Indian Journal of Science and Technology, *Vol 10(16), DOI: 10.17485/ijst/2017/v10i16/114316, April 2017*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Controlling Pitch Angle of Wind Turbine in Grid Connected System

Ashish Kumar* and Harvinder Singh

Electrical Department, Chandigarh University, Gharuan, Mohali – 140413, Punjab, India;
ash58ish@gmail.com, harvinder7@rediffmail.com

Abstract

Objectives: The motive of this paper is to build the structure or system which can help in stablizing the wind generation by controlling its pitch angle. **Methods/Statistical Analysis:** The movement of blades of turbine about its own axis is due to the support of pitch angle. By using this control system we can also able to control pitch angle in unsteady and noisy situations. The major objective of control systems in the power conversion system of wind farm is to manage or control the power flow at certain speed of wind by varying the incoming torque to the generator. **Findings:** This control system will also control the output power and enhance the stability of wind turbine. This paper comprises a model of fuzzy-PI control network and analysis of the change in grid energy because of variation in pitch position of the wind turbine has been done. **Improvements:** The advantage in fuzzy based control system is that the power at the output has limited oscillation as compared to PI controller. It will provide stable output.

Keywords: Fuzzy Control, Pitch Angle, Stability, Wind Turbine

1. Introduction

In recent years, due to introduction of large generators, big turbines and effective control system, wind powers become the major source of electric power. The best thing of wind power is that its 100% pollution free. However due to proper control on pitch angle, absence of stable flow of wind, wind generators are not able to supply the electric power to consumer alone. Hence they are using in combinations like solar-wind, diesel-wind or with any combination. Now a day's wind generators are synchronized with the main grid.

Past day's development of WECS i.e. (wind energy conversion system), researchers merely focus on fixed speed of wind turbine[1,2]. But in recent years the trend has been changed. Now the manufacturer and researchers are interested in varying the speed configuration because it of better energy capturing and lower loading capability[3,4].

Pitch control is applied on high speed when turbine is running at a speed more than given rated speed. But rotation more than higher rated speed will generate excess aerodynamic torque which break or tear the mechanical structure of turbine. So to prevent the turbines from falling or tearing, braking technique is to be implemented. Flow separation in the blades is enhanced throughout with the help of pitch control technique which allows the blades to move on their own axis[5,6]. This results in high dragging force than lifting. When the speed becomes less than the given rated speed, the lifting speed is tried to improve with the help of pitch control process to inflate the extraction of power[7,8].

This paper comprises the implementation of fuzzy based pitch control system under different wind scenarios.

2. Wind Turbine Configuration

Power generating system of wind farm comprises of:

- Turbine with number of blades
- Gear box
- Synchronous generator
- Converter

**Author for correspondence*

Initially, the pitch controller controls the output power given to the grid and secondly with the help of Pulse Width Modulation converters systems.

Now, incoming power to the turbine is given by:

$P\ (input) = 0.5\Pi R^2$ (1)

Here, R= radius of turbine blade

Let V_W is speed of wind

Therefore, input torque of turbine can be given as

$Twind = \lambda / Ww\ Vw$ (2)

$Twind = 0.5\pi R3V_W^2$ (3)

Here Ww is turbine's angular velocity

Also tip speed ratio (λ) is given by:

$\lambda = R/WwVw$ (4)

The turbine transforms this input power to mechanical power

i.e. $P_{mech} = 0.5\pi R^2 V_w^3 C_p$ (5)

Where Cp is input power coefficient. It always relies on pitch angle and tip speed ratio.

$C_p = (0.44-0.016\beta)\sin[\pi(\lambda-3)/15-0.3\beta]-0.0018(\lambda-3)$ (6)

Output torque by wind turbine $T_{w\ is}$ given as

$T_w = 0.5\pi R^2 V_w^2\ C_t$ (7)

C_t=torque coefficient which is given by

$C_t = C_p / \lambda$

Since its never possible for manufacturer to design such type of turbine which can change entire power of wind into mechanical power, so one function is inserted which is called torque loss function (T_f), which is given as:

$T_f = T_w - T_{wind}$

$= \partial V_w^2 + \sigma V_W W_W + \psi W_w^2$ (8)

Here, ∂, σ, ψ are loss coefficients of wind turbine.

Now this power is actual incoming power for induction generator. Output power (P_e) for the induction generator is:

$P_e = T_f W_w$

$= (T_w - T_{wind}) W_w$

$= (0.5\rho\pi R_0 - \partial) V_w^2 W_w - \sigma V_w W_w^2 - \varphi W_w^2$ (9)

Optimum rotational (W_{opt})speed of turbine ca be calculated by differentiating the generator output power with respect to W_w and put them equal to zero,$dP_e/dW_w=0$.

$W_{opt} = (-\sigma V_w + \sqrt{(\sigma V_w)^2} - 3\varphi((0.5\rho\pi R_0^2 - \partial)V_w^2)/3\varphi$ (10)

As we increase the pitch angle or tip speed ratio, there will be increase in the power coefficient. As a result, there will be increase in output power. In most of cases we maintain tip ratio constant. Rapid change in pitch angle may result in stall of generator. So it is very necessary to change the pitch angle very gently.

Figure 1 shows the relationship between Coefficient of input power (C_p), tip speed ratio (λ) and pitch angle of blade (β).

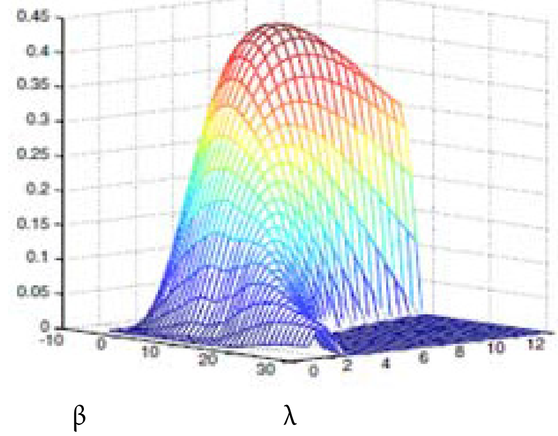


Figure 1. Turbine tip ratio, pitch angle variation with power coefficient[1].

3. Techniques

In today's time, pitch control wind turbine are most preferable control system for getting maximum power. Basically there are two types of controllers which control the irregular speed of turbine which is cross coupled with each other. During less speed controller will try to stable the ratio of tip speed to extract more energy from wind. At higher speed controller will keep rotational speed constant to halt the mechanical power to cross the design limit. Figure 2 shows the basic grid connected WECS control network

Optimum shaft speed is obtained by using Equation (10). Actuators are used put the blades in desired position. Pitch actuator system may contain mechanical as well as electrical system. Desired pitching value under normal winding condition is 0-5°. To avoid the extravagant load,2°/s is rate of increase in pitch angle during normal wind condition.

3.1 Based Control System for Wind Speed

Basic technique to change the pitch angle relies on getting reference pitch angle from input signal. Velocity curve between wind velocities vs. β is simplest method. This method completely depends on changing speed of wind. Because it is not feasible to exactly determine speed of wind, therefore this method in not appropriate. Figure 3 shows wind speed based control system.

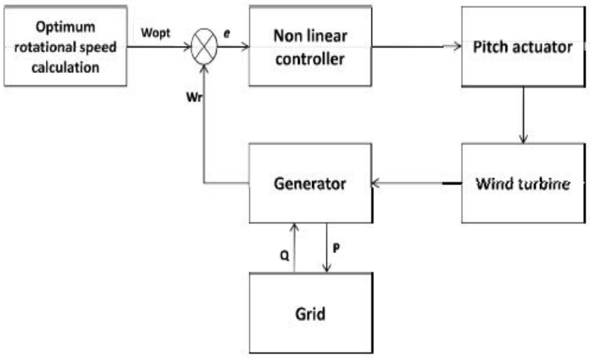


Figure 2. Pitch controlled WECS block diagram[2].

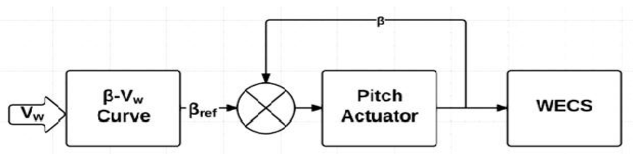


Figure 3. Wind speed based control system[1].

Power feedback control for generator. This methodology uses error signal among generator's nominal power and the produced power feedback. This fallacy signal is utilized as input to a PI controller. This will give pitch reference for pitch actuator.

$$B_d = k_p e_w + k_i \int e_w dt \quad (11)$$

Here e_w is fallacy signal among nominal power output and feedback of generator. The block diagram for this type of control system is shown in Figure 4.

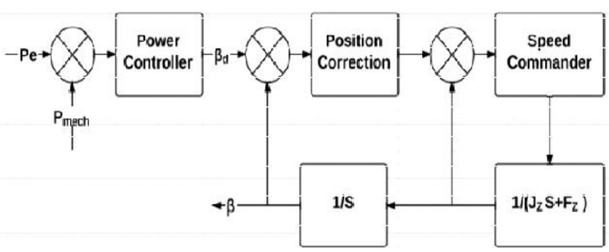


Figure 4. Generator power feedback pitch control block diagram[2].

3.2 Fuzzy Based Controller

Another and more suitable method of controlling is by fuzzy based logic controller. This method is best where system parameter fluctuates or not known. The major advantage of the fuzzy based controllers is that it does not necessitate accurate explanation of the model. This makes the designers and manufacturer to design the controller easily. There are many methodologies which are used to control the pitch angle of turbine but fuzzy based control systems are best control system to control the pitch angle. Although our main objective is to change the pitch angle to get maximum power even under the below rates speed. At the same instant it is remark that pitch angle deviation or variation must be smooth and gentle. It cannot be rapid. Rapid variation in the pitch angle may cause stalling of the generator. Error signals are being input from mean speed wind power and generator power in this control network.

Fuzzy control system block diagram is shown in Figure 5.

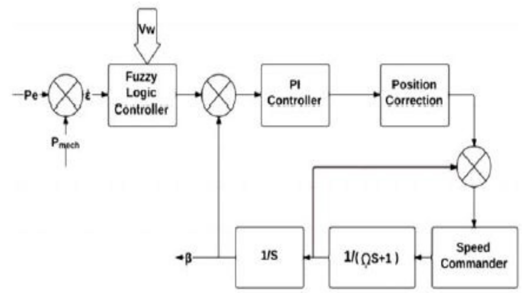
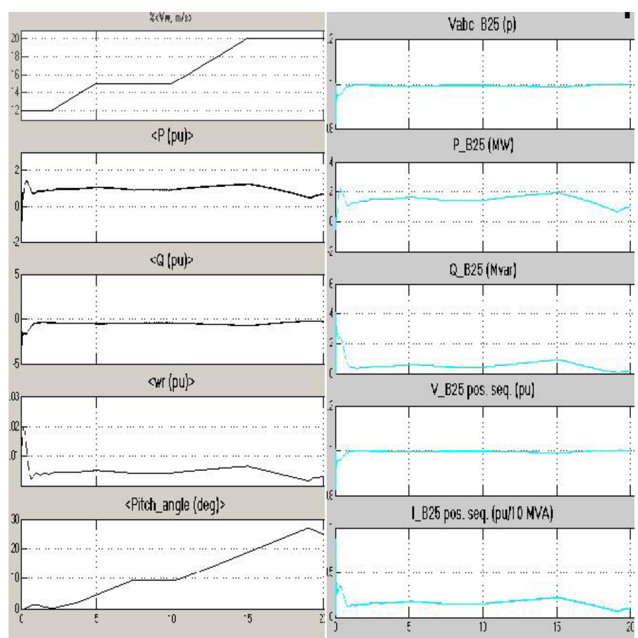


Figure 5. Fuzzy-PI controller block diagram[5].

4. Simulink Results

Figure 6(a) shows output power of the generator and Figure 6(b) shows grid components.



(a) (b)

Figure 6. (a) Output power of generator, (b) Grid positive sequence components.

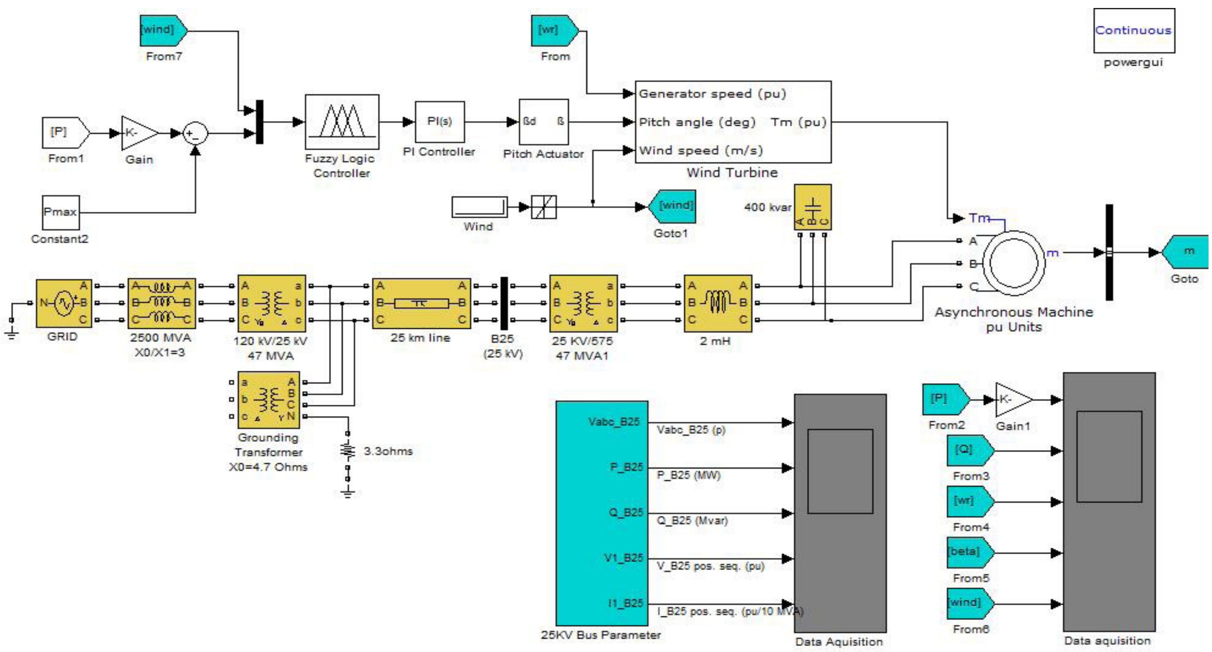


Figure 7. Simulation diagram of Fuzzy controller.

4.1 Simulataion Model of Fuzzy Based Control System

Figure 7 shows the simulation of Fuzzy controller.

5. Conclusion

In this paper, fuzzy based Proportional Integral control system for blade pitch angle is implemented. In this paper we analyzed the output power from wind turbine. Pitch angle of the turbine is controlled by Fuzzy controllers. But it is notice that the rapid change in the disparity of the pitch angle may cause the stalling of the induction generator. So by gentle imbalance of the pitch angle by the controller we can increase the output power of the wind turbine. The result of fuzzy based Proportional Integral is analogized with a classic Proportional Integral controller. It is observed that fuzzy based controller gives good operating condition for Wind Energy Conversion System combined with short transmission line. It is also found that transient response given by fuzzy base Proportional Integral control network is better than conventional PI controller.

6. References

1. Boukhezzar B, Lupu L, Siguerdidjane H, Hand M. Multivariable control strategy for variable speed variable pitch wind turbines. Renewable Energy. 2007; 32(8):1273–87.
2. Global Wind Power Production to Break 300,000 MW This Year Could Top 425,000 MW by 2015 [Online]. 2014. Available from: http://inhabitat.com/global-wind-power-production-to-break-300000-mw-this-year-could-top-425000-mw-by-2015/
3. Barakati SM, Kazerani M, Aplevich JD. Maximum power tracking control for a wind turbine system including a matrix converter. IEEE Transactions on Energy Conversion. 2009; 24(3):705-13.
4. El-Tous Y. Pitch angle control of variable speed wind turbine. American Journal of Engineering and Applied Sciences. 200; 1(2):118-20.
5. Hamane B, Benghanem M, Bouzid AM, Belabbes A, Bouhamida M, Draouf A. Control for variable speed wind turbine driving a doubly fed induction generator using fuzzy control. Energy Procedia. 2012; 18:476-85.
6. Boukhezzar B, Siguerdidjane H. Nonlinear control of variable speed wind turbines for power regulation. IEEE Conference on Control Applications Toronto; 2005. p. 114-9.
7. Senjyu T, Ochi Y, Kikunaga Y, Tokudome M, Muhando EB, Yona A. Output Power Leveling of Wind Generation System using Inertia of Wind Turbine. 2008. p. 1217-22.
8. S. Heier. Grid integration of wind energy conversion systems. 2nd ed. Chichester: John Wiley & Sons Ltd; 2006.