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Study Of Wind Energy Conversion System Connected To Grid Using Doubly Fed Induction Generator

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Abstract—From past few years, wind mills has become one of the most significant and valuable sources of renewable energy, in which better transmission capability and improved system reliability is needed. Also there has been a significant growth in the wind energy scenario. The World Wind Energy Association has told in World Wind Energy Report that, "The around the world [wind] capacity reached 318,137 MW, out of which 35,467 MW were added more". The wind system here is a variable speed wind generation system working principle based on Doubly Fed Induction Generator (DFIG).The Doubly fed induction generator brings the additional feature of utilizing the turns ratio of the machine, so the power converter need not to be rated for the machine's full rated power. The rotor side converter (RSC) generally provides active power and reactive power control of the machine while the grid-side converter (GSC) retains the voltage of the DC-link constant. The added feature of generation of the reactive power by the grid-side converter is generally not used because of the fact that it is more desirable to generate reactive power by using the Rotor side convertor. Though, within the usable current capacity the grid side converter can be controlled to participate in generation of reactive power in steady state and during low voltage durations as well. The Grid side convertor can contribute the necessary reactive current very quickly while the RSC passes the current through the machine appearing in a difficulty. The pair of converters can be overburdened for a short time, so the DFIG is able to give an ample contribution to grid voltage support at the time of short circuits. This abstract deals with the introduction of wind turbines, DFIG, power converter control and for study of Grid Connected Wind Energy system with DFIG and corresponding results.

Keywords- *DFIG, Voltage Source Converters, DC-link, Rotor side converter, Wind Turbine, Wind Energy.*

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I. INTRODUCTION

Alternative energy, sustainability, and green have become buzz words that are heard on an almost daily basis. This is basically due to increasing concerns about the impact humans have on the environment as well as the future state of the production and transmission of the power the world depends on. With the rising cost of oil and increasing demand for energy, countries around the world have taken the initiative to increase the production of renewable types of energies. This has lead to an interest in the ability to capture energy from natural resources such as hydro, sunlight and wind. There has been quite a recognizable growth in the wind energy market. According to the Global Status Report from the Renewable Energy Policy Network for the 21st Century, there were 85 countries with policy goals intended to increase the renewable energy usage and production [1]. The major types of renewable energy described in these goals are sun light, geothermal, biomass, hydro energy and wind energy. The Electricity Industry Center at Carnegie Mellon (CEIC) boiled the question between the two down to capacity factor. Through the investigation of data collected over a two-year period, it was found that solar energy tends to have more short-term output power fluctuations and up to 20% less output capacity than wind energy [2]. Findings such as this have led to substantial funding increases for the technological advancement of wind energy in particular. The kinetic energy in the wind is converted into mechanical energy by the turbine by way of shaft and gearbox arrangement due to the different operating speed ranges of the wind turbine rotor and generator.[6] The generator converts this mechanical energy into electrical energy. As wind is an irregular renewable source, the wind energy extracted by a wind mill is not constant. Thus For the irregular wind power results in fluctuated power output from wind turbine generator. From the utilities, due to the swing in generator output, it is not suitable for the generator to be directly connected to the electrical grid. And to achieve the condition that the generator output power is useful for grid-connection, it is important to use a controller to govern the output produced by the turbine generator. Manny types of generators are employed with wind turbines. The common types of AC generator that are possible candidates in modern wind turbine systems are as follows:

- Squirrel-Cage rotor Induction Generator.
- Wound-Rotor Induction Generator.
- Permanent Magnet Synchronous Generator.
- Synchronous Generator (With external excitation)
- Doubly-Fed Induction Generator.

II. PROBLEM WITH WIND POWER GENERATION AND GRID CONNECTION

The wind power production varies according to the availability of wind throughout the year, and hence there should be some other source of power in case of inadequate power production. This will evolve in wastage of wind power in the time of availability and at the time of heavy wind the problem of saving electrical generating unit arises. Also the problem of harmonics arises in the production of wind power. Because when the 3 Blade wind turbine rotates and passes by the limb of the wind mill the hindrance will cause the production of harmonics in the generated voltage and current. This will increase the third harmonic component in the voltage waveform. Another major problem faced is the 'flickering effect' of induction generator being used for the purpose of power production. This occurs due to fluctuations in wind speed thereby varying the output power due to 'tower shadow effect. The prime complication in wind power production is also to synchronized generated power with the grid.

Our purpose is to abstract maximum available power from the wind and by properly smoothening the produced output harmonics has to be reduced. By using proper techniques the produced output should be matched with the grid requirements and the power should be delivered keeping the power quality improved.For the following purpose Doubly fed induction generators are used with back to back converters. The double connection with stator and rotor will allow the abstraction of maximum wind power while the smoothening chokes will work to reduce the harmonics present in the generated power output. Back to back convertor employed here will solve the power flickering problem as DC link is installed to maintain the generated power and voltage constant [11]. In thorough approach, actual converter representation with PWM (Pulse Width Modulation) averaged model has been proposed. The proposed model ignores high frequency effects of the PWM firing scheme and therefore it is not possible to accurately determine DC-link voltage in the event of fault.

III. SYSTEM DESCRIPTION

A. *Wind turbine*

Wind turbines can be differentiated in two types based on the axis of rotation of turbine.

1. Horizontal-axis turbines.
2. Vertical-axis turbines.

B. *Fundamental Advantages of Horizontal Axis Wind Turbine*

- Variable blade pitch, which gives the turbine blades the optimum angle of attack. Allowing the angle of attack to be altered gives greater control, and then the amount of collected wind energy will be maximum for the full time of the day and in any season.
- The tall tower base allows access to stronger wind in sites with wind shear. In some windy sites, every ten meters up, the wind speed can increase by 20% and the power output by 34%.
- High efficiency, since the blades always move perpendicularly to the wind, and receives power through the complete rotation. Almost All vertical axis wind turbines, and most expected airborne wind turbine designs, includes different types of alternating actions.

C. Doubly Fed Induction Generator

DFIG is Double Fed Induction Generator, a principle used for power generation widely used in wind turbines. The concept is basically based on an induction generator with a multiphase wound rotor and a multiphase slip-ring assembly with brushes for access to the rotor windings. Delivers Better performance to permanent magnet synchronous generator.

Figure 1.Doubly fed induction Generator.

D. Principle of a Double Fed Induction Generator Connected to a Wind Turbine

The doubly fed induction generator works on the principle that rotor windings are connected to the electrical grid by way of the slip rings and to the voltage source converter which controls the grid current as well as the rotor currents. The frequency of the rotor can freely vary from the grid frequency (either 50 Hz or 60 Hz) [10]. Not depending on the generators turning speed it is possible to adjust the active and reactive power fed to the grid from the stator which can be done by controlling the rotor current by the converters. The principle used to control is either the 2-axis current vector control or the direct torque control scheme. Direct torque control is having better stability than current vector control scheme when high reactive current is required from the generator.

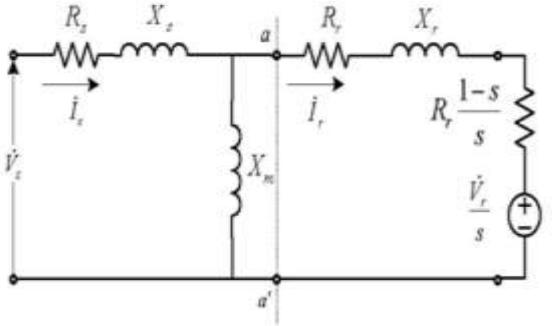

Figure 2. Steady state equivalent circuit of DFIG.

The rotors used in doubly-fed generator are normally wound from 2 to 3 times the number of turns of the stator. Due to which the voltage of the rotor is higher and the current respectively is lower. Because of this the normal range for the speed of operation ± 30 % around the synchronous speed and the rated converter current is therefore lower for a low cost for the power converter used in the system. The main problem is controlled operation out of the range of operational speed, it is impossible because the voltage of rotor is rotor voltage is higher than the rated voltage value. The voltage transients because of the grid disturbances like voltage dips will be increased [4]. In order to avoid high value rotor voltages and due to these voltages resulting in high currents that can destroy the IGBTs and diodes of the converter a crowbar as a protection circuit is used.

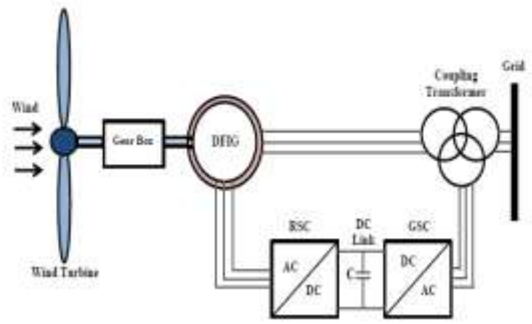

Figure 3. DFIG connected to grid

When heavy currents or voltages are detected the crowbar will short-circuit the rotor windings through a small resistance. For continuing the operation as quickly as possible an active crowbar should be used. The rotor short can be eliminated in a controlled way by the active crowbar and thus the rotor side converter can be started only after 20-60 ms from the moment from the start of the disturbance in the electrical grid. Because of which it is possible to provide reactive current to the grid during the rest of the voltage dip and in this way the fault can be corrected in the grid. Concluding we can say a induction machine which is doubly fed is a wound-rotor doubly-fed electric machine and has several advantages over a conventional induction machine in applications of wind power. Primarily the rotor circuit is controlled by a power electronics converter, the export and import of the reactive power will be possible by the induction generator. This has significant effect for stability in the power system and allows the machine to support the grid during critical voltage disturbances like LVRT. Also the rotor voltages control and currents equips the induction machine to stay synchronized with the electrical grid while the wind turbine speed varies.

IV. CONTROL METHODS

A. *Rotor side converter control for DFIG*

The rotor-side converter controller is used for controlling the stator voltage (or reactive power) and output active power of the wind turbine independently. The converter operates in a stator-flux qd-reference frame, the rotor current broke down into an active power in the q-axis component and a reactive power in the d-axis component. When speed of the wind speed change, there will be a change in the active and reactive power of the generator also. As (actual P) that is actual active power of the generator is compared with reference value of P (ref P) which is determined by the wind speed. The variations between these two values will be provided to a Proportional Integral (PI) controller which will generate (ref I) that is the required value of q-axis rotor current. Similarly, a Proportional Integral controller is used in the reactive power side to generate (ref I) that is the required d-axis rotor current [10].

B. *Grid side converter control for DFIG*

The role of the grid-side converter is to control the value of the DC-link voltage by controlling it to constant and it is also utilized for generating or absorbing the reactive power. The voltage of DC link is used as well, with the q-d reference frame aligned along the stator currents and stator voltages, sets up separate control of the active and reactive power between the converters and the grid. The compensation and decoupling procedures of a typical grid-side converter control can be seen in system model. The (DC actual E) that is actual DC link voltage is compared with (DC ref E) that is reference value. The variations between these two values will go to two Proportional Integral controllers which are utilized to generate the required value of d-axis stator voltage. Also the difference between the actual reactive power that is actual Q and reference value that is ref. Q will go to another two Proportional Integral controllers to generate value of the q-axis stator voltage which will be required.

IV. RESULT

Also From the Above study we can understand that the Doubly fed Induction Generator used for Wind energy conversion in more reliable and efficient than other wind turbine generators. Efficiency can be improved and maximum power can be extracted by pitch control and by changing blade angle parameters. Some Limitations about harmonic components exists with DFIG which can be accepted with all the better result it is providing. Also Proper maintenance required due to complex control mechanism.

VI. CONCLUSION

From the above study we understand that around the world wind has a lot of energy keeping inside and if we are able to extract this energy properly we will be able to contribute much in the world energy crises. The detailed study of the turbines used in wind mills and turbine characteristics reveals that how we can design them properly to extract the maximum power from the wind and get the maximum electrical output. The power electronic circuitries used here have helped the production of wind power much. Without the power electronic elements generation of wind energy would have been very complex, too expensive and improbable.

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