WORKING ANALYSIS OF WIND TURBINE AS A DISTRIBUTED GENERATION UNIT WITH DIFFERENT SIMULATED CONDITIONS

Prakash Kumar Sen[1], Tarkeshwer Chandra[2], Shailendra Kumar Bohidar[3]

[1]Student of M. Tech. Manufacturing Management, BITS Pilani

[2]Student of Mechanical Engineering Kirodimal Institute of Technology, Raigarh, (India)

[3]Ph.D. Research Scholar, Kalinga University, Raipur

ABSTRACT

In this paper presents the working analysis of wind turbine as a distributed generation unit with different simulated conditions. Wind energy is natural and renewable, wind turbines are similar to hydraulic turbines, hence the technology is mature and well establish. What is good about wind energy, its available even in winter, when solar energy is not so good, so it makes a natural compliment so solar energy. Wind energy is becoming popular despite some concerns about visual impact and so on, and its is one of the most competitive renewable energy in most cases. In this paper, the performance analysis of wind turbine as a distributed generation unit is presented. In this study a model of wind power is driven by an induction machine. Wind power that is distributed generation is capable of supplying power to ac power distribution network. Wind power generation system is modeled and simulated using Matlab Simulink software such that it can be suitable for modeling some kind of induction generator configurations. To analyze more deeply the performance of the wind turbine system, both normal and fault conditions scenarios have been applied. Simulation results prove the excellent performance of the wind power unit under normal and fault conditions in the power distribution system.

Keywords: Distributed Generation, Wind Turbine, Working Analysis, Power Input & Output, Blades, Wind Energy, Controlling

I. INTRODUCTION

There are three major challenges in the world at present, i.e. conservation of energy resources, protection of environmental and development of sustainable [1]. One of the important issues is how to satisfy the needs of energy for people without causing depletion of the natural energy resources rapidly and damage the environmental. In power electrical energy field, the use of Distributed Generation (DG) has the new issue in the last decade. DG is related to the use of small generating units, usually less than 10 MW, that are connected to transmission or distribution systems. The emerging new technologies such as wind energy, fuel cells, solar photovoltaics, and microhydro power sources make DG more and more affordable and popular [2]. The government of Indonesia has targeted that DG from renewable energy resources for up to 25% of all electrical power generation capacity going online to the distribution network by the year 2025 [3]. The target has been emerged because the fuel and coal energy sources are limited and have pollution to the environment.[1]

The power output of a turbine will increase with the swept area (i.e. proportional to the square of the length of the blade). For this workshop, however, the fact that the wind source is a fan means that beyond a certain blade length, there will be no increase – in fact it will decrease due to the extra weight and increased drag force. Blade shapes which are more aerodynamic will increase the power output. Blade angle is an optimum at around 20o in this case, with lower and higher angles giving less power output. The wind output from the fan is not very similar to real wind conditions, due to the rotating blades that increase the kinetic energy in the air (the windspeeds are similar though – on the highest setting, the wind speed from the fan is around 4.8ms-1, and in the square kilometer in which the engineering department is situated, the average windspeed 10m above ground level is 4.7ms-1, 25m above ground level it is 5.5ms-1, and 45m above ground level it is 6ms-1). This means that there will not be a steady power output from the turbine. The small turbines in this workshop work similarly well with both 3 and 6 blades.[3]

II. WORKING OF WIND TURBINE

Wind turbines usually consist of a set of blades attached to a rotor hub, which together form the rotor; this rotor deflects the airflow, which produces a force on the blades, which in turn produces a torque on the shaft such that the rotor rotates about a horizontal axis (N.B. this does not apply to all wind turbines, some rotate about a vertical axis), which is connected to a gearbox and generator. These are housed in the nacelle (at the top of the tower) with other electrical components. The generator produces electricity, which is transmitted down the cables through the tower and out to a transformer, to convert it from the output voltage (typically around 700V) to the right voltage for either the national grid (33000V) or for whatever personal use it is being put to (so 240V).[2]

These Horizontal Axis Wind Turbines must always be pointed in the correct direction (into or away from the wind, depending on the design) if they are to be used efficiently. Those which face away from the wind – downwind turbines ("downwind" referring to the position of the turbine relative to the tower) – are blown into the correct orientation. In older and smaller upwind wind turbines, correct orientation is achieved through use of a simple wind vane; larger turbines contain a yaw meter and yaw motor. The yaw meter detects the direction of the wind, and the yaw motor rotates the turbine so that it is always facing into the wind. Because it is possible for the turbine to thus yaw in the same direction for many turns, twisting the cables, turbines have a cable twist counter which causes the system to yaw back around so that the cables untwist, once they have reached a certain number of turns in one direction.[2]

The shape of the blades is very important in controlling the turbine. The shape must be optimised to give lift so that the rotor will turn. To this end, for the most part they have an aerofoil shape (as an aeroplane's wing), but for large wind turbines the blades are always twisted. From the point of view of the blade, the wind will be coming from a much steeper angle as you move towards the root of the blade. Since the blade will stop giving lift (it will stall) if the blade is hit at an angle of attack which is too steep, the rotor blade must be twisted to achieve an optimum angle of attack throughout the length of the blade.[1]

III. DISTRIBUTED GENERATION

In the future, Distributed Generation (DG) is expected to provide the most economical solution for load growth. The impact due to load growth such as low voltage or overload is expected to be resolved by applying the DG in many locations. There are many locations in a series of problems, where the DG may be located to provide the necessary control to overcome the problems of voltage drop. In theory, the DG is able to provide the lowest cost solution to the problem and the circuit will be installed to provide the required voltage control. DG further placement in the circuit can lead to improvements in both losses and reliability of the electrical power system.[4]

IV. WIND ENERGY SYSTEM

Have made many effort to build large-scale wind-powered systems to generate electrical energy. Historically, power generation using wind power in the world created by Charles Bush in Cleveland, Ohio, USA in 1887. In creation of wind power, he uses a DC generator for electricity production and is designed to charge the battery. While the use of an induction generator as wind power for the first time was in 1951.[5]

In the principle of operation, wind turbines convert the kinetic energy contained in wind into mechanical energy in the form of a round by way of producing torque. The amount of kinetic energy generated depends on the air density and wind speed. This is due to the energy contained in wind is in the form of kinetic energy.

V. LIFT AND STALL

The reason that an aeroplane can fly is that the air sliding along the upper surface of the wing will move faster than the air on the lower surface, such that the pressure will be lower on the upper surface. This creates the lift, i.e. the force pulling upwards that enables the plane to fly. Lift is perpendicular to the direction of the wind.

If an aeroplane tilts backwards in an attempt to climb higher into the sky, the lift of the wing will increase at first as the wing is tilted backwards, but with increasing angle the air flow on the upper surface will separate and become turbulent. This means that the lift from the low pressure on the upper surface of the wing disappears – this is stall. A wing will stall if the shape of the wing tapers too quickly; in this case it is not due to the wing changing shape but the angle of the wing relative to the general direction of the airflow (angle of attack) is increased.

Stall can be provoked if the surface is not completely even and smooth. A dent can be enough to start turbulence on the back side of a rotor blade[7]

VI. POWER OUTPUT

The power output of the turbine is found using the following equation:-

Power Delivered = Cp x (swept area) x ½ x d x u3

where Cp is the power efficiency of the rotor, swept area = πr2 where r is the blade length, d is the density of the air, and u is the wind speed.

The theoretical maximum for Cp is 0.59; this is the Betz limit. Ideally, a turbine which operates as close to this limit as possible over a wide range of wind speeds would be best. This would make the power output approximately proportional to u3. The power must be limited at high u to protect mechanical and electrical components of the turbine from overloading – this is done by reducing Cp as the wind speed increases (as described above).[6]

The power at which a turbine is rated will not be achieved most of the time. Wind in the UK is estimated to blow at a high enough speed to achieve the rated power 30-40% of the time, so the installed capacity of a turbine or farm will be multiplied by this percentage to find a “declared net capacity”, the expected amount of power from the site. Power output of a turbine in general will depend on many things, including: the size of the turbine; the shape and smoothness of the blades; the angle (pitch) and number of the blades; the wind speed; the height of the tower; the terrain of the location; the arrangement of turbines in a wind farm situation (to shelter each other as little as possible from the prevailing wind).[6]

VII. NUMBERS OF BLADE

The number of blades will affect the power output from the turbine. The optimum number of blades for a wind turbine depends on the purpose of the turbine. Turbines for generating electricity need to operate at high speeds, but do not need much torque – these turbines generally have two or three blades, since this gives enough torque without adding the extra weight that can slow the turbine down. Wind pumps need a lot of torque but not much speed, and so have many blades.[2]

Rotors with odd numbers of blades (and at least three) are more stable. Two-bladed rotors require a hinged (teetering hub) rotor, since it needs to be able to tilt or bend in order to avoid excessive shocks to the turbine under relatively strong winds.

The three-bladed rotor is the most popular model with a much smoother power output, more efficient and higher energy yield, a balanced gyroscopic force and a much better mechanical system compared to the rotors with two blades.[2]

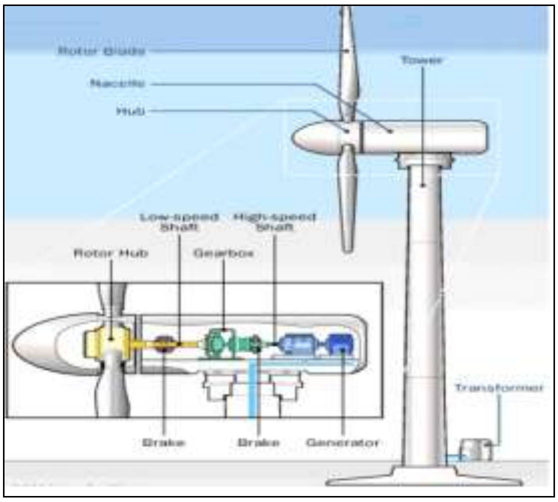

Fig (1) Wind Turbine

VIII. INDUCTION MACHINE IN WIND ENERGY

Induction machine is widely used in power system as an electric motor, but not the induction machine is widely used as electrical generators. Although it has simplicity in construction, induction motors do not like as much as synchronous generators. This is mainly due to the output and absorption of active and reactive power that the correlation is not good. However, induction generators provide useful damping torque is great as main propulsion, making it suitable for applications in the fixed-speed wind turbines. Wind turbines that have a fixed rate using a squirrel cage induction generator-type combined with large-scale power system through a transformer. To overcome the differences in speed of operation of the wind turbine rotor and generator, the gearbox used to match this speed. Slip of generators therefore varies slightly with the amount of power generated and therefore not entirely constant.

The general concept of induction machines in wind power generation system is shown in Fig.2. . Induction machine system to date is considered the most suitable for use on wind power. Turbine speed can be controlled by the load, not by adjusting the turbine. In general, the management company has several electrical load management capabilities, but most of the burden they can not be controlled by the utility. Therefore, the utility adjusts the input prime mover to follow load variations. That is, in this case the supply keep pace with demand. In the case of wind power, the input power wind turbine wind power only and not subject to control. Speed wind turbine still needs to be controlled for optimum performance, and this can be achieved by the electrical load with the appropriate characteristics. in this case a microcomputer not so important for the mode of operation, but does not allow more flexibility in the choice of the load. We can have a system where demand follows the supply, the situation is inherently desirable.[5]

Most of the leading wind turbine manufacturer in the world uses a system of induction machine. The use of induction machines is due to the fact that the power electronic converter must handle only a small fraction (20% - 30%) of the total power, ie, the power slipping. This means that if the speed is within the range of ± 30% around the synchronous speed, the converter is rated for 30% of the turbine power generated, reducing the losses in the power electronic converter. This is in comparison with which the system must handle the total power converter. Apart from that the other consideration is the cost of the converter becomes lower. Induction machine has been used in wind power for a long time. At the beginning used in the past, from AC to AC converter connected to the rotor which consists of the rectifier and inverter that utilizes thyristor bridge. The technology used today is that the AC-AC converter is equipped with bi-directional IGBT, which connects the rotor of the variable speed induction generators to the power grid.[5]

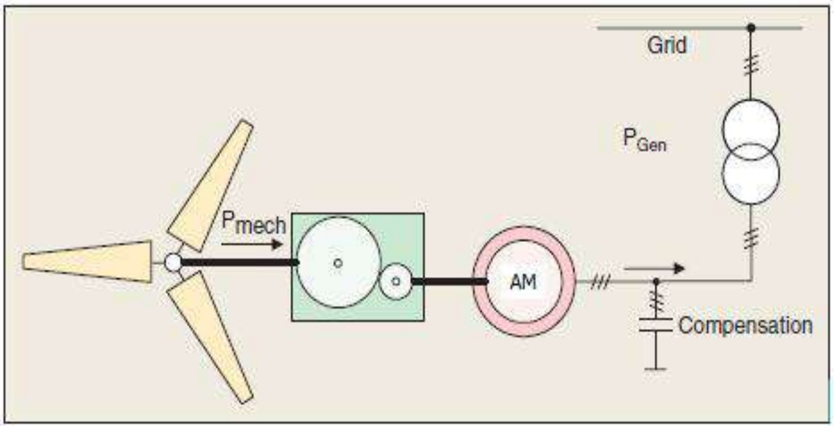

Fig (2) Induction Machine in Wind Energy

IX. SYSTEM MODELING

In Fig. (3). shown a model wind turbine and induction machines. Caused by the production of a more realistic importance of induction machine behavior, it is intended to adopt the physical model rather than a functional model to assess the performance of the induction machine. Induction machine has to be excellent in wind power generation systems. A wind power system consisting of six 1.5 MW wind turbines connected to the electric distribution system exports 25 kV to 120 kV grid through a 25 km 25 kV feeders. wind power plant with a capacity of 9 MW modeled by three pairs of 1.5-MW wind turbines. Induction machines used in wind turbine models using machine induction squirrel-cage type. Stator coils are connected directly to the 60 Hz grid and the rotor is driven by a wind turbine having a variable-pitch. Pitch angle is controlled to limit the power output of the generator at the nominal value for the wind speed exceeds the nominal (9 m / s). In order to generate optimal induction engine, the engine speed should induski slightly above synchronous speed. In this simulation speed varies between 1 pu no load and 1,005 p.u. at full load. Each wind turbine has a monitoring system voltage protection, current and engine speed.[8]

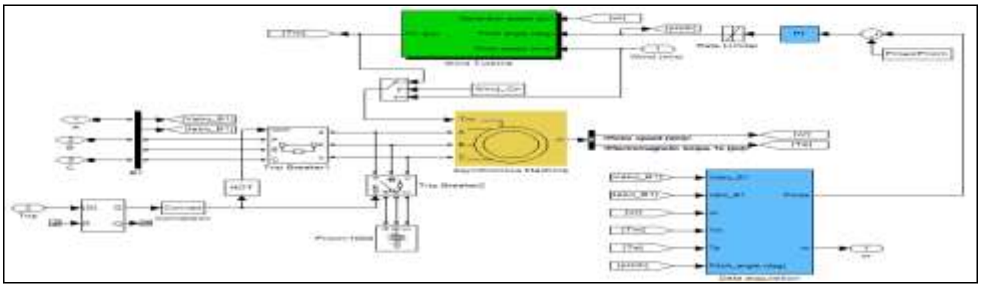

Fig (3) System Modeling

X. SIMULATION IN WIND TURBINE

In order to analyse analyze the performance of wind turbine as a part of distributed generation in power distribution system, the overall system is simulated using Matlab Simulink software. The simulation described in this section illustrates the steady-state and dynamic performance of a 9 MW wind power generation system connected to a distribution system. The wind power generation system consists of six 1.5 MW wind turbines connected to a 25 kV distribution system exporting power to a 120 kV grid through a 30 km 25 kV feeder. In this simulation, all of the system is observed during 20 s.

Fig. (4) shows the characteristics of the wind turbine with a pitch angle of 0 □ . This shows that the wind speed will produce a variety of different turbines in the power output per unit of nominal mechanical power. Turbine mechanical power is shown as a function of turbine speed to wind speed ranged between 4 m s to 10 m/s. In this system it is assumed that the nominal wind speed produces a nominal mechanical power for base 1 p.u. = 3 MW is 9 m/s. [5]

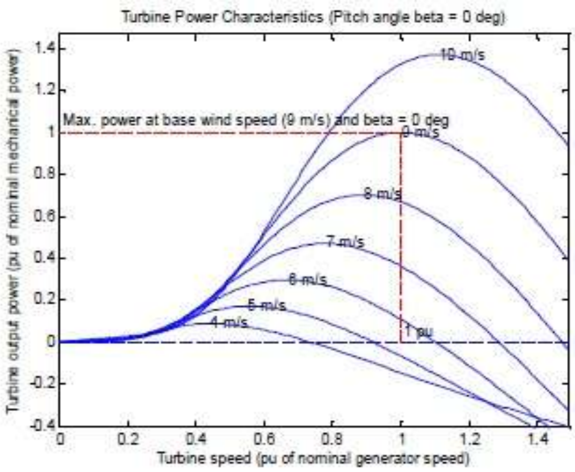

Fig (4) Wind Turbine Characteristics With Pitch Angle Of 0□

10.1 Simulation under Normal condition

In this part, we have simulated power distribution system including wind turbine as distributed generation under normal condition. Simulation has started with monitoring both active and reactive powers, generator speed, wind speed and pitch angle for each wind turbine.

Fig. (5) and Fig. (6) show the active and reactive power of wind turbine under normal condition, respectively. That Figures illustrate each of the resulted both active and reactive power of three pairs of wind turbines.[5]

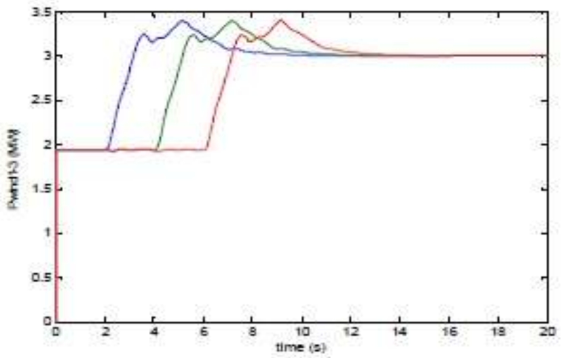

Fig (5) Active Power of Wind Turbine Under Normal Condition

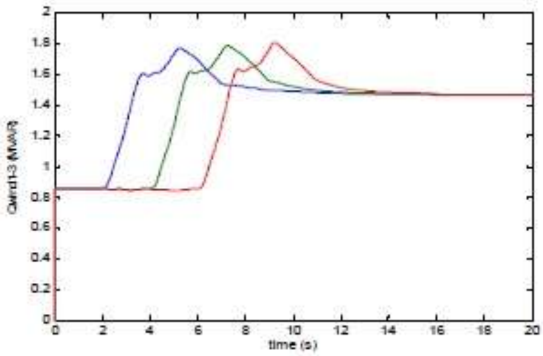

Fig (6) Reactive Power of Wind Turbine Under Normal Condition

10.2 Simulation under Fault Condition

In this session, we have simulated power distribution system including wind turbines as distributed generation under fault condition. At the time t = 15 s, three-phase fault is applied to the wind turbine 2 terminals, causing the wind turbine to trip experience at t = 15.11 s. Once the turbine 2 has tripped, turbine 1 and 3 continued to produce 3 MW each turbine.

Fig. (7) and Fig. (8) show the active and reactive power of wind turbine under fault condition, respectively. The Figures illustrate each of the resulted active and reactive power of three pairs of wind turbines. In Fig. 15, for each pair of active power generating turbines began to rise in tandem with increasing wind speeds to achieve the assessed value of 3 MW in about 8 s. During this period the wind turbine speed has increased from 1.0028 p.u. to 1.0047 p.u. At first turbine blade pitch angle is zero degrees. When the output power exceeds the value of 3 MW, the pitch angle is increased from 0□ to 8□ [5]

XI. CONTROLLING OF WIND TURBINE

Wind turbines must not be run during wind speeds which are too high, since this may cause vibration that can shake the turbine into pieces; because of this they have brakes, and also a way to decrease the lift given to the blades. This can be done using a pitch-controller on the blades or a stall-controller (which can be active or passive). The passive stall controller makes use of the shape of the blade, designing it so that at high wind speeds it will stall gradually from the root of the blade. This occurs because as the actual wind speed in the area increases, the angle of attack of the rotor blade will increase until it starts to stall.[6]

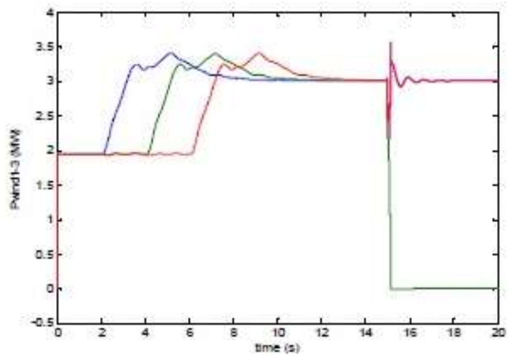

Fig (7) Active Power of Wind Turbine Under Fault Condition

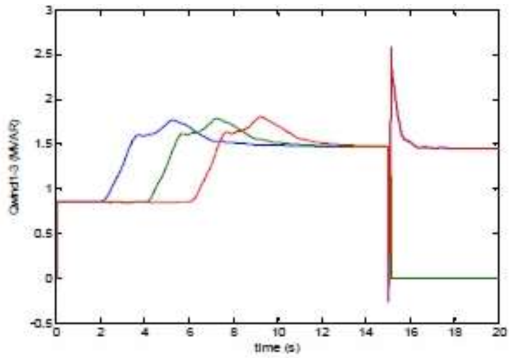

Fig (8) Reactive Power of Wind Turbine Under Fault Condition

The pitch controller and the active stall controller use similar principles, rotating the blade to change the lift so that in low wind speeds they have a large torque. However, at high wind speeds the pitch controller will pitch the blades out of the wind (and turn them back whenever the wind drops), whereas the stall controller will pitch its blades in the opposite direction, increasing the angle of attack in order to make the blades go into a deeper stall, thus wasting the excess energy in the wind. This allows the active stall-controlled turbine to be run at almost exactly rated power for all high wind speeds, whereas the passive stall-controlled turbine will usually have a drop in the electrical power output for higher wind speeds as the blades go into deeper stall. With stationary blades, the passive stall system requires solving a complex aerodynamic design problem; but with pitchable blades, the engineering required to ensure that the rotor blades pitch exactly the right amount is also complex.[8]

XII. CONCLUSION

This paper presents a working analysis of wind power as a distributed generation unit. Wind power plant in this study is driven by an induction machine. Wind power that is distributed generation is capable of supplying power to ac power distribution network. Wind power generation system is modeled and simulated using Matlab Simulink software such that it can be suitable for modeling some kind of induction generator configurations. To analyze more deeply the performance of the wind turbine system, both normal and fault conditions scenarios have been applied. Simulation results prove the excellent performance of the wind power unit under normal and fault conditions in the power distribution system.

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