FUZZY AND PID BASED PITCH ANGLE CONTROL OF VARIABLE SPEED WIND TURBINES

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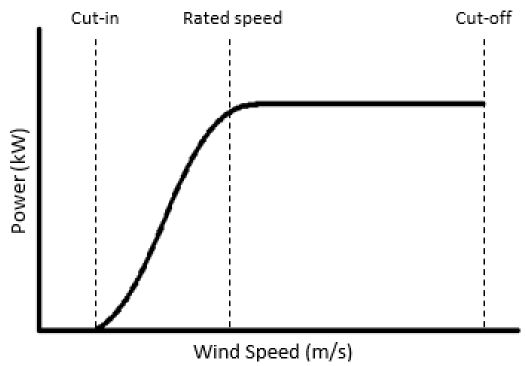
Abstract - *The process of obtaining electrical energy from kinetic energy present in the winds is the main idea behind the wind turbine. There are various types of control strategies that have been presented in many journals. The most common control strategy involved is the Pitch Angle control. The speed of the wind turbine must be kept in check to avoid damage. In this paper, a pitch angle based speed control mechanism is presented by using two different types of control systems- PID and Fuzzy Logic. A comparison between both the systems is also documented.*

Key Words: **Wind turbine, Pitch angle, PID control, Fuzzy logic control, Turbine speed control..**

1. INTRODUCTION

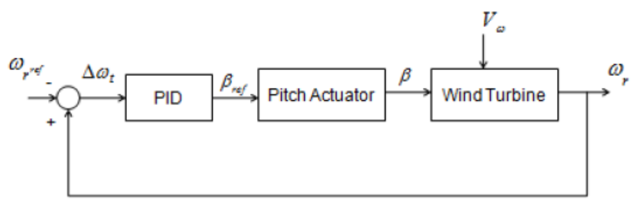
Wind is an inexhaustible source of energy and is growing rapidly in the efforts to make use of alternate source of energies is many parts of the world. If we analyze the wind power over a long period of time (a year), it can be considered as a consistent source. However, the lesser the time scale of analysis, the less consistent it is as a source of energy. In the recent years, renewable sources of energy like wind have been gaining significant importance. By the year 2016, the total amount of electricity generation in the world from wind amounts to 432,883 MW. When compared to the previous year, there was found a 17% growth. [1]

A common issue associated with wind is the damage that is caused to the turbine due to exceeding speed of wind. A lot of control strategies have been developed to avoid turbine damage from high speed winds. The most common type of control strategy used is pitch control mechanism. The variable speed wind results in different operation phases of the turbine. Optimum speed of wind is required for keeping the turbine free from damages. The curve that shows the operation phases comparing the power and wind speeds. The power-speed curve is shown in Fig. 1



2. MODEL OF WIND TURBINE

The wind turbine speed control systems consists of mainly three parts- the actuator, the controller and the turbine drive. A basic block diagram is as shown in the figure below



The main job of a pitch actuator is to adjust the blade's rotation along its longitudinal axis. The equation that represents the actuator is given by,

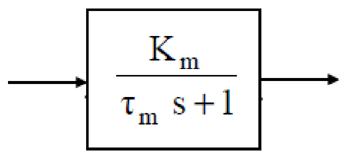
$$\frac{\delta\beta}{\delta t} = \frac{1}{\tau c}\beta_{ref} - \frac{1}{\tau c}\beta$$

Where β is pitch angle output from the actuator

β_{ref} is the reference pitch angle

τc is the pitch actuator time constant (the time constant value is taken as 0.5).

The block of Pitch Actuator is shown below:



For simpler design, the turbine drive is modelled using linearization method. The mathematical fundamental dynamics of the turbine can be given by the equation:

$$J_t\, \omega_t = T_w - T_m \text{ ---------- (1)}$$

Where, J_t= moment of inertia of turbine rotor

ω_t= angular shaft speed

T_m= mechanical torque

Now, the turbine equation (1) is linearized to get the below equation,

$$J_t\, \Delta\omega_t = \gamma\Delta\omega_t + \xi\Delta V_w + \delta\Delta\beta \text{ ------------ (2)}$$

Where γ, ξ, δ are linearization coefficients.

Laplace Transform of equation (2) is taken to get the below equation,

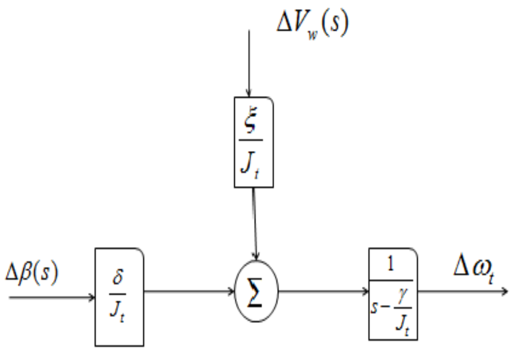
$$J_t\, s\, \Delta\omega_t = \xi \Delta V_w(s) + \gamma \Delta\omega_t + \delta \Delta U(s)$$

Let us assume $\frac{\gamma}{Jt}$ to be equal to Z

The turbine rotor speed can now be represented as,

$$\Delta\omega_t = [\frac{\xi}{Jt} \Delta V_w(s) + \frac{\delta}{Jt} \Delta U(s)]\, \frac{1}{s-Z}$$

The above equation is the linearized model of the wind turbine which can be represented as a block diagram shown in figure.



3. PID CONTROL

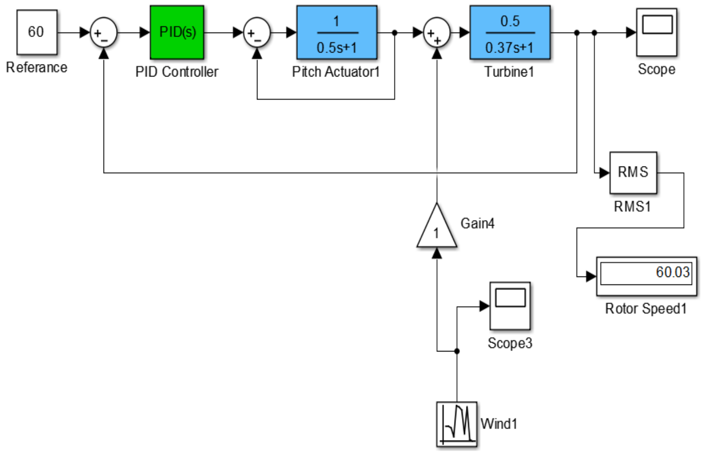
The wind turbine drive train model along with pitch actuator model shown in Section 3.2 and 3.3 together constitute the system model.

- PID control strategy is deployed on the system to get the desired speed output of the turbine.
- The input desired value of the speed of rotor is 60rpm.

The controller gives a changed value of the pitch angle that is given to the pitch actuator, the output of which goes into the wind turbine drive train to get the final rotor speed as system output.

- The wind input is given a value that has average speed 10m/s with a fluctuation of +-3m/s.

The system model is built in SIMULINK software and simulation are performed.

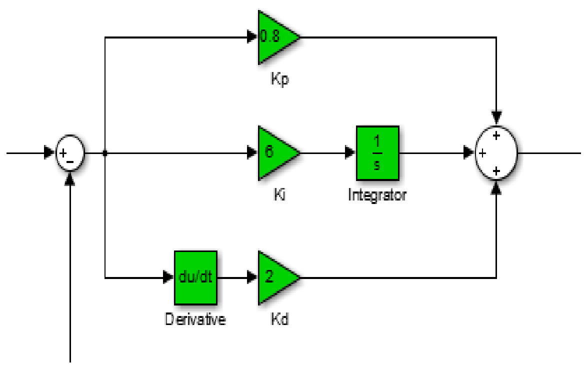


The values of the P, I and D gains are

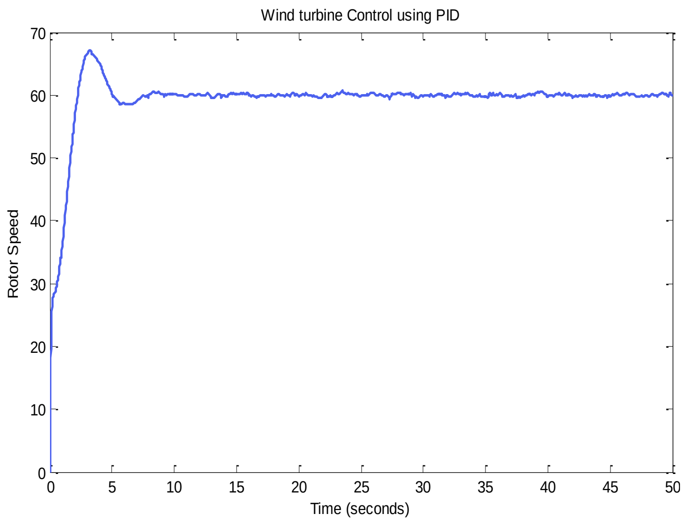
Kp = 0.8

Ki = 6

Kd = 2

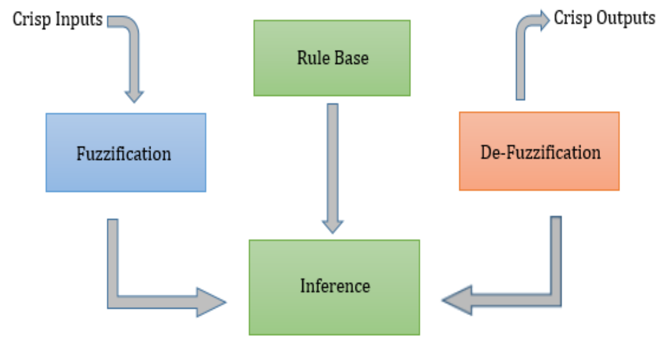


The output Rotor Speed is shown in figure below



4. FUZZY LOGIC CONTROL

Representation of fuzzy control operation is shown in the figure below.



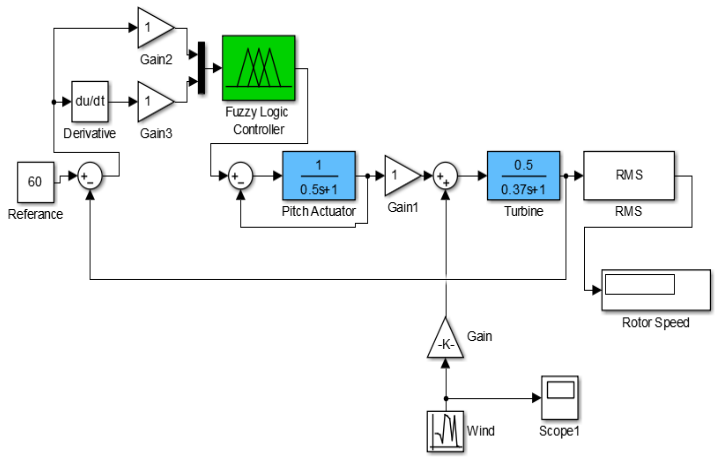
Fuzzification generally involves 2 steps: [2]

- To get the membership functions for input and output
- To represent them as linguistic variables.

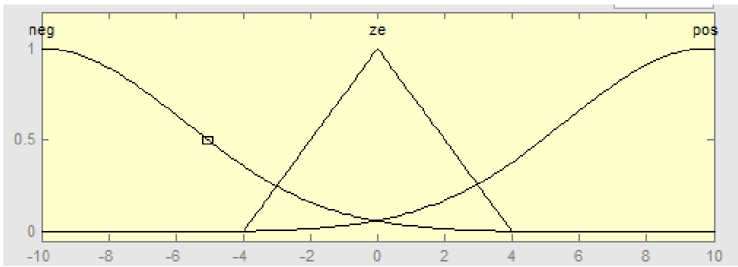
The process of defuzzification basically involves the process of converting the fuzzy outputs back to crisp outputs. The outputs that from the fuzzy system are linguistic variables that need to be converted into crisp values.

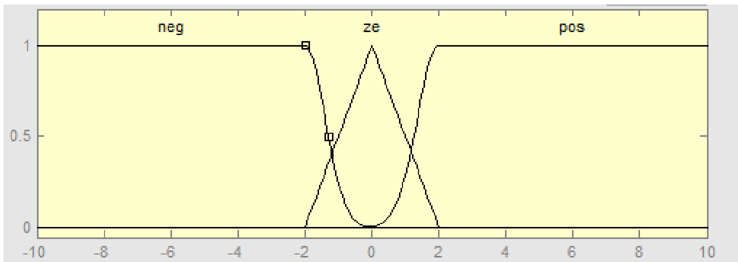
This process is done in the defuzzification step.

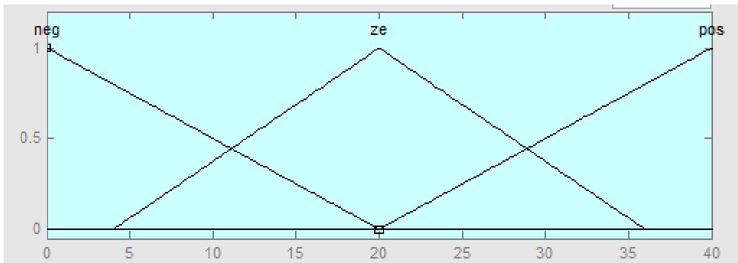
The wind turbine system along with Fuzzy controller is designed as shown below



The designed fuzzy controller has two inputs and one output. The inputs are error and change in error. The membership functions of the inputs and the output are shown in the figures below.







There are nine number of rules that are defined in the fuzzy controller. The Surface as well as the graphical view of the Fuzzy rules is shown in figures below.

1. If error is 'neg' and error change is 'neg', then output is 'neg'
2. If error is 'neg' and error change is 'ze', then output is 'neg'
3. If error is 'neg' and error change is 'pos', then output is 'ze'
4. If error is 'ze' and error change is 'neg', then output is 'neg'
5. If error is 'ze' and error change is 'ze', then output is 'ze'
6. If error is 'ze' and error change is 'pos', then output is 'pos'
7. If error is 'pos' and error change is 'neg', then output is 'ze'
8. If error is 'pos' and error change is 'ze', then output is 'pos'
9. If error is 'pos' and error change is 'pos', then output is 'pos'

The output rotor speed is shown below.

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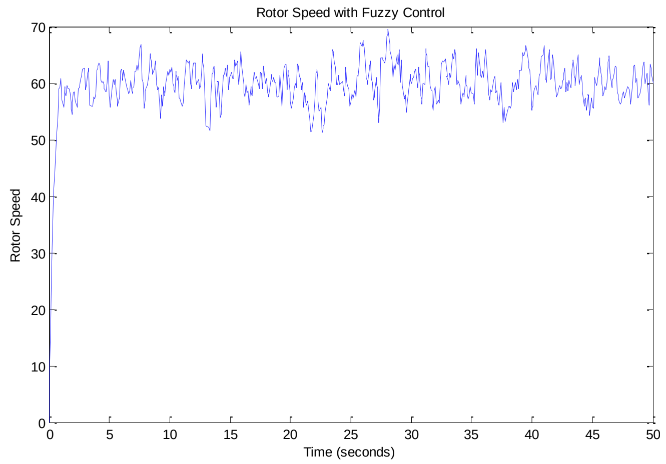
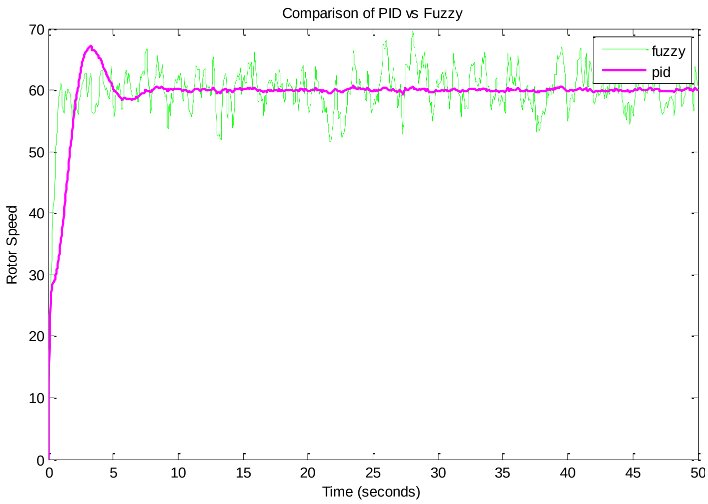


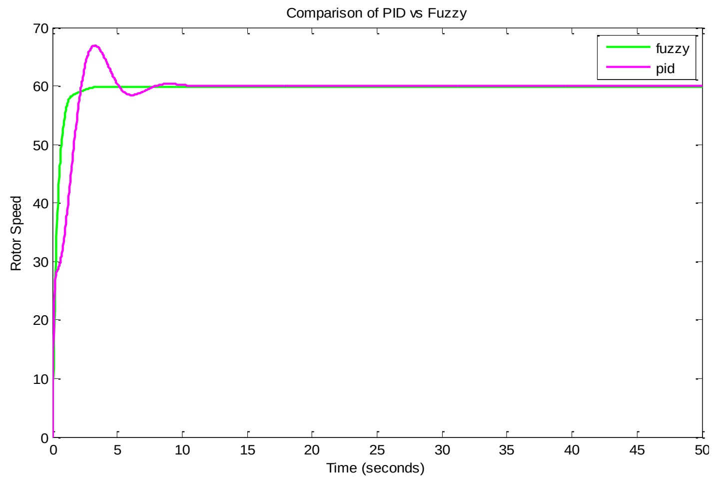
The irregularity is due to the changing wind speed. However, we can notice that the desired rotor speed has been achieved.

5. CONCLUSIONS

The simulations of the wind turbine with PID and Fuzzy control are designed and controlled. We find that PID controller has a faster response but the overshoot and the settling time is an issue. However, when fuzzy logic controller was incorporated into the system, the settling time was improved and overshoot was zero. Thus we can say that fuzzy logic controller proved better as compared to the classical PID controller. The desired rotor speed was obtained in both the systems but the one with fuzzy was better and a more stable system (as shown in comparison graphs).



If we do not consider the irregularities in the wind, the comparison graph can be seen as shown below:



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BIOGRAPHIES

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