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Soft Computing Techniques in Wind Electric Generation

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Abstract: The role of soft computing in the field of hybrid power systems are worth to mention and it is been increasingly employed to evaluate their performances, control strategies and optimization of power output. The hybrid power system includes the major potentials from wind, solar and minor resources like gasoline, biomass etc., Fuzzy logic is an efficient tool in modelling and control applications helps to improve optimized efficiency in electric power transfer, control robustness and search of maximum power point tracking both in wind and solar systems.

Keywords: fuzzy logic, power co-efficient, pitch angle, mppt, tip speed ratio, WEG

I. INTRODUCTION

The usage of renewable sources over past decades has intensified to compete with the awful energy scarcity and terrible global warming. Being freely available and non-polluting, wind energy has been preferred among the alternating sources as the most feasible and competitive option.

This paper outlines the control strategies used in wind electric generation with modeling and simulation of the entire system using Simulink/Matlab. Section II depicts the picture of wind turbine model and how maximum energy can be retrieved from it. The implementation of fuzzy logic control in wind conversion systems is explained in Section III. Conclusions are summarized in the last section.

II. WIND TURBINE MODEL

The main components of wind electric generating system are the wind turbine, the mechanical drive train, the generator, the power grid, and the controller. The wind turbine converts the kinetic energy of the wind into mechanical energy. The generator converts the mechanical energy into electrical energy.Fig.1 depicts the general block diagram of a wind power system.

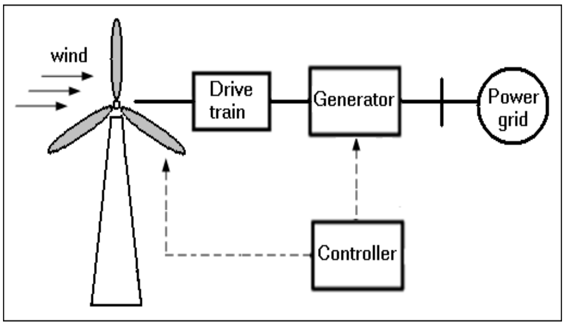

Fig.1.Wind Power System

Designing the wind turbine system essentially involves determination of the diameter of the rotor, number of blades, blade profile, chord length, setting angle, height of the tower, and the type of transmission system and gear box. The turbine power and torque developed are given by the relation

$$P_m = \tfrac{1}{2}\rho\pi R^2 v^3 C_p(\lambda,\beta) \qquad (1)$$

$$T_m = \frac{P_m}{\Omega} = \frac{1}{2\lambda}\rho\pi R^3 v^2 C_p(\lambda,\beta) \qquad (2)$$

where λ presents the ratio between the turbine angular speed and the wind speed called the tip speed ratio and is defined as $\lambda = \frac{\Omega R}{v}$

(3)

where ρ is the air density, R is the blade length, v is the wind speed, C_p is the power co-efficient and Ω is the turbine angular speed [1,2]. The power coefficient presents the aerodynamic efficiency of the turbine and depends on the specific speed λ and the angle of blades. The Fig.2 shows the performance characteristics of the turbine with respect to tip speed ratio λ and the pitch angle β

Physically as the pitch angle increases, the

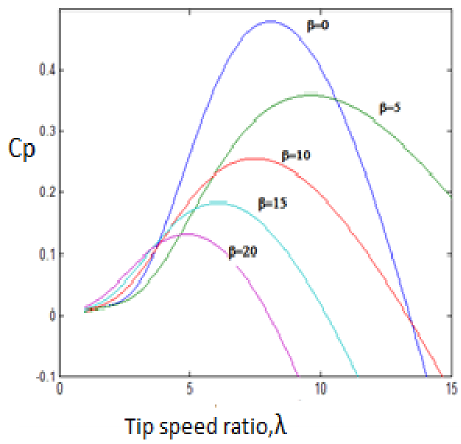

Fig.2.Performance characteristics of Wind turbine

effective wind area decreases which in turn decreases the power co-efficient. For one particular pitch angle, there exists an optimal tip speed ratio that maximizes the power co-efficient C_p . For better utilization of wind energy and make wind energy competitive with other forms of energy from an economical perspective, it is desirable to operate the turbine at its most efficient point.

To operate the turbine efficiently requires keeping the tip speed ratio at its optimal value. So when the wind speed changes, the system rotation speed should change correspondingly to keep the tip speed ratio at its optimal value. The rotational speed of the generator is directly proportional to the frequency of the generated electricity.

The characteristics of mechanical power as a function of turbine rotor speed is given in Fig.3

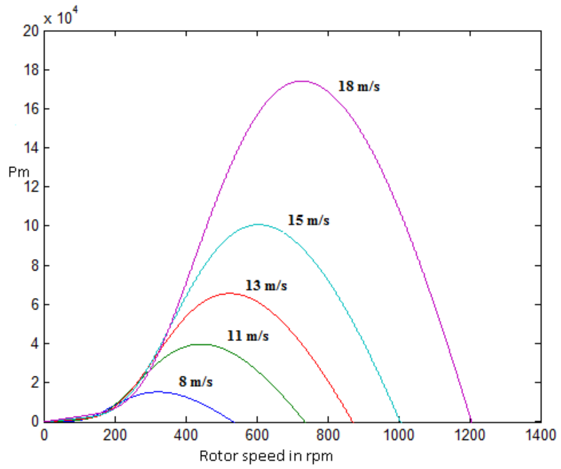

Fig.3.Rotor speed Vs mechanical power P_m

The model of the turbine [3] in Simulink/Matlab has been given in Fig.4

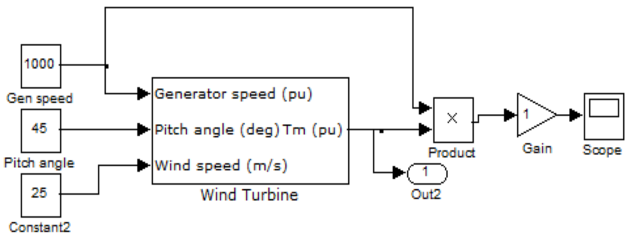

Fig.4.A wind turbine model

If Tm is positive, the machine acts as a motor. If Tm is negative, the machine acts as a generator. The electromechanical torque Tm obtained is of negative and hence the wind turbine acts as a generator and the scope looks as in Fig.5.

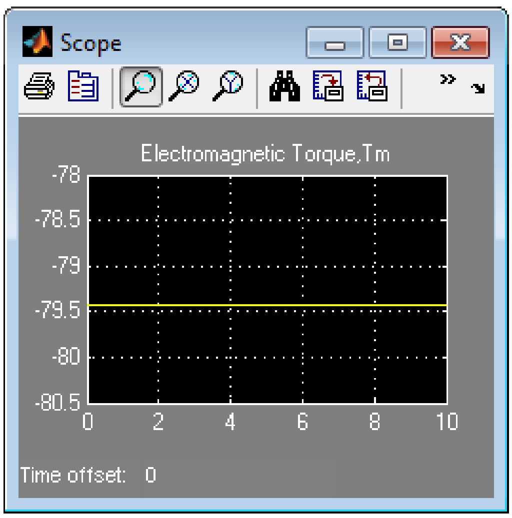

Fig.5.Scope showing the output

III. Fuzzy Logic in WEG

Fuzzy logic becomes versatile for systems which are non-linear in their behavior. The wind turbine system contains several nonlinearities, which must be considered while modeling. The maximum power searches, control of pitch angle, turbine rotor speed are some of them which can use fuzzy logic controller aided with fuzzy inference systems [4]. The fuzzy rules represent the knowledge and abilities of a human operator who makes necessary adjustments to operate the system with minimum error and fast response.

Searching the maximum could be based on a rule called as 'Fuzzy Metarule', which is given as follows: "If the last change in the input variable (x) has caused the output variable (y) to increase, keep moving the input variable in the same direction; if it has caused the output variable to drop, move it in the opposite direction."

The basic structure of fuzzy logic controller includes fuzzifier, rule base and defuzzifier. Two input signals of the fuzzy logic controller, the main signal and change in main signal for each sampling are first converted to fuzzy numbers in fuzzifier. Then they are used in the rule table to determine the fuzzy number of the compensated output signal. Finally, the resultant united fuzzy subset representing the controller output is converted to the crisp value [5, 6].

Here is the Simulink block diagram of the open loop wind electric system in Fig.6.

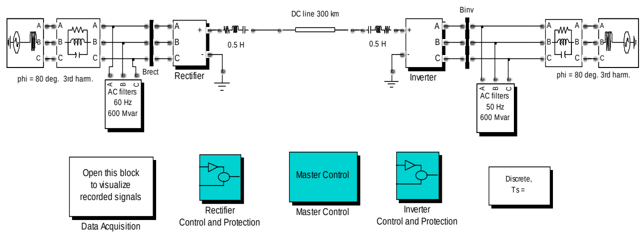

Fig.6.Model of simple wind electric generator

The master control block in Fig.7 includes three fuzzy logic controllers with protection circuits.

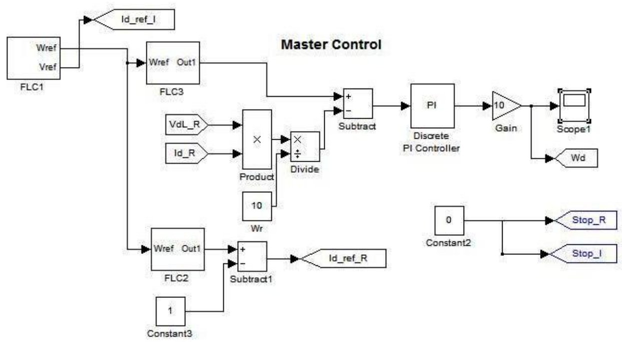

Fig.7.Master control block

The first fuzzy logic controller tracks the rotor speed with the varying wind speed to extract maximum power. The main function of it is to search the generator speed until the system settles down at the maximum output power condition. The second fuzzy logic controller programs the machine flux for light load efficiency improvement. The light load efficiency of the generator-converter system is optimized on the basis of on-line search of the machine rotor flux.

The last one performs robust speed control against wind vortex and turbine oscillatory torque. There are two inputs ω_r and ω_r^* and one output $i_{qs}*$. In the implementation of fuzzy control, the input variables are fuzzified, valid control rules are evaluated and finally the output is defuzified to get the crisp value. Each Fuzzy logic control blocks in Simulink and their corresponding outputs are depicted in Figs.8-11.

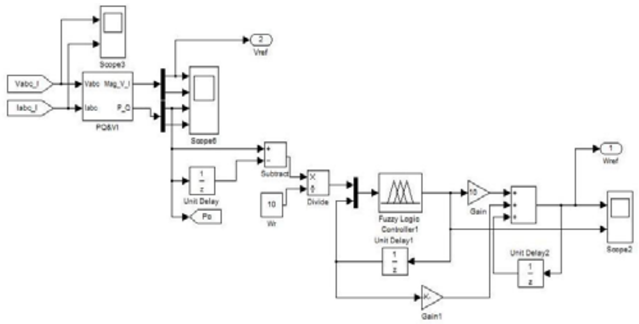

Fig.8.Block of FLC-1

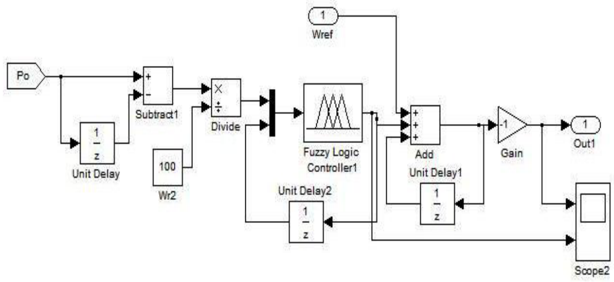

Fig.9.Block of FLC-2

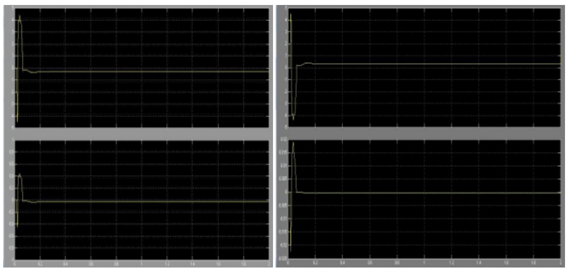

Fig.10.Scope of FLC-1 and FLC-2

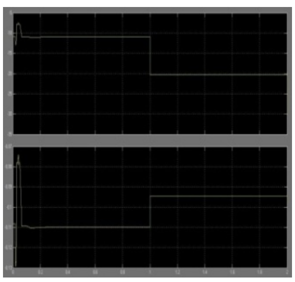

Fig.11.Scope of FLC-3

IV. RESULTS AND DISCUSSION

The set of the input values of the whole system is formed by the wind speed, which can be represented by the measured curve of the real wind speed or by the curve from the wind model, and by the stator supply voltages that correspond to the voltage level of the grid [7].The set of outputs of this wind power plant model is formed by the shaft torque and mainly stator phase currents.

FLC-1 will track the generator speed with the change in wind velocity to extract maximum power. So as the wind velocity increases, generator speed is also increased by FLC.1. As a result of which the corresponding line output power is also increased during the interval. Similar is the case for the decrease in wind velocity. FLC-2 will reduce the generator rotor flux for light load efficiency improvement.FLC-2 reduces the flux component of current i.e. i_{ds}. Thus core loss of machine decreases but on the other hand torque component of current i_{qs} is increased, which in turn increases the copper loss of the machine.

However, the total system loss i.e. machine and converter loss decreases, resulting in an increase of total generated or output power Po. As in Fig.10 the output power Po is increased by FLC-2, by means of ΔPo i.e. change in output power. The fuzzy logic based variable speed cage machine wind generation system has been analyzed and the system performances have been studied with Matlab/Simulink to validate the theoretical concepts.

V. REFERENCES

[1] A. G. Aissaoui, A. Tahour, N. Essenbouli, F. Nollet, and M. Abid, "An optimal power extraction of wind turbine based on Synchronous generator," EFEEA'10 International Symposium on Environment Friendly Energies in Electrical Applications 2-4 November 2010, Ghardaïa, Algeria.

[2] Márton Örs,"Maximum Power Point Tracking for Small Scale Wind Turbine with Self-Excited Induction Generator," Control Engineering And Applied Informatics, Vol.11, No.2, pp. 30-34, 2009

[3] Suman Nath and Somnath Rana, "The Modeling and Simulation of Wind Energy Based Power System using MATLAB," International Journal of Power System Operation and Energy Management, ISSN (PRINT): 2231–4407, Volume-1, Issue-2, 2011

[4] I.H. Altas and A.M. Sharaf, "A Generalized Direct Approach for Designing Fuzzy Logic Controllers in Matlab/Simulink GUI Environment", ", International Journal of Information Technology and Intelligent Computing, Int. J. IT&IC no.4 vol.1, 2007.

[5] Evgenije Adzic, Zoran Ivanovic, Milan Adzic, Vladimir Katic, "Maximum Power Search in Wind Turbine Based on Fuzzy Logic Control", Acta Polytechnica Hungarica Vol. 6, No. 1, 2009

[6] S.R.Vaishnav, Z.J.Khan, "Design and Performance of PID and Fuzzy Logic Controller with Smaller Rule Set for Higher Order System," Proceedings of the World Congress on Engineering and Computer Science 2007,WCECS 2007, October 24-26, 2007, San Francisco, USA.

[7] Vlastimil Šantín, "Model of wind power plant with asynchronous generator in Simulink platform," in Intensive Programme 'Renewable Energy Sources'May 2011, Železná Ruda-Špičák, University of West Bohemia, Czech Republic.

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