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Study of Power Generation of Doubly Fed Induction Generator in Wind Energy Conversion System

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Abstract - In recent days the wind power is rapidly growing renewable energy source The combustion of conventional fossil fuel across the globe has caused increased level of environmental pollution. Several international conventions and forums have been set up to address and resolve the issue of climate change. Renewable energy like solar, wind, and tidal currents of oceans is sustainable, inexhaustible and environmentally friendly clean energy. In this paper firstly we present the literature survey DFIG application in wind energy conversion system. The main problem of grid is being discussed and analytical approach is given for the issues. Future we study the different topology of wing turbines advantage, application. This paper we study the measure grid problem and grid codes operation and grid connection of wind farms.

Index Terms— fixed speed turbine, variable speed turbine, grid problem, DFIG.

I. INTRODUCTION

Electrical power is the most widely used source of energy for our homes, work places and industries. Population and industrial growth have led to significant increases in power consumption over the past three decades. Natural resources like coal, petroleum and gas that have driven our power plants, industries and vehicles for many decades are becoming depleted at a very fast rate. This serious issue has motivated nations across the world to think about alternative forms of energy which utilize inexhaustible natural resources.

The combustion of conventional fossil fuel across the globe has caused increased level of environmental pollution. Several international conventions and forums have been set up to address and resolve the issue of climate change. Renewable energy like solar, wind, and tidal currents of oceans is sustainable, inexhaustible and environmentally friendly clean energy. Due to all these factors, wind power generation has attracted great interest in recent years. Undoubtedly, wind power is today's most rapidly growing renewable energy source. Even though the wind industry is young from a power. These forums have motivated countries to form national energy policies dedicated to pollution control, energy conservation, energy efficiency, development of alternative and clean sources of energy. The "Kyoto Protocol to the Convention on Climate Change" has enforced international environmental regulations which are more stringent than the 1992 earth summit regulations.

systems point of view, significant strides have been made in the past 20 years. Wind turbine capacity has grown from 1-3 kW to machines producing 1-3 MW and more. Increasing reliability has contributed to the cost decline, with availability of modern machines reaching 97-99%. Wind plants have benefited from steady advances in technology made over past 15 years. Much of the advancement has been made in the components dealing with grid integration, the electrical machine, power converters, and control capability. There is lot of research going on around the world in this area and technology is being developed that offers great deal of capability. days of the simple induction machine with soft start are long gone. We are now able to control the real and reactive power of the machine, limit power output and control voltage and speed. It requires an understanding of power systems, machines and applications of power electronic converters and control schemes put together on a common platform.

Typically wind generation equipment is categorized in three general classifications:

1) Utility scale- Corresponds to large turbines (900kW-3.5MW) used to generate bulk power for energy markets.

2) Industrial Scale- Corresponds to medium sized turbines (50kW-250kW) mainly used by industries for remote grid production to meet local power requirement.

3) Residential Scale- Corresponds to small sized turbines (400 watts-50kW) mainly utilized for battery charging. In conjunction with solar photovoltaic, it can be utilized for remote power requirement where normal power distribution lines do not exist.

Most of the commercially available utility-scale wind turbines are based on the "Danish concept" turbine configuration. This configuration has a horizontal axis, three-bladed rotor, an upwind orientation, and an active yaw system to keep the blades always oriented in the direction of wind flow. The drive train consists of a low-speed shaft connecting the rotor to the gearbox . As per World Energy Outlook (WEO)-2010 the prospects for renewable energy based electricity generation hinge critically on government policies to encourage their development. Worldwide, the share of renewable in electricity supply increases from 19% in 2008 to 32% in 2035 in the New Policies Scenario; it reaches only 23% in the Current Policies Scenario, but 45% in the 450 Scenario. In all three scenarios, rising fossil-fuel prices and declining costs make renewable more competitive with conventional

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Hydropower has been the dominant renewable source of electricity for over a technologies century. The recent strong growth in new technologies for wind power and solar photo voltaic (PV) has created expectations among policy makers and the industry alike that these technologies will make a major contribution to meet growing electricity needs in the near future. It has also been forecasted that the increase in electricity generation from renewable sources between 2008 and 2035 will be primarily derived from wind and hydro power, which will contribute 36% and 31% of the additional demand respectively [1].

Wind power is projected to supply 8% of global electricity in 2035 up from just 1% in 2008. In the year 2010 the wind capacity has reached 196.630GW world wide and it will reach 240GW by the end of 2011.

II. LITERATURE REVIEW

Maiden production of electrical energy with wind power was done in 1887 by Charles brush in Cleveland, Ohio. DC generator was the base for power production and was designed to charge the batteries. There were many endeavors to create large scale wind powered system to produce electrical energy Various studies have been focused out with respect to modeling of DFIG for stability analysis. Ancient power systems, including their generation, were run by monopolies, but after the late 1990s governments over the world have worked at deregulating electricity markets on the assumption that competition will result in their more efficient activities.

Ch. Eping, J. Stenzel et all[19] has been carried out focus on transient stability issues and analyses the impact of various aspects like generator technology, connection points, distributed generation etc. separately for getting a thorough understanding about the impact of these aspects on transient stability.

Marcelo Godoy Simoes et all [20] in this paper which describes a variable speed wind generation system where fuzzy logic principles are used for efficiency optimization and performance enhancement control. A squirrel cage induction generator feeds the power to a double-sided pulse width modulated converter system which pumps power to a utility grid or can supply to an autonomous system. The generation system has fuzzy logic control with vector control in the inner loops. A fuzzy controller tracks the generator speed with the wind velocity to extract the maximum power. A second fuzzy controller programs the machine flux for light load efficiency improvement, and a third fuzzy controller gives robust speed control against wind gust and turbine oscillatory torque. The complete control system has been developed, analyzed, and validated by simulation study. Performances have then been evaluated in detail.

III. WIND TURBINE TOPOLOGY

There are a large number of choices of topologies available to the designer of a wind turbine and, over the years, most of these have been explored. However, commercial designs for electricity generation have now converged to horizontal axis, three-bladed, upwind turbines. In this way the power fluctuations caused by wind variations can be more or less absorbed by changing the rotor speed and thus power variations originating from the wind conversion and the drive train can be reduced. The largest machines tend to operate at variable speed whereas smaller, simpler turbines are of fixed speed. For a fixed-speed system the turbulence of the wind will result in power variations, and thus affect the power quality of the grid where as in a variable-speed wind turbine the generator is controlled by power electronic equipment, which makes it possible to control the rotor speed. Hence, the power quality impact caused by the wind turbine can be improved compared to a fixed-speed turbine. Although a high rotor speed is attractive in that it reduces the gearbox ratio required, a high blade tip speed leads to increased aerodynamic noise and increased blade drag losses. Most importantly, three-bladed rotors are visually more pleasing than other designs and so these are now always used on large electricity generating turbines [24].

Modern electricity generating wind turbines now use three-bladed upwind rotors, although two bladed, and even one-bladed, rotors were used in earlier commercial turbines. Reducing the number of blades means that the rotor has to operate at a higher rotational speed in order to extract the wind energy passing through the rotor disk.

A. Fixed speed wind turbine

This type of turbines are also called Type A turbine. Fixed-speed wind turbines are electrically fairly simple devices consisting of an aerodynamic rotor driving a low-speed shaft, a gearbox, a high-speed shaft and an induction (sometimes known as asynchronous) generator. The generator operating slip changes slightly as the operating power level changes and the rotational speed is therefore not entirely constant. However, because the operating slip variation is generally less than 1%, this type of wind generation is normally referred to as fixed speed.

From the electrical system viewpoint they are perhaps best considered as large fan drives with torque applied to the low-speed shaft from the wind flow. Fig 2 illustrates the configuration of a fixed-speed wind turbine [26]. Also, by applying the network voltage slowly to the generator, once energized, it brings the drive train slowly to its operating rotational speed. It consists of a squirrel-cage induction generator coupled to the power system through a turbine transformer. Squirrel-cage induction machines consume reactive power and so it is conventional to provide power factor correction capacitors at each wind turbine. The function of the soft-starter unit is to build up the magnetic flux slowly and so minimize transient currents during energization of the generator .

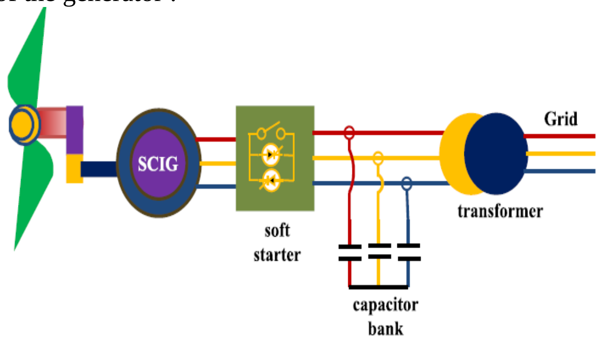

Figure 1 Schematic diagram of a fixed speed wind turbine

B. Variable speed wind turbine

Variable-speed wind turbines are designed to achieve maximum aerodynamic efficiency over a wide range of wind speeds. During the past few years the variable-speed wind turbine has become the dominant type among the installed wind turbines. With a variable-speed operation it has become possible continuously to adapt (accelerate or decelerate) the rotational speed of the wind turbine to the wind speed V□. Contrary to a fixed-speed system, a variable-speed system keeps the generator torque fairly constant and the variations in wind are absorbed by changes in the generator speed. This way, the tip speed ratio is kept constant at a predefined value that corresponds to the maximum power coefficient. It is typically equipped with an induction or synchronous generator and connected to the grid through a power converter. The electrical system of a variable-speed wind turbine is more complicated than that of a fixed-speed wind turbine. A variable-speed turbine with (DC) generator is being used to charge batteries as an alternative jobs was done through much of the 1930s on farms throughout countries before the Rural Electrification for direct power distribution equipment .such kind of machine is basically usually employed conventional commutator type DC generators. Short range turbine rotor, however, can drive an alternative current generator that produces variable AC voltages and frequencies and, by using current power electronics and controllers, which convert that AC to DC and back to AC of uniform utility frequency. by the way In this mode they can be connected director to electrical grids for supply power to an individual modern home and to return excess power to the l grid., they can be located over directly on the electrical grid at the final position of remote distribution lines to minimize the need for enhancement old or undersized distribution systems. If we talk about exam related to this then Bergey Excel is a better one . In case of large turbine ,There is a wide range of methods for controlling aerodynamic forces over the turbine rotor and the limiting the highest power output of turbine. The easiest method is passive stall control, under which the rotor is being designed aerodynamics causes rotor to stall (lose power) whenever the velocity crosses the limited reason . the methods which include yawing, under which the rotor is turned external of alignment with the wind by few of mechanical device when by a given wind speed is exceeded. The most useable sophisticated method is to control active aerodynamic control, in such as flaps or full-span pitch control. On other hand The latter can be implemented as an emergency control various controlling methods method that only feathers the blades in an crosses over speed condition . it can be a highly active method controlling power output over a large range of wind speeds and for starting the rotor .[7]

Various projects and concepts have been projected for illustration and the behavior of DFIG based WECS which is connected to the grid. With the increased growth of wind power the interaction between WECS and gird will create a new troubles regarding the reliable operation of systems and safe. With High diffusion of intermittent wind power can affect the network in following terms Impact of low power factor Power flow Power Quality link Poor grid stability Low-frequency operation Short circuit. Generally , the grid codes for wind reacts with the technical requirements. The main requirements of such a grid connection of wind turbines and grid codes for operation .[8]

Frequency operating range:

The WTs which are desired to operate under typical grid frequency variations. The Frequency tolerance range is 47.5 to 51.5 Hz, the tolerance range is specified by the manufacturer beyond this .this is able to withstand variable in time period up to 0.5 Hz/sec.

Voltage operating range:

it is required to operate within typical grid voltage variations For wind turbines (WT). for the reliable operation of the grid and safe operation , Operational voltage limits of the wind farms (kV) should be lie in between the range as specified by authority.

Frequency control:

It is to desired that wind farms to provide frequency regulation of wind form capability to assist for maintaining the desired network frequency. System frequency is a principal indicator of the power system which is to balanced.

Active power control:

The characteristics and ability of the WT according to system requirement generators to regulate the active power output of wind turbine. This is used to certify stable frequency in the system which to avoid overloading of transmission lines and to stay away from large voltage steps , in-rush currents in shut down of WTs and start up of WTs .

High voltage ride through (HVRT):

voltage goes above its higher limit value, In the occasion that the WTs should be ability to stay on line for a given length of time.

Voltage & Reactive power control:

It is require that individual wind turbines control their own terminal Grid codes voltage to a constant value by means of an provide dynamic reactive power control automatic voltage regulator capability the power factor in the desired range to maintain the reactive power balance . There should be wind farm should maintain a power factor of 0.95 lagging to 0.95 leading at least

Wind farm modeling and verification

To facilitate the system operator to examine by simulations the interface between the wind farm and the power system , Grid codes require wind farm owners/developers to give models and system data

Power Quality

Capability of a wind farm, to operate loads without damaging or disturbing them Wind farms are required to make available the electric power with a desired quality & with no reducing the efficiency of the system.

Communications and external control

Wind farm operators are required to provide signals corresponding to number of parameters which is important for the system operator by enable proper operation of the power system. On other hand Moreover, it should be possible to connect and disconnect the wind turbines through wireless .

IV. DOUBLY FED INDUCTION GENERATOR

The overall control strategy of the system is divided in various ways, one is scalar control and other is vector control. The limitations of scalar control provides an importance to vector control. By which the scalar control strategy is simple to implement but the coupling effect provides sluggish response. The inherent problem is being solved by the vector control. Vector control is invented in the beginning of 1970s. by Using this control strategy an IM can be performed such as like dc machine. Because of dc machine like efficiency of vector control is also known as decoupling, orthogonal or Trans vector control[9]. the power electronic converter only has to handle a fraction (20–30%) of the total power In DFIG based variable-speed WECSs **.**

A) Introduction

This means that the losse in the power electronic converter may be reduced to compared to a system where converter has to handle the total power. the cost of the converter becomes lower which is additional to this . The rotor circuit is connected to a converter via slip rings while The stator circuit of the DFIG is connected to the grid. We can connect the DFIG to the grid consists of two stages which includes synchronous stage and running stage . On other hand rotor blades are in a top feathering position and which the regenerator is disconnected to the grid . From a permanent stop, the initial step is to charge the dc-link voltage by shutting down SW1 The anemometer which measures the wind speed and if the wind speed is higher than there should be the cut-in value, the switch SW2 is off and the pitch controller changes the blade pitch angle like that the turbine starts to rotate. Controller of the generator rotor side is started and so an excitation current is sent through the rotor.[10]

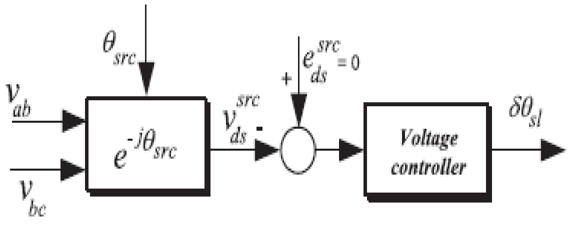

Figure: 2 Phase difference compensation for synchronization

B) Operational Principle

The stator is directly connected to the AC mains, whilst the wound rotor is fed from the Power Electronics Converter via slip rings to allow DIFG to operate at a variety of speeds in response to changing wind speed. Indeed, the basic concept is to interpose a frequency converter between the variable frequency induction generator and fixed frequency grid. The DC capacitor linking stator- and rotor-side converters allows the storage of power from induction generator for further generation. To achieve full control of grid current, the DC-link voltage must be boosted to a level higher than the amplitude of grid line-to-line voltage. The slip power can flow in both directions, i.e. to the rotor from the supply and from supply to the rotor and hence the speed of the machine can be controlled from either rotor- or stator-side converter in both super and sub-synchronous speed ranges. As a result, the machine can be controlled as a generator or a motor in both super and sub-synchronous operating modes realizing four operating modes. Below the synchronous speed in the motoring mode and above the synchronous speed in the generating mode, rotor-side converter operates as a rectifier and stator-side converter as an inverter, where slip power is returned to the stator .

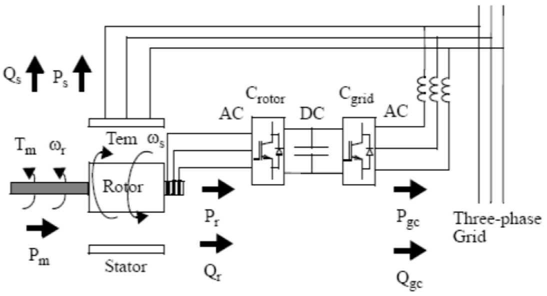

Figure :3 Power flow diagram of DFIG

Below the synchronous speed in the generating mode and above the synchronous speed in the motoring mode, rotor-side converter operates as an inverter and stator side converter as a rectifier, where slip power is supplied to the rotor. At the synchronous speed, slip power is taken from supply to excite the rotor windings and in this case machine behaves as a synchronous machine.

C) Advantage

The DFIG has ability to control reactive power and reactive power control and to decouple active by independently controlling the rotor excitation current. Thus DFIG has not required necessarily to be magnetized from the power grid , which can be magnetized from the rotor circuit . DFIG is also capable of generating reactive power which can be delivered to the stator by using grid-side converter. On other side However, the grid-side converter operates at unity power factor and is not interrupted in the reactive power exchange between the grid and turbine . DFIG may be ordered to produce or absorb an amount of reactive power to or from the grid, with the purpose of voltage control In the case of a weak grid, where the voltage may fluctuate.

D) Applications

Voltage sag

A voltage sag is defines by IEEE standard 1159-1995 IEEE recommended practice for monitoring electric power quality , is a decreases in RMS voltage at the power frequency for duration from 0.5 cycles to a minute reported as the remaining voltage.

*E) Characteristics of wind turbine (*Power verses speed characters tics)

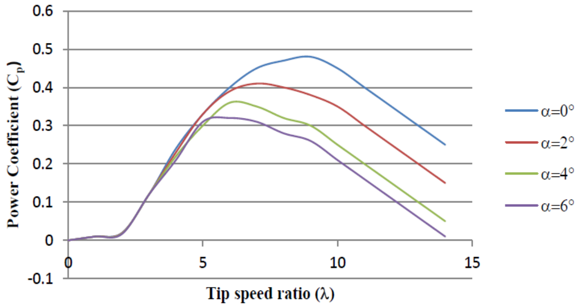

Figure:4 The typical curves of Cp versus for various values of the pitch angle[22]

The wind turbine power graph shown in above figure illustrate how the mechanical power can be taken away from the wind depends over the rotor speed. There is an optimum turbine speed at which the extracted wind power For each wind speed at the shaft reaches its maximum.

V. TYPICAL CHARACTERISTICS OF WIND TURBINES

The following characteristic curves are plotted to explain the behavior of wind turbine at different wind speeds [25].

A) Power versus speed Characteristics

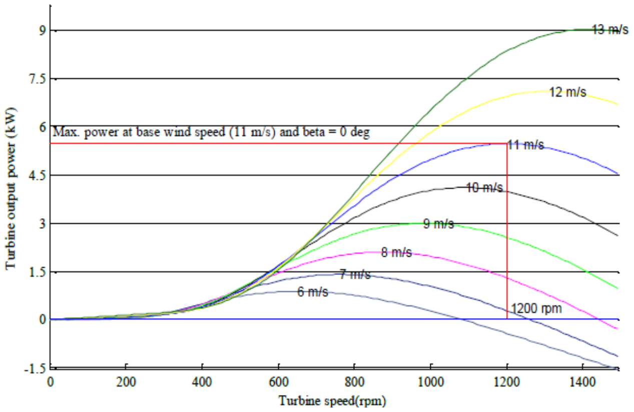

Fig 2.6. The typical power versus speed characteristics of a wind turbine

The wind turbine power curves shown in Fig 2.6 illustrate how the mechanical power can be extracted from the wind depends on the rotor speed. For each wind speed there is an optimum turbine speed at which the extracted wind power at the shaft reaches its maximum.

B) Power coefficient versus TSR Characteristics

For a given wind turbine the power coefficient depends not only on TSR but also on the blade pitch angle. Fig 2.7 shows the typical variation of the power coefficient with respect to TSR (λ) with blade
pitch control.

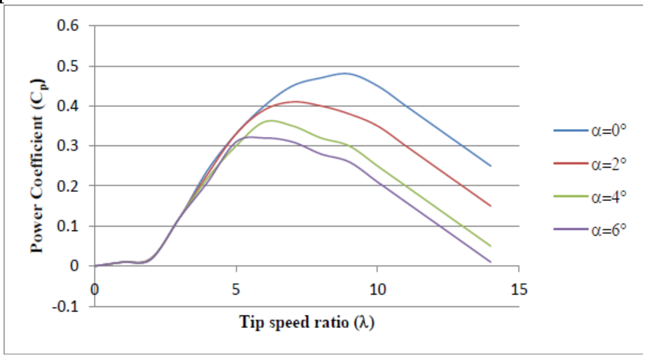

Fig 2.7. The typical curves of Cp versus λ for various values of the pitch angle α

For a wind turbine with radius R Eq. 2.3 can be expressed as

$$P_m = \frac{1}{2}\rho C_p \Pi R^2 V_\infty^3$$

For a given wind speed the power extracted from the wind is maximized if Cp is maximized. Always there is a optimum value of TSR for a optimum value of Cp (Cp-optimum). This means for varying wind speed the rotor speed should be adjusted proportionally to follow to the optimum value of TSR (λoptimum) for maximum mechanical power output from the turbine.

Using Eq. 2.4 the maximum value of shaft mechanical power for any wind speed can be expressed as

For a wind turbine with radius R Eq. 2.3 can be expressed as

$$P_{max} = \frac{1}{2}\rho C_{p-optimum}\pi\left[\frac{R^5}{\lambda^3_{optimum}}\right]\omega^3$$

Thus the maximum mechanical power that can be extracted from wind is proportional to the cube of the rotor speed, i.e. $P_{max}\,\alpha\,\omega^3$.

C) Torque versus speed Characteristics

The typical torque versus speed characteristics of horizontal axis (two blade propeller type) wind turbine is shown in Fig 2.8.

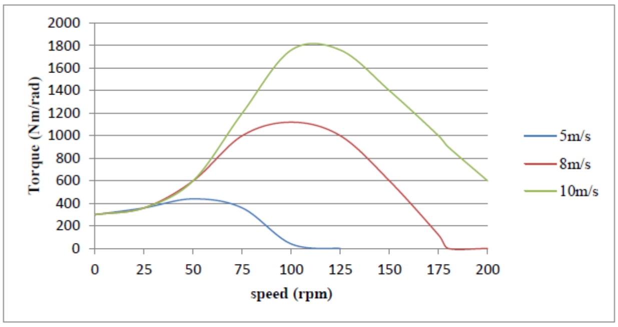

Fig 2.8. The torque versus speed characteristics of wind turbine (horizontal axis turbine)

The curves shown in Fig 2.8 follow the power curve shown in Fig 2.6 because there is a direct relationship exists between power and torque. The relation is given in Eq. 2.7.

$$T_{max} = \frac{1}{2}\rho C_{p-optimum}\pi\left[\frac{R^5}{\lambda^3_{optimum}}\right]\omega^2$$

The curve in Fig 2.8 shows that for any wind speed the torque reaches a maximum value at a specific rotational speed, and this maximum torque varies approximately as the square of rotational speed. In the case of electricity production the load torque depends on the electrical loading. The torque can be made to vary as the square of the rotational sped by choosing the load properly.

VI. CONCLUSION

The presented study presents a DFIG based wind turbine literature and different wind turbine topology . the main issue of grid is discussed and analytical survey has been introduce for the grid problems. The different topology of wind turbine has been explain with there corresponding application and advantages. The study includes grid problem , grid code operation and grid connection of wind form .

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