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Variable Speed Wind Power Generation System Based on Fuzzy Logic Control for Maximum Output Power Tracking

Ms. Epsita Pal, Mr. Yogesh Tiwari, Dr. Anup Mishra

Abstract

The power output from wind turbines varies nonlinearly with the wind speed, the speed of the turbine blade tips and the blade pitch angle. At a given pitch angle and wind velocity, maximum power is obtained at a specific turbine angular speed. Since wind speeds typically vary over a wide range ,the turbine speed needs to be continously adjusted so that its power output can be maximised . In this paper fuzzy logic is used for adjusting the turbine speed so as to track the maximum power. The aim of fuzzy controller is to establish maximum power delivered to the grid from available wind power. The fuzzy logic controller is used to track generator speed with varying wind speed to optimize turbine aerodynamic efficiency in the outer speed loop. Pitch angle control of wind turbine has been used widely to reduce torque and output power variation in high rated wind speed areas. It is a challenge to maximize available energy in the low rated wind speed areas. A fuzzy logic pitch angle controller is developed in this paper. The simulation shows that the fuzzy logic controller can achieve better control performances than conventional pitch angle control strategies, namely lower fatigue loads, lower power peak and lower torque peak.

Key words: Fuzzy logic control, Pitch angle, Wind turbine.

1. Introduction

Wind power is the conversion of wind energy into a useful form of energy, such as using wind turbines to make electrical power, windmills for Mechanical power, windpumps for water pumping or drainage, or sails to propel ships. Wind power, as an alternative to fossil fuels, is plentiful, renewable,widely distributed, clean, produces no greenhouse gas emissions during operation and uses little land .Wind turbine is the system that converts wind energy to electric energy. Now in the market there are two kinds of wind turbine i.e fixed speed and variable speed.

A fuzzy logic controller (FLC) is optimized to achieve high performance of wind turbine for the low rated wind speed . Pitch-adjusting variable-speed wind turbines have become the dominating type of yearly installed wind turbines in recent years. There are usually two controllers for the variable-speed wind turbines which are cross-coupled each other as shown in fig 1

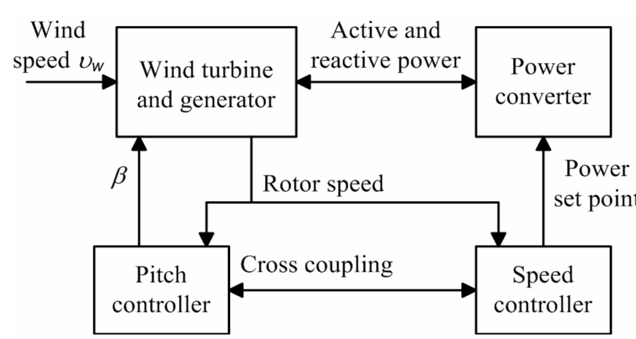


Fig 1.

2.MAXIMUM POWER POINT TRACKING (MPPT)

The maximum extractable power depends not only on the strength of the source (i.e. wind) but also on the operating point of the WECS. The concept of MPPT is to optimize the generator speed relative to the wind velocity intercepted by the wind turbine such that the power is maximized. Variable-speed wind turbines are designed to operate at an optimal rotation speed as a function of the wind speed. The power electronic converter may control the turbine rotation speed to get the maximum possible power by means of a MPPT.

As from the problem identification it has been seen that the maximum power is obtained as

$$P_{max} = \frac{16}{27 g_c} \frac{1}{2} \rho A V_i^3 = 0.593 \left(\frac{1}{2} \frac{\rho V_i^3 A}{g_c}\right) = 0.595 P_{total}$$

Therefore , the ratio of the maximum power obtained from the wind to the total power available in the wind is known as Betz coefficient or power coefficient and represented by C_p , which is equal to 0.593

The power P_{MAX} of the wind turbine is given by:-

$$P_{MAX} = C_p P_{total}$$

It can be shown that the theoretical static upper limit of Cp is I6 /27(approximately 0.593) that is, it is theoretically possible to extract approximately 59% of the kinetic energy of the wind. Cp is the turbine rotor power coefficient, which is a function of tips peed ratio (λ) and pitch angle (y) Vwind is the wind speed in m/s,ωm is rotational speed of turbine rotor in mechanical radls. The coefficient of performance of a wind turbine is influenced by the tip-speed to wind speed ratio,which is given by

$$TSR = (\lambda) = \frac{\omega_m R}{V_{wind}}$$

The maximum power is obtained by keeping the value of Cp maximum . Under this condition the value of pitch angle is kept constant ,with the change of wind speed and rotational speed of turbine rotor . If the wind speed varies , the rotor speed should be adjusted to follow the change.

To control the pitch angle of the blade, the FLC is developed.

There are three steps to develop the FLC: (i) determining the inputs, (ii) setting up the rules, and (iii) designing a method to convert the fuzzy result of the rules into output signal, a so called de-fuzzyfication. Mamdani method with a middle of maximum method (MOM) is used in this paper.

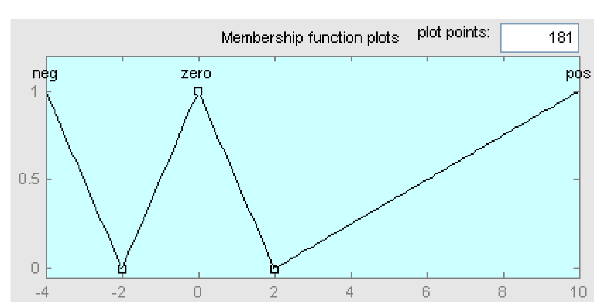
3. FUZZY LOGIC CONTROLLER

A fuzzy logic controller may consist of three basic blocks, namely, Fuzzification, Inference system and Defuzification

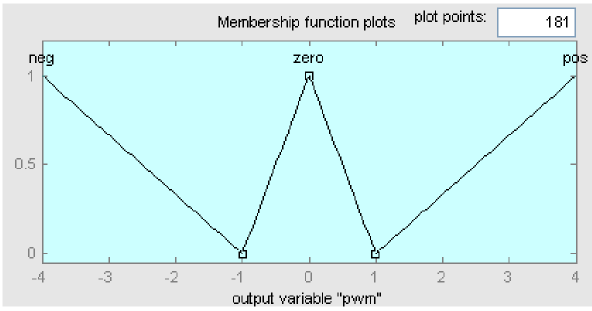
Fuzzification

Fuzzification is the procedure to process the input variables with membershp functions and determine the degree to which the input variables are belong to each of the appropriate fuzzy sets via membership functions. Membership functions (MF) are used to convert each value of input variables into a membershp value between 0 and 1. Membership functions may take any arbitrary shape or form, such as Gaussian distribution curves, Sigmoidal curves, bell shape curves, triangular functions or tables . The selection of membership functions is very important as it means a kind of controller tuning. Once the membership function shape has been chosen, the values they are centred about and the width of the functions have to be set. Overlapping of membership functions is required as it means that more than one rule is fired at any time, which is a key feature of fuzzy systems.

Triangular membership function are used as they are easier to lmplement and quicker to process.In the proposed fuzzy system, seven fuzzy sets have been considered for each input: negative large (NL), negative medium **(**NM**),** negative small (NS), zero (ZE), positive small (PS), positive medium (PM) and positive large (PL). Before fuzzification, the input variables are normalised using base values



Membership function for input variables



Membership function for input variables

Fuzzy inference system

The fuzzy inference includes the process of fuzzy logic operation, fizzy rule implication and aggregation. In the fuzzy inference system, the fuzzified input variables are processed with fuzzy operators and the IF-THEN rule implementation. The output fuzzy sets for each rule are then aggregated into a single output fuzzy set.

Aggregation is the process by which the fuzzy sets that represent the outputs of each rule are combined into a single fuzzy set. The input of the aggregation process is the list of output fuzzy sets and the output of the aggregation process is one fuzzy set for each output variable

Defuzzification

The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single value. The centroid method is used for defuzzification, it returns the centre of the area under the curve representing the aggregated output fuzzy set.

4. Conclusion

A fuzzy logic controller for wind generation system has been developed to perform the optimal power control of wind generation systems. The use of pitch angle fuzzy logic-based control can improve mechanical power response performance of wind turbine compared to the use of a fixed pitch angle or without control. Pitch angle control also has an effect on the aerodynamic loads which may be controlled by the controller to achieve lower torque peak as well as lower fatigue loads

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Epsita Pal is currently working as an Astt. Prof. in EEE Department of BIT Durg. She received the B.E degree in Electrical Engineering from BIT, Durg in 2010 and. Pursuing M.E. in Electrical Engineering from SSCET. She has 3 years teaching experience. She has published near 3 research papers in national conferences and journals.

Mr.Yogesh Tiwari is currently working as an Asso. Prof. in EEE Department of SSCET Bhilai. He received the B.E degree in Electrical Engineering from BIT, Durg in 1997 and M.Tech. Degree in Instrument & Control Engineering from BIT, Durg in 2006. Pursuing PhD in Electrical Engineering from C.V. Raman University Bilaspur. He has over 4 year industrial & 10 year teaching experience. He has published near 15 research papers in national & international conferences & journals.

Dr. Anup mishra received his Ph.D degree in 2010 from BUIT, Bhopal and M.Tech degree in 2006 with Instrumentation and control from BIT, Durg. He completed his B.E in 1997 from BIT, Durg. He has teaching and research experience of more than 13 years. He has published more than 10Research papers in reputed International Journals & Conferences .At present, he is working as professor and H.O.D. in Electrical and Electronics Department of BIT, (Durg)