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Implementation of Pitch Control Of wind Turbine Using Simulink (Matlab)

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Abstract— **In this paper, it is shown that how the variable speed wind turbine can be used to generate a fixed value of voltage at the output with the help of a pi controller and it is done by varying the pitch angle of the blades Pitch angle control is the most common means for adjusting the aerodynamic torque of the wind turbine when wind speed is above rated speed and various controlling variables may be chosen, such as wind speed, generator speed and generator power. As conventional pitch control usually use PI controller, the mathematical model of the system should be known well. The block diagram of the proposed speed control system which consists of speed controller, actuator model and the turbine linearized model is simulated by Matlab-Simulink software package. the simulation results show that the controller accurately adjusts the blade pitch angle to set the wind turbine power output to its reference value.**

A rotor swept area
Cp aerodynamic coefficient of performance
ρ air density
α angle of attack
β pitch angle of the blade
λ tip-speed ratio
ω rotor-speed

Index Terms— **PI Controller, Speed control ,variable speed wind turbine. Wind Turbine**

I. Introduction

Wind power has become one of the most attractive energy resources for electricity production as it is virtually pollution-free. power system involves high performance As a result, a great deal of research has been focused on the development of new turbine design to reduce the costs of wind power and tomake wind turbines more economical and efficient. The investigation of wind wind turbine simulators, especially for the development of optimal control solutions. There are usually two controllers for the variable-speed wind turbines which are cross-coupled each other, In low wind speed below rated value, the speed controller can continuously adjust the speed of the rotor to maintain the tip speed ratio constant at the level which gives the maximum power coefficient, and then the efficiency of the turbine will be significantly increased.

Variable-speed wind turbines offer improved energy capture over constant-speed machines because of the increased range of wind speeds under which maximum power can be generated. Rotor speed must be regulated to achieve maximum aerodynamic efficiency to ensure that mechanical limitations are not exceeded in high winds .Rotor speed can be controlled by either regulating the generator torque or manipulating the blade pitch angles. The advantage of blade pitch actuation is that aerodynamic loads are controlled directly without undesirable transmission through the drive train and turbine structure. In this paper, we deal solely with control via individual blade pitch. Pitch angle regulation is required in conditions above the rated wind speed when the rotational speed is kept constant. Small changes in pitch angle can have a dramatic effect on the power output.

Work Objective

The main objective of this work is to contribute to the topic of wind energy systems modelling and control by developing an accurate model for a wind turbine and based on this model contemplate control issues. The scientific objectives of this research include the following:

· Modelling and dynamic behaviour investigation of the aerodynamic,mechanical and electrical parts of a variable speed wind turbine equipped with an induction generator and blade pitch angle control.

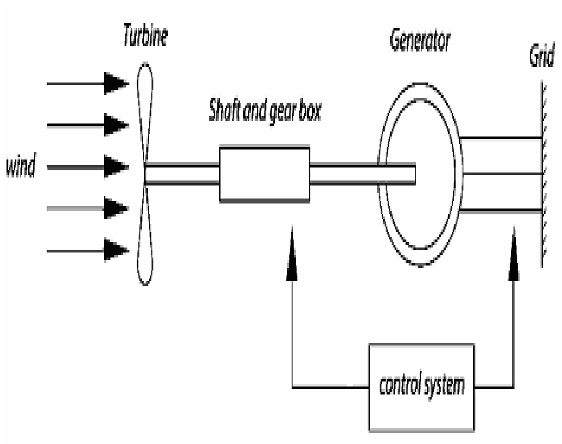
· Simulation of the overall wind energy system .

SOFTWARE USED

The computer model for this paper was created in a software package called Simulink, which is the control systems software component of MATLAB, a MathWorks, Inc. software package. “Simulink is a software package for modeling, simulating, and analyzing dynamic systems, it supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two” . Unlike most programming packages, “Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations” . With this interface, modelers can draw models just as they would on paper. In addition, “Simulink includes a comprehensive block library of sinks, sources, linear and nonlinear components, and connectors” (The MathWorks, Inc, 2002 b). Another feature of Simulink is that programmers can customize and create their own blocks. Included in the library of customizable blocks are a series of subsystem blocks. Programmers can use these blocks to consolidate their models by condensing several linked blocks into one subsystem block, hence creating hierarchical structures in the computer models. After creating a model, the user can simulate it using a choice of integration methods, including standard techniques or specified custom approaches.

TYPICAL WIND TURBINE GENERATOR

The basic components involved in the representation of a typical wind turbine generator are shown in Figure



Components of a typical wind system

An entire wind energy system can be sub divided into following components:

1. Model of the wind,
2. Turbine model,
3. Shaft and gearbox model,
4. Generator model and
5. Control system model.

The first three components form the mechanical part of the wind objectives of this research include the following objectives of this research include the following turbine generator. The generator forms the electro-mechanical link between
the turbine and the power system and the control system controls the output of the generator. The control system model includes the actuator dynamics involved, be it the hydraulics controlling the pitch of the blades, or the converters controlling the induction generator.

DYNAMIC MODELING OF THE WIND TURBINE

The wind turbine is characterized by no dimensional curves of the power coefficient (Cp) as a function of both the tip speed ratio(λ) and the blade pitch angle(B). In order to fully utilize the available wind energy, the value of (λ) should be maintained at its optimum value. Therefore, the power coefficient corresponding to that value will become maximum also.

Tip ratio

The tip speed ratio (λ) can be defined as the ratio of the angular rotor speed of the wind turbine to the linear wind speed at the tip of the blades. It can be expressed as follows:

$$\lambda=\omega_t R/V_w$$

Where R is the wind turbine rotor radius, V_w is the wind speed and ω_t is the mechanical angular rotor speed of the wind turbine. The output power of the wind turbine, can be calculated from the following equation

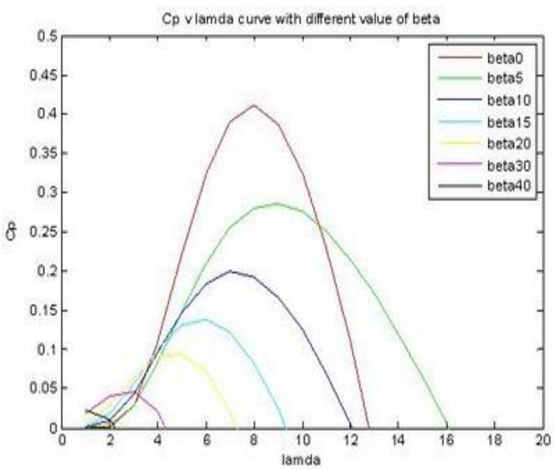
$$P_m=1/2*\rho\ A\ C_p\ V^3_m$$

Then, the aerodynamic torque, Tm can be written as

$$T_m = ½*\rho\ A\ R\ Ct\ V^2_m$$

Where C_t *i*s the torque coefficient which is given by $C_t= C_p/\lambda$

POWER COEFFICIENT VS TIP SPEED RATIO CURVE WITH DIFFERENT VALUE OF PITCH ANGLE



Where,
Lamda = Tip speed ratio
Beta = Pitch angle
Cp = Rotor power coefficient

COEFFICIENT OF POWER (CP)

The coefficient of power of a wind turbine is a measurement of how efficiently the wind turbine converts the energy in the wind into electricity.

By now you already know how to calculate the amount of electricity a wind turbine is producing, and you also know how to calculate the total power available in a given area of wind. To find the coefficient of power at a given wind speed, all you have to do is divide the electricity produced by the total energy available in the wind at that speed.

$$Cp = \frac{\text{Electricity produced by wind turbine}}{\text{Total Energy available in the wind}}$$

For most of the wind turbines the value of C_p is 0.59.

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PITCH ANGLE AS A CONTROL VARIABLE

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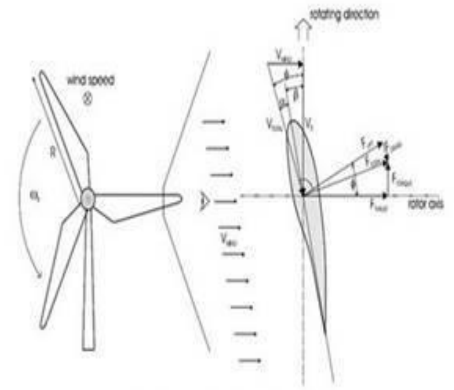
- The Cp (λ, β) characteristic gives us a power coefficient, that depends on the tip speed ratio λ and the pitch angle β .

- For blade profiles two forces are generally used to describe the characteristics, lift force component (F_{LIFT}) and a drag component (F_{DRAG}) which resulting as F_{TOTAL}.

- The F_{LIFT} component and a F_{DRAG} together are transformed into a pair of axial F_{THRUST} force and rotor's directions F_{TORQUE} components, where only the F_{TORQUE} produces the driving torque around the rotor shaft. By varying the pitch angle, β the size the direction of F_{TOTAL} components can be changed.

- The axial forces F_{THRUST} has no driving effect but puts stress on rotor blades and furthermore, leads to a thrust on the nacelle and on tower.

AERODYNAMIC FORCES AND VELOCITIES AT ROTOR BLADE



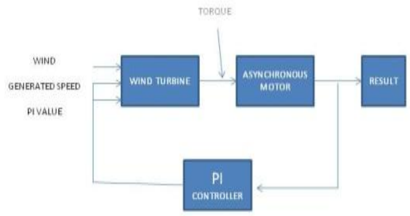
Blade system

NEED OF PITCH CONTROLLER

- Because of the fluctuating nature of the wind speed the output of the wind turbine varies.
- At the high wind speed, fatigue damage can be occurred to the mechanical parts of the wind turbine.

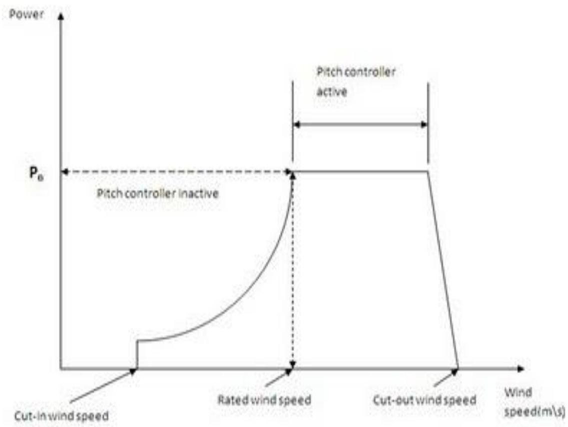
- By controlling the pitch angle the output power can be limited as the wind turbine rotor power coefficient decreases with the increase of pitch angle.
- At the high wind speed the automatically activated pitch controller keep the output power within rated level by increasing the value of pitch angle.

BLOCK DIAGRAM



Wind turbine scheme with pi controller

OPERATIONAL WAVE SHAPE



MATHMATICAL EXPRESSIONS

The mechanical output power equation is given by,

$$P_a = \frac{\rho}{2}\pi R^2 C_p(\lambda,\beta) WS^3$$

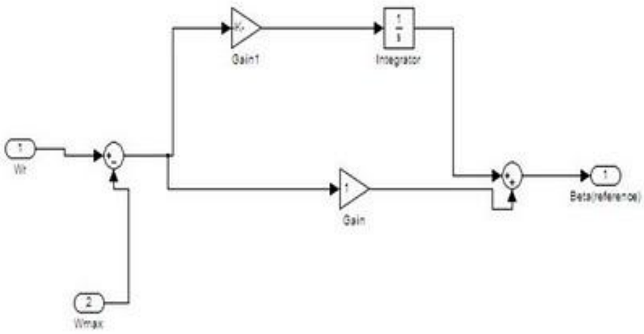
And the expression for power coefficient is given by,

$$c_p = 0.5\left(\frac{116}{\lambda_i} - 0.4\beta - 5\right)e^{\frac{-21}{\lambda_i}}$$

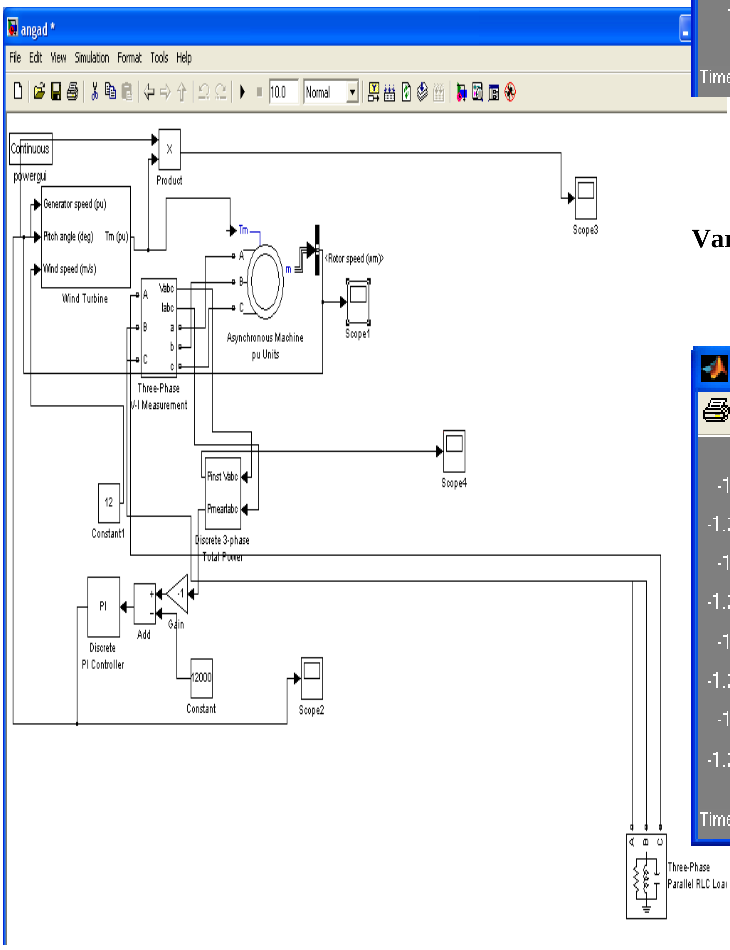
Where,

$$\lambda_i = \frac{1}{\lambda + 0.088} - \frac{0.035}{\beta^3 + 1}$$

SIMULINK MODEL OF PI CONTROLLER



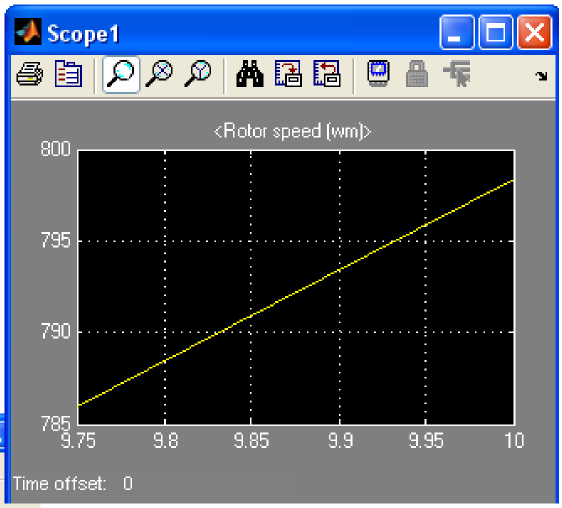
SIMULINK BLOCK OF WIND TURBINE MODEL



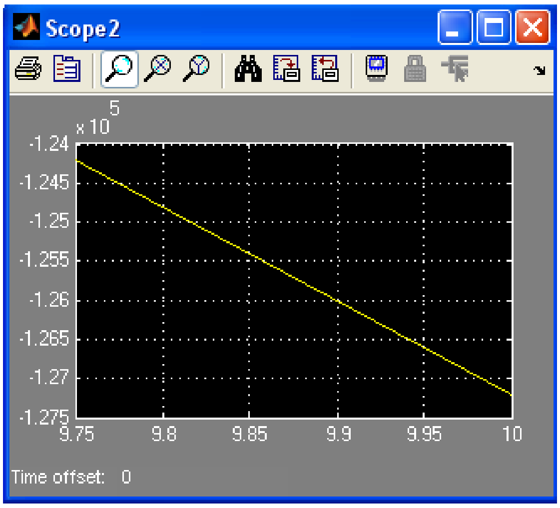
SIMULATION RESULT

The simulation results obtained from the MATLAB/SIMULINK wind turbine model are given below(for various wind speed)

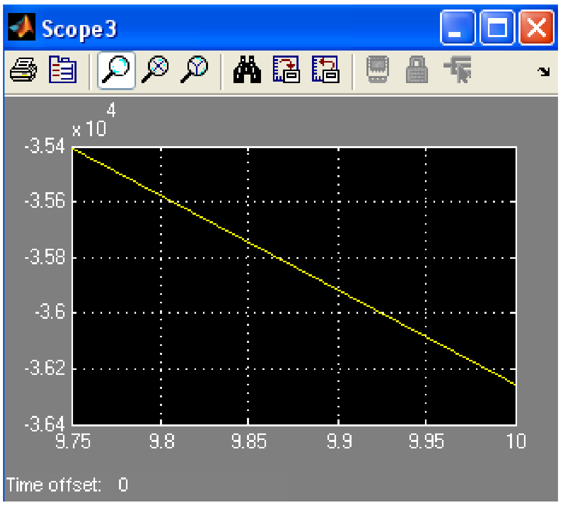
Variation of Rotor Speed



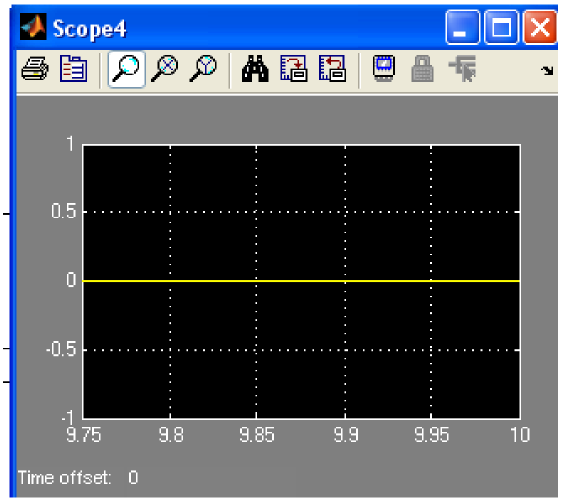
Variation of PI Controller



Variation of Pitch



Constant value of Output



CONCLUSION

Thus by using pitch controller the output power has been limited at variable wind speed and wind turbine can operate safely. The results are taken at the values which are inherent in the simulink blocks and from the simulink results it is clear that as the wind speed changes then their is a corresponding change in the values of rotor speed ,PI controller, Pitch angle to maintain the output at some constant value.

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