Introduction and Controlling of Wind Turbine in Wind Energy Conversion System

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Abstract - *The present scenario of India is total wind power generated about 37 GW. This is possible by better monitoring and controlling of wind turbine by power electronics devices and recent controlling technologies. in this paper wind turbine main component of wind turbine, its types are represented and different controlling method discuss for maximum efficiency. the non conventional energy resource are used to promote low carbon energy in India to maintain our economical as well as ecological system. In wind turbine the output torque and power depends on the incoming wind speed. Due to the rapid changes in the incoming wind speed the quality of output power becomes a serious problem. Many controls are introduced in wind turbines in order to get a constant output rated power. In this research work we have focused on dynamic analysis and Pitch control of horizontal axis wind turbine. Pitch control is one of the most useful and important control that is present in all of the current wind turbine models*

Key Words: WECS, Wind Turbine, Controlling of Wind Blade.

1. INTRODUCTION

Energy is the considered to be the pivotal input for development. At present owing to the depletion of available conventional resources and concern regarding environmental degradation, the renewable sources are being utilized to meet the ever increasing energy demand . Due to a relatively low cost of electricity production wind energy is considered to be one of the potential sources of clean energy for the future[1] . But the nature of wind flow is stochastic. So rigorous testing is to be carried out in laboratory to develop efficient control strategy for wind energy conversion system(WECS). The study of WECS and the associated controllers are, thus, becoming more and more significant with each passing day. Nowadays, many of asynchronous machine is that the variable speed operation allows extracting maximum power from WECS and reducing the torque fluctuations. Induction generator with a lower unit cost, inherent robustness, and operational simplicity is considered as the most viable option as wind turbine generator (WTG) for off grid applications[2-3].

2. MAIN COMPONENT OF WIND TURBINE

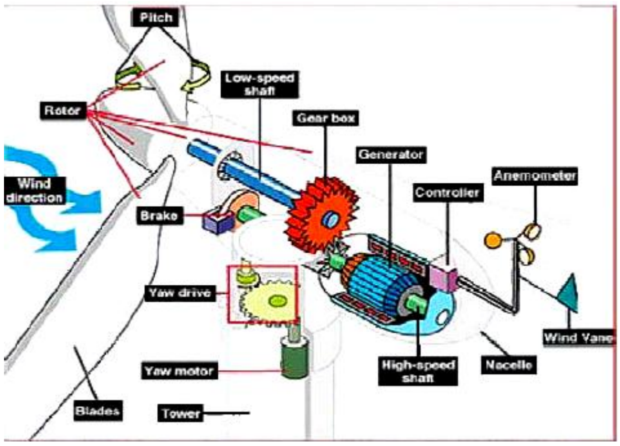

Figure.1: Wind turbine block Diagram

- ✓ ***Anemometer:*** This device is used for measurement of speed. The wind speed is also fed to the controller as it is one of the variables for controlling pitch angle and yaw

- ✓ ***Blades:*** These are aerodynamically designed structures such that when wind flows over them they are lifted as in airplane wings. The blades are also slightly turned for greater aerodynamic efficiency.

- ✓ ***Brake:*** This is either a mechanical, electrical or hydraulic brake used for stopping the turbine in high wind conditions.

- ✓ ***Controller:*** This is the most important part of the turbine as it controls everything from power output to pitch angle. The controller senses wind speed, wind direction, shaft speed and torque at one or more points. Also the temp of generator and power output produced is sensed.

- ✓ ***Gear box:*** This steps-up or steps down the speed of turbine and with suitable coupling transmits rotating mechanical energy at a suitable speed to the generator. Typically a gear box system steps up rotation speed from 50 to 60 rpm to 1200 to 1500 rpm.
- ✓ ***Generator:*** This can be a synchronous or asynchronous Ac machine producing power at 50Hz.
- ✓ ***High-speed shaft:*** Its function is to drive the generator.
- ✓ ***Low-speed shaft***: The rotor turns the low-speed shaft at about 30 to 60 rotations per minute.
- ✓ ***Nacelle:*** The nacelle is the housing structure for high speed shaft, low speed shaft, gear box, generator, converter equipment etc. It is located atop the tower structure mostly in the shadow of the blades.
- ✓ ***Pitch:*** This is basically the angle the blades make with the wind. Changing the pitch angle changes weather the blades turn in or turn out of the wind stream.
- ✓ ***Rotor:*** The hub and the blades together compose the rotor.
- ✓ ***Tower:*** Towers are basically made up of tubular steel or steel lattice. Taller the towers greater is the amount of power generated as the wind speed generally goes on increasing with height.
- ✓ ***Wind direction***: Generally erratic in nature, hence the rotor is made to face into the wind by means of control systems.
- ✓ ***Wind vane***: Basically the job of a wind sensor, measuring the wind speed and communicating the same to the yaw drive, so as to turn the turbine into the wind flow direction.
- ✓ ***Yaw drive***: This drive controls the orientation of the blades towards the wind. In case the turbine is out of the wind, then the yaw drive rotates the turbine in the wind direction[4-5].

3. TYPES OF WIND TURBINE

Wind turbine are classified into two broad category on the basis of their structure.

- ➢ Horizontal Axis wind turbine (HAWT)
- ➢ Vertical Axis wind turbine (VAWT

A. HORIZONTAL AXIS WIND TURBINE (HAWT):

Horizontal-axis wind turbines (HAWT) get their name from the fact that their axis of rotation is horizontal. They have the main rotor shaft and electrical generator at the top of a tower, and are pointed into the wind. The variability of wind distribution and speed brings up the requirement of a gear system connected to the rotor and the generator. The gear system enables a constant speed of rotation to the generator thus enabling constant frequency generation. Turbine blades are made stiff in order to prevent the blades from being pushed into the tower by high winds. Downwind machines have also been built, as they no longer require a yaw mechanism to keep them facing the wind, and also because in high winds the blades can turn out of the wind thereby increasing drag and coming to a stop[6]. Most of the HAWTs' are upwind as downwind systems cause regular turbulence which may lead to fatigue.

HAWT Advantages

- ➢ Variable blade pitch, which gives the turbine blades the optimum angle of attack.
- ➢ Changing the angle of attack provides greater control over power generated and enables maximum efficiency.
- ➢ As wind energy increases with height, the tall tower in the HAWT gives access to higher wind speed. In some cases increase of even 10m height leads to increase in wind speed by 20 %
- ➢ In HAWTs' the blades move horizontally that is perpendicular to the wind and hence have minimum drag and they receive power throughout the rotation.

HAWT Disadvantages

- ➢ Due to inherent large structures, construction costs are very high and so are transportation costs.

- Civil construction is costly due to erection of large towers.
- Wind turbine operation often leads to production of electronic noise which affects radar sites.
- In case of downwind HAWTs' the regular turbulence produced leads to structural failure.
- HAWTs require an additional yaw control mechanism to turn the blades toward the wind.

B. VERTICAL AXIS WIND TURBINE (VAWT)

Vertical-axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically as the plane of rotation is vertical. Blades are also vertical in this arrangement. The biggest advantage of VAWTs is they don't require a yaw control mechanism to be pointed into the wind. Thus these are useful in sites where wind direction is random or there is presence of large obstacles like trees, houses etc. Also VAWTs' don't require a tower structure and can be placed nearby a ground enabling access to electrical components. Some drawbacks are the low efficiency of wind production and the fact that large drag is created for rotating the blades in a vertical axis[7-8].

VAWT advantages:

- A massive tower structure is not required, as VAWTs' are mounted closer to the ground
- They don't require yaw mechanisms.
- These are located closer to the ground and hence easier to maintain.
- These have lower start up speeds than their horizontal counterparts. These can start at speeds as low as 10Kmph.
- These have a lower noise signature.

VAWT disadvantages

- VAWTs' have lower efficiency as compared to HAWTs' because of the additional drag produced due to rotation of blades.
- Even though VAWTs' are located closer to the ground, the equipment now resides at the bottom of the turbines structure thus making it inaccessible.
- Because of their low height they cannot capture the wind energy stored in higher altitudes.

4. STRUCTURE OF WIND ENERGY SYSTEM

In a wind energy conversion system, the wind turbine converts the kinetic energy of the wind into the rotational energy; this rotational energy rotates the generator[9].

The wind nature either is constant speed or variable speed. The power fluctuation caused by the variable wind speed which can be reduced by using power electronic equipments such as converters with BESS, (Battery Energy Storage System)

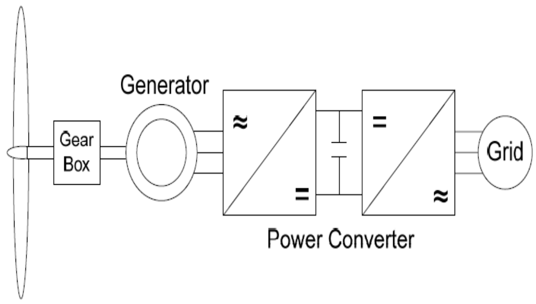

Figure.2. Wind Turbine with Induction Generator

Figure.2. shows the constant speed wind turbine which consists of induction generator. In this, the wind turbine is connected to the induction generator through the gear box and the pitch control technique is used to maintain the maximum speed.

5. CONTROL OF THE WIND TURBINE

There are many results on wind turbines control from the aerodynamic to generator energy. In this paper, we only discuss the horizontal axis wind turbine and doubly fed induction generator (DFIG).This type of wind turbine is the most used in the market [1]. The performance of the wind turbine depends not only on hardware, also on the wind turbine control technique [10]. The main control objectives of the wind turbine are as follows [11-12]:

(i) capture the wind power as possible as it can,

(ii) Maximize the wind harvested power in partial load zone,

(iii) Guarantee a certain level of resilience of the mechanical parts by alleviating the variable loads,

(iv) Meet strict power quality standards (power factor, harmonics, flicker, etc.),

(v) Transfer the electrical power to the grid at an imposed level in wide range of wind velocities.

The control system has three subsystems: aerodynamic control, variable speed control, and grid connection control; see Figure 3. In the following sections several popular control techniques will be discussed [13].

A. AERODYNAMIC CONTROL

The wind turbine aerodynamics are very similar to the airplane. The blade rotates in the wind, because the air flowing along the surface moves faster than the upwind surface. This creates a lifting force to remove the sheet to rotate [14]. The attack angle of the blade plays a critical role in determining the amount of force and torque generated by the turbine. Therefore, it is an effective means to control the amount of power. There are three methods to aerodynamically control for large wind turbines: passive stall, active stall, and pitch control.

(i) Passive stall control: The blade is fixed on the rotor hub in an optimum (nominal) attack angle. When the wind speed is less than or equal to the nominal value, the turbine blades with the nominal attack angle capture the maximum possible power wind. With wind speed above the nominal value, the strong wind can cause turbulence on the surface of the blade, which faces away from the wind. As a result, the lifting force is reduced and eventually disappears with increasing wind speed by reducing the speed of rotation of the turbine. This phenomenon is called stall. The passive stall control does not need complex pitch mechanisms; however, the blades need a good aerodynamic design.

(ii) Active stall control: The stall phenomenon can be induced not only by higher wind speeds, but also by increasing the attack of the blade. Thus, active stall wind turbines have blades with adjustable pitch control mechanism. When the wind speed exceeds the rated value, the blades are controlled towards the wind to reduce the captured power. Consequently, the captured power can remain at the nominal value by adjusting the blade angle of attack.

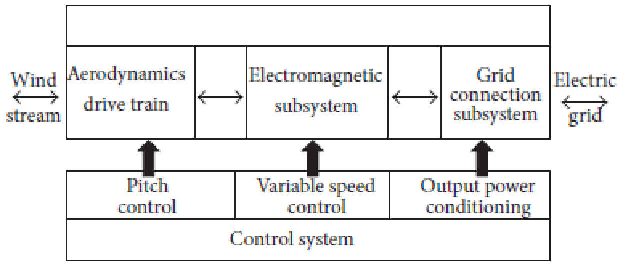

Figure.3.Aerodynimic control block diagram

(iii) Pitch control: for the light and medium wind, the pitch control can optimize the operation of the wind turbine in the sense of maximizing rotor power. For the strong wind that exceeds the nominal level, pitch control maintains a desired operating condition [15]. The optimization operation by the pitch control can increase rotor power up to 2% [16]. This accuracy of the pitch angel is important but is not relevant for the stability investigations of short-term stress. Therefore, the steady-state angle of inclination can be adjusted to zero when the incoming wind is below the normal level. For strong wind, the steady-state angle is greater than zero and increases with increasing wind speed. Similar to the active stall control, the wind turbines with pitch control have adjustable blade in the rotor hub. When wind speed exceeds nominal value, the pitch controller reduces the attack angle, turning the blades (pitching) from wind gradually. The difference pressure in front and in the rear of the blade is reduced. The pitch control reacts faster than active stall control and provides better controllability.

B. LINEAR CONTROL

Since the drive train is very rigid, its train dynamics do not need to be included. Furthermore, the drive system used in the turbine pitch is very fast. The actuator dynamics are not required. Without considering viscous damping, the dynamic of the direct drive turbine is as follows [16-17]:

$$T\text{aero} - T\text{gen} = I\,\dot{\omega}$$

where Taero is the aerodynamic torque generated by the rotor, Tgen is the generator torque, I is the inertia of the rotating system, and $\dot{\omega}$ is the rate of change of rotor speed. Considering Tgen as a constant in the power regulation region, [18]

$$T\text{aero} = I\,\dot{\omega}$$

The aerodynamic torque change depends on the change in wind speed, the change in the pitch angle of the rotor blades, and also the change at the current operating point of the turbine. For this representation of the turbine dynamics, the transfer function of the change rate of aerodynamic torque to the rotor speed is a double integrator. It is scaled by the inverse of the rotational inertia. Thus, this linear system is the control model

C. INTELLIGENT CONTROL

Neural control for the wind turbine is shown in Figure 13. Here the adaptive controller has the learning ability [50–53/19-21]. The objective is to train the neural network so that the controller will allow the plant to produce the desired result. To accomplish this, the neural network must be trained so that the input error $\varepsilon\ p = (t) = Pref - Pw = x(t) - xn$
(t) produces the proper control parameter $TA=(t)$to be applied to the plant to produce the aerodynamic power$Pw = xn(t)$.
Fuzzy control for the wind turbine is shown in Figure 14. $\varepsilon p = \Delta Q = Pref - Pw = Q* - Q$ is the tracking error, $Pref = Q*$is the reference, $Pw = Q$is the aerodynamic power, and $TA=Vdr*$ is the control input. Here each input is evaluated by the triangular or trapezoidal membership functions [48, 55–57].The degree of membership of the fuzzy sets is associated with each input. The defuzzification is obtained by averaging each output membership function [22]. In each input/output variable that is used in the controller design is expressed in fuzzy set using linguistic variables. Seven linguistic variable are used for LLP, CII, and the flow change rate. The rules are expressed by IF-THEN rules. The defuzzification uses the canter gravity technique.

D. GENERALIZED PREDICTIVE CONTROL.

Model predictive control (MPC) usually represents the behaviour of complex dynamic systems. It is also applied to the wind turbines. It appears in the form of generalized predictive control (GPC) [23] and bias estimation model (BEM). GPC uses the estimations of future output to calculate current control [11]. A discrete model of wind turbine is shown in Figure 15. It is a finite difference approximation of the double integrator model. Here Δp is the change in the angle of the blade pitch, Δv is the wind speed change, and ω is the rotor speed. The coefficients b and c are obtained by a recursive least squares filter. This model can predict the rotor speed with varying ratios and wind speed. The coefficients b and c increase with the wind speed increasing.

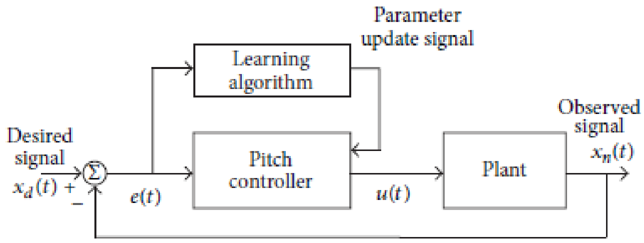

Figure.4. Neural network controller

6. CONCLUSIONS

The design and controlling analysis were carried out for the selected wind turbine blade. The design work was done by blade element momentum theory. From this the following conclusions were obtained.

- With the increases in turbine size the labour and maintenance cost increase gradually. The wind farm turbine cost are minimized by limiting the strength of blade materials and requirements. In the optimal wind speed ratio during energetic gust of wind allows the wind turbine to improve energy capture.
- The noise of the wind turbine blades increases with higher blade tip speeds. For increasing the tip speed without increasing the noise would allow reduction the torque into the gear box and generator. It reduces the overall structural loads and their by reducing cost. The noise level reduction is linked the factors that abrupt stalling.

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