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Modeling and Simulation of 1.5MW Wind Turbine

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Abstract:- In this paper we are going to design the wind turbine with the help of MATLAB software. The design of wind energy and stimulation with the help of MATLAB is getting very easy as compare to physical. In this we analyze the type of equipment used in this project for better output and getting high efficiency.

Keyword:- *Wind Turbine, Controller, Pitch Angle, Actuator, Power.*

I. INTRODUCTION

Wind energy is fastest growing demand in the world for the less costing wind energy, by optimizing the wind turbine component has been gaining the attaint ion for its improvement in design and its efficiency especially early stage of the designing. At various steps of the process, presenters isolate different systems for testing, and then integrate those changes into the on the whole system to calculate the impact on system presentation. In this scenario wind energy is fastest growing energy type due to its cost effective and easily aviability and most important pollution free energy conversion type. In wind energy design the turbine by means of our requirement i.e. the power output the speed of wind on that particular area where we want to install the plant and many more. We are discuss all the thing which is important in the designing of turbine. Most important goal when we design the turbine is accurate determination of structural dynamic and control which is directly related to the exhaustion life and cost of energy production. When we talk about the designing of wind turbine we focused on the control strategies. Here two type of control strategies for Pitch variable speed turbine. In low wind speed below a rated value the speed controller can frequently adjust the speed of the rotor to sustain the speed at a required level which gives the maximum power coefficient and then the efficiency of the wind turbine will be improved. Pitch

Angle regulation is required in condition above the rated wind speed when the rotation speed is constant. Small changes in pitch angle will affect the power output. The need pitch angle control is as follows

- Optimizing the wind turbine output, below the rated speed the pitch setting should be at it’s optimize value to give greatest power.
- Preventing the mechanical input to beat the limit which is designed. Above the rated wind speed pitch angle control provides an effective method of regulation the aerodynamic power and loads produced by the rotor.
- To reduce the fatigue load of the turbine mechanical component. Actions of the control system have a major impact on the load experienced by the turbine.

II. PITCH ANGLE WIND TURBINE MODEL

In a pitch angle control in wind turbine the controller of turbine checks the output of the time many times per second. When the power output cross their threshold value master controller send a actuating signal to the blade pitch controller after receiving the control signal controller quickly turns the rotor blade slightly out of the wind. On other side blades are turned back on their place when the speed of wind goes slow again. The relationship between electrical and mechanical power is shown in power curve. Hydraulic mechanism is used in pitch control.

The turbine have two type of speed first one is cut in speed, cut in speed is the speed at which our wind turbine start to move usually cut in speed is 3-5m/s. below the cut in speed turbine fails to move. Second is cut out speed, it is the speed at which wind turbine is getting stopped due to avoid damages because of high speed of wind 25 and above m/s is cut out speed.

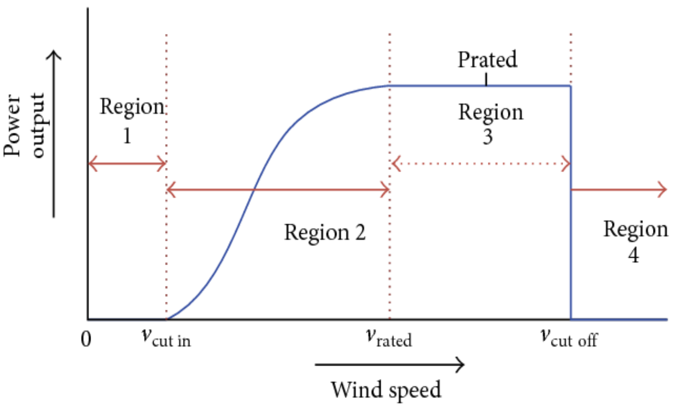

Fig 1. Theoretical power angle characteristic of wind turbine

All the work i.e stopping the turbine is programmed. Next is rated speed it is the speed at which turbine give maximum power(rated power), 12 to 16 is the rated speed. The efficiency is high near the rated speed.

III. WTG MODELING

WTG is the type of machine which extracts the mechanical energy from wind and convert into the electrical energy by means of various arrangement. The wind power equation is given by[1]

$P=\frac{1}{2}ʃ\ AV^3$ (Eq01)

Where ʃ = air density, $A=\pi r^2$ area of swept by turbine, V= velocity of wind. The efficiency of WTG is about 59%. The power conversion limit is termed as Betz limit. The power extracted from wind turbine blade in terms of pitch angle (β), blade tip speed ratio (ƛ). The power coefficient (c_p) variation curve is given by blade tip ration[6]. The power extracted by wind is denoted by non linear equation[5]

$P_{wt}=\frac{1}{2}ʃ\ AV^3C_p(\beta,ƛ)$ (Eq-2)

$C_P=0.5176(\frac{116}{ƛi}-0.4\beta-5)e^{\frac{-21}{ƛi}}+0.0068ƛ$ (Eq-03)

Where $\frac{1}{ƛ}=\frac{1}{ƛ+0.08\beta}-\frac{0.035}{\beta 3+1}$ (Eq-4)

The tip speed ratio is defined as the ratio between the blade tip seed and wind speed

$ƛ=\frac{\omega wtR}{V}$ (Eq-5)

Where W_{wt} = tip speed ratio
R = radius of the turbine

Therefore any change in speed of rotor or the wind speed induces a change in the tip ratio principal to power coefficient difference. This type of control strategies is very useful in this method the wind turbine getting stopped by change the speed or getting high speed i.e violet the limits which is programmed. In other word turbine is stopped when speed is exceeding cutout airstream speed by means of safety consideration[5]

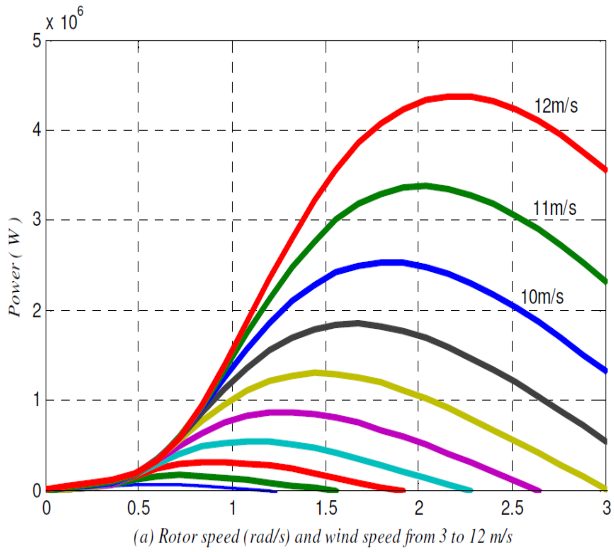

Fig 2 rotor speed vs wind speed

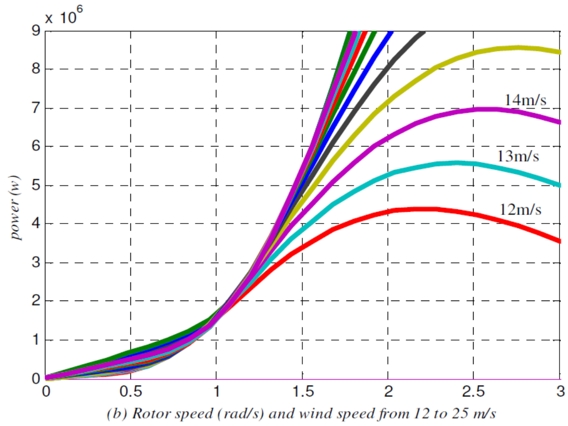

Fig.3. wind power vs rotor speed

IV. ACTUATOR MODEL

The proportional integral controller is generally used in wind turbine for pitch control. Although for its simplicity PI controller may not achieve the intended optimum performance due to non linear dynamics with WTG. The actuator model contain hydraulic and mechanical system with is work on the actuating signal. This model describe the behavior between the pitch require from the pitch controller and calculated pitch angle. It consists of non linear equation with a saturation limit which is cause by high frequency component present in system on both factors.

The change in pitch angle

$\beta=\frac{\beta r-\beta}{\tau\beta}$ (Eq-6)

(Eq-06)

where β_r = required pitch angle, τ_β= time constant. By using Laplace transform we get the transfer function as below

$\frac{\beta}{\beta r}=\frac{1}{\tau\beta s+1}$ (Eq-7)

V. PI CONTROLLER

Generally we used PI controller in wind turbine system for the easy and achieved our desired output. Wind turbine generated system is very sensitive system for this we have to use the accurate controller. When we use controller the output of controller is β_r(desired pitch angle). The required pitch angle is expressed as

$\beta_r=K_pe+K_i\int edt$ (Eq-8)

where

$e=\omega_{mreference}-\omega_m$ (Eq-9)

$\omega_{m=}$ angular speed

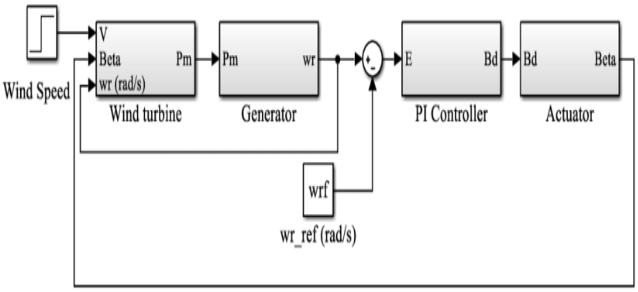

Fig 4 PI controller

On solving equation 8 we get

$$\frac{d\beta r}{de} = K_p + Ki\frac{e}{de/dt} \qquad \text{(Eq-10)}$$

For variable slip generator, the range of e is narrow and K_p is greater than K_i. so we can neglect the K_i and above equation can be written as

$$K_p = \frac{d\beta r}{de} \qquad \text{(Eq-11)}$$

For simplicity take the initial value and time constant is 1 second then the transfer function is

$$\frac{\beta}{\beta r} = \frac{1}{s+2} \qquad \text{(Eq-12)}$$

In the steady state response we can calculate the K_P and K_i by using above equations

$$K_p = \frac{2\beta}{\omega m\ ref - wm} \qquad \text{(Eq-13)}$$

$$K_i = \frac{1}{\omega\ reference - \omega m} \cdot \left(\frac{2\beta}{\omega m\ reference - \omega m} - K_p \right) \frac{\delta\Delta\omega}{\delta t}$$

(Eq-14)

VI. CONCLUSION

In this paper we see the how a wind turbine is modeled and the control strategies. Pitch angle control is used for smooth controlling and PI controller is used to identify a small change. We also discuss the cut in and cut out speed of the turbine. The main focus on this is the controller used in it is sensitive. We also observe the power output w.r.t. wind speed.

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