable power and integrating wind plants successfully with existing power infrastructure. Fast and efficient controls are required to cater to the transient nature of wind speed and simplify wind power control. This paper presents an efficient control mechanism for operating a wind energy conversion system (WECS) over its full operating range by incorporating a six phase permanent magnet synchronous generator (SPMSG) to generate suitable active current references based on generator voltage and achieve the maximum power output from a wind turbine. Figure 1 shows the main configuration of SPMSG based WECS. Figure 2 depicts the grid real and reactive power of ANFIS Model. It is observed that ANFIS model has considerably effective performance compared to PI controller. Figure 3 & 4 shows the proposed hybridized PI- ANFIS scheme comparison of real and reactive power at the grid. The settling time of the PI controller is around 0.2 seconds, ANFIS controller is 0.1 seconds. Hence, the simulated results show the effectiveness and ability of the proposed hybrid model to cope with safe operating limits of WECS.

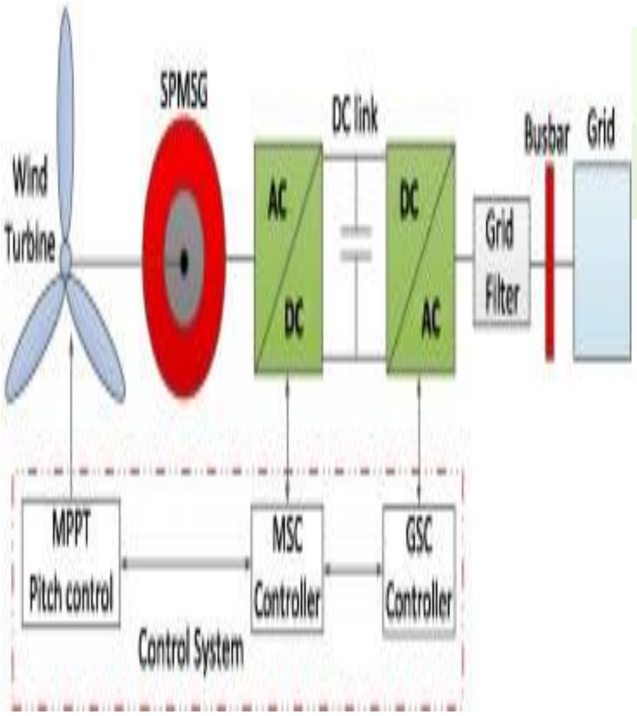

Figure 1: Configuration of SPMSG based WECS

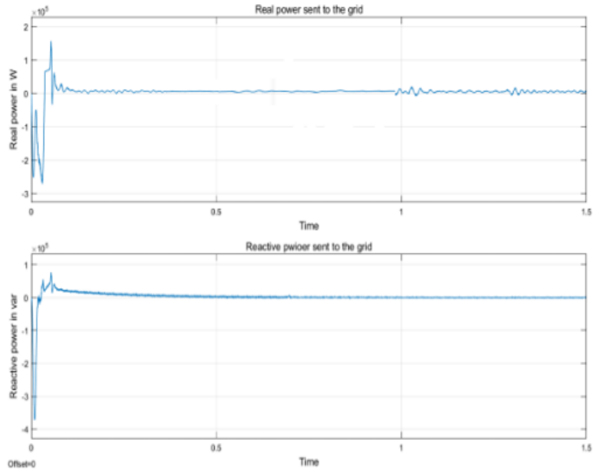

Figure 2: Plot of grid real and reactive power vs time in sec.

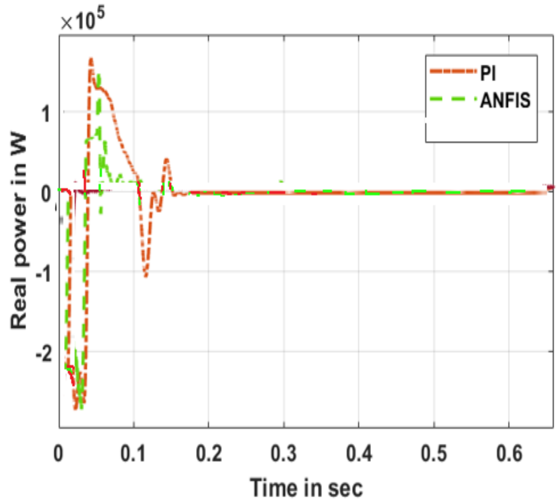

Figure 3: Plot of real power comparison with PI & ANFIS

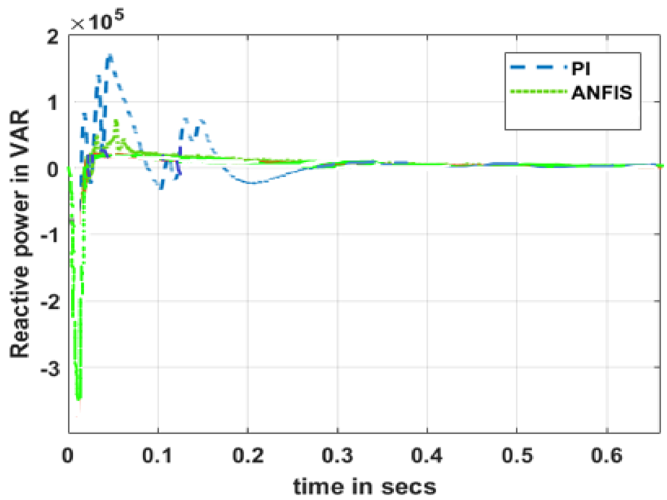

Figure 4: Plot of reactive power comparison with PI & ANFIS

4. CONCLUSION

In this research, ANFIS modeling of 5 kW wind turbine is done using MATLAB-Simulink. One important aspect of a proposed method is a combination of fuzzy systems and neural networks, so it has an advantage of both of them, which uses fuzzy theory for presenting knowledge and employs the capability of learning from neural network to optimize the parameters. Employing the proposed method, computation time and computation complexity are remarkably reduced. To illustrate the effectiveness of the proposed methodology, the results of the proposed method are then compared indicating improved performance of the WECS.

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