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Overview paper on doubly fed induction generator wind turbine technology

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ABSTRACT

Wind energy is a renewable and non-polluting source of energy. This source is widely accepted in recent years and mainly used for power generation. It uses various generators for generation of energy. Now days mostly used generator type is double fed induction generator (DFIG) which is used for units above 1MW. This encourages research on various aspects and effects of installation of wind power plants. DFIG machine allows active and reactive power control through a rotor side converter while stator is connected directly to the grid. This paper includes an overview of DFIG and its characteristics which are very exceptional and stand alone in all generators. Also rotor side protection is provided

***Keyword-** Wind power generation, doubly fed induction generator (DFIG), dfig converter protection, characteristics.*

1. INTRODUCTION

Wind power has a significant demand in the global power market due to rapid depletion of fossil fuels. Wind is a renewable and non-polluting energy source Due to environmental concerns caused by excessive exploitation of conventional resources, now the focus is diverted to non renewable resources especially solar & wind as these are environmentally clean and eco-friendly.

In the 1990s, wind power turbines were characterized by a fixed-speed operation. Basically, they consisted of the coupling of a wind turbine, a gearbox and an induction machine directly connected to the grid. Additionally, they used a soft starter to energize the machine and a bank of capacitors to compensate the machine power reactive absorption. Although being simple, reliable and robust, the fixed-speed wind turbines were inefficient and power fluctuations were transmitted to the network due to wind speed fluctuations.[1]In the mid-1990s, variable-speed wind power turbines gave an impulse to the wind power industry. A better turbine control reduces power fluctuations. In addition, optimal power extraction from wind was possible by operating the turbine at optimal speed. Among the different configurations of variable-speed wind power turbines, the doubly-fed induction generator, at present, is the most used in the development of wind farm projects.[2]

2. GENERATION OF WIND POWER

Wind turbines produce electricity by using wind energy to run an electric generator. The wind passes over Blades which generate lift and rotational force. The rotating blades rotate the shaft inside the nacelle, which It goes to the gearbox. The gearbox increases the rotation speed to the speed appropriate for the generator, which uses magnetic fields to convert rotational energy into electrical energy. The output power goes to a transformer that converts the electricity from the generator about 700 volts into an appropriate voltage for Energy harvesting system, normally 33 kV. Wind turbines extract kinetic energy from the eroded region of the blades [3]. Wind turbines convert the kinetic energy present in the wind into mechanical energy. Since the energy contained of the wind is in the form of kinetic energy, its magnitude depends on the density of the air and the speed of the wind.

The equation of power which given by turbine is

$$P = 0.5\, C_p A \rho V^3$$

Where Cp is power coefficient, A is area of turbine blades in sq.mtr, ρ is density of air and V is velocity of wind m/sec.

As per Betz the German physicist no turbine can capture more than 16/27 (59.3%) of the kinetic energy in wind factor 16/27 is Betz coefficient. [7]

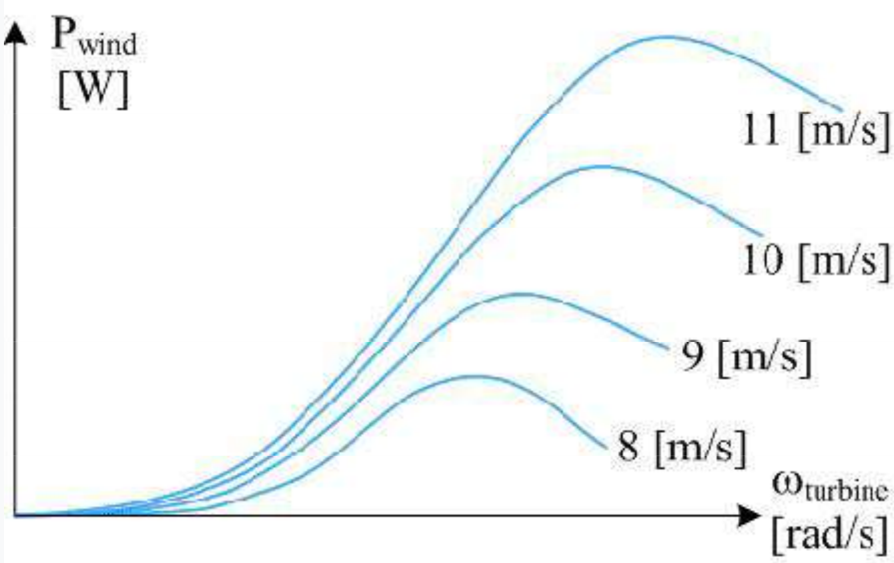

Fig. 1. Extracted power from the wind [1]

3. INITIAL WIND TURBINE

In 1990s, the wind turbine generator systems employed were mostly fixed speed wind turbine squirrel-cage induction generators (FSWT - SCIGs) to generate wind power as these system are more simple and reliable But as they need fixed wind speed to operate so due to wind speed variation overall efficiency becomes poor.[9] (as in fig.1) The major problems observed with the system are voltage fluctuation (flicker) & Low voltage ride through (LVRT), when they are connected to weak power grids where the wind power penetration levels are high.[10] As the available wind energy generation equipment is most often installed in remote, rural areas, and these remote areas usually have weak grids, often with voltage unbalances and under/overvoltage.[11-12] Also it has one more disadvantage of requiring capacitors at the stator terminals to provide for the reactive power demand of the machine.[13] The system delivers the rated power only at a given wind speed, leading to low energy conversion efficiency. Due different speed wind power varies with rated speed and due to this wind turbine produces active power with fluctuations. Also when it connected to weak grid the voltage instability occurs due to over speeding of wind mills. Therefore the need of hour arises the concept of variable speed wind turbine which includes DFIG.

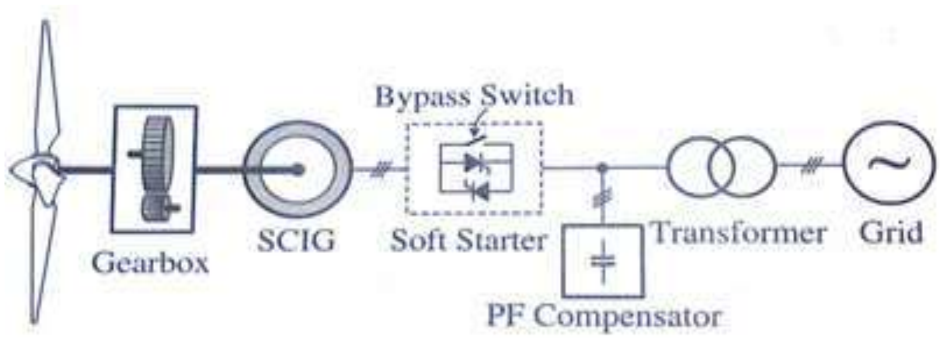

Fig. 2 Initial Wind turbine model [8]

4. DOUBLY FED INDUCTION GENERATOR

During the last years, the most used configuration in wind power projects has been the doubly-fed induction generator shown in figure 3. The main advantage of this configuration is that it allows variable-speed operation. Therefore, the power extraction from the wind can be optimized. [7]

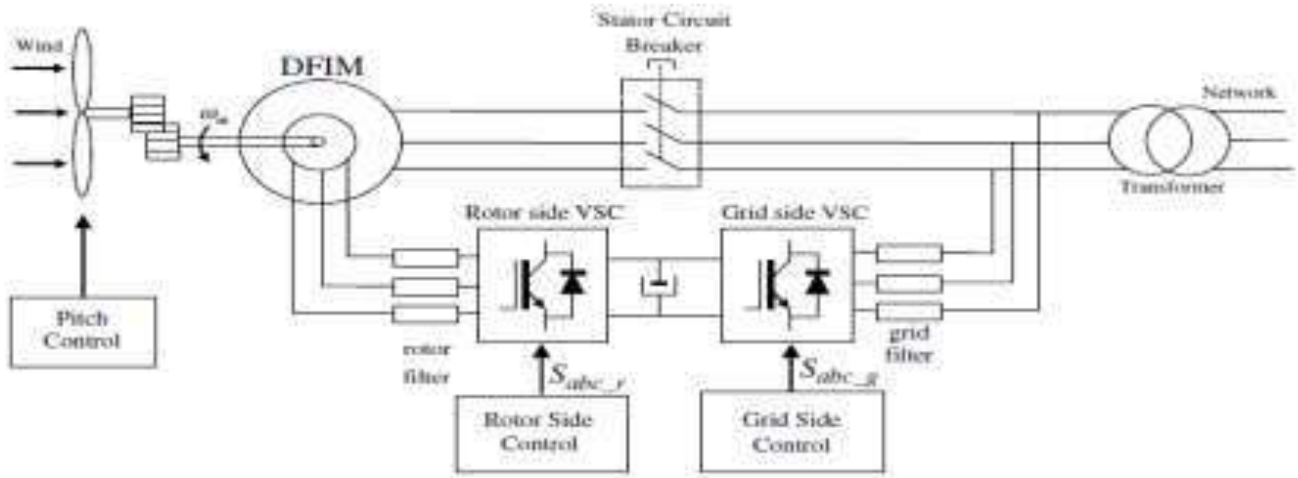

Fig. 3 *doubly fed induction generator[8]*

The mechanical energy generated by the wind turbine is transformed into electrical energy by an induction generator and fed into the main grid through the stator and rotor windings. Back-to-back converters consist of two voltage source converters (ac-dc-ac) which are connected by a DC link capacitor. The rotor side converter takes the variable frequency voltage and converts it to DC voltage. The grid-side converter has the AC voltage of the DC link as the input and the voltage in the grid parameters as the output. With the rotor side converter it is possible to control the torque or the speed of the DFIG and also the power factor at the stator terminals, while the main purpose of the converter on the mains side is to keep the intermediate circuit voltage constant regardless of the magnitude and direction of the rotor power. There is a DC link capacitor between the two converters. placed, as an energy store, to keep the voltage variations (or ripple) in the DC link voltage small. The stator is directly connected to the network. The rotor, on the other hand, needs a step-down transformer to be able to do this connect to the network. For a normal generation regime, the energy obtained by processing the wind speed as an input it is fed to the mains by both the stator and the rotor.

5. DFIG CONVERER PROTECTION SYSTEM

The prevalent DFIG converter protection scheme is crowbar protection. A crowbar is an electrical circuit which consists of resistors that are connected in parallel with the rotor winding on occurrence of an interruption. The crowbar circuit bypasses the rotor-side converter.[2] The active crowbar control scheme connects the crowbar resistance when necessary and disables it to resume DFIG control.[2] A braking resistor (DC-chopper) can be connected in parallel with the DC-link capacitor to limit the overcharge during low grid voltage. This has no effect on rotor current but it protects the IGBTs from overvoltage and can dissipate energy. In a similar way to the series dynamic braking resistor, which has been used in the stator side of generators, to limit the rotor over-current a dynamic resistor is proposed to be put in series with the rotor (series dynamic resistor).. In normal operation, the switch is on and during fault conditions, the switch is off and the resistor is connected in series to the rotor winding. The rotor equivalent circuit is shown with all the above protection schemes in Fig.4

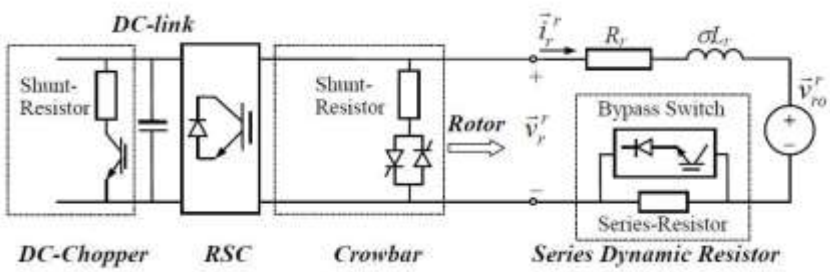

*Fig. **4**. DFIG rotor equivalent circuit with all protection schemes shown [2]*

3. DFIG CHARACTERISTICS

Figure 5. shows how the rotor and stator power vary as the rotor slip changes from sub- to super-synchronous modes. The speed of the rotor has to change as wind speed changes in order to track the maximum power point of the aerodynamic system. Slip, *s*, therefore is related to incident wind speed. In this case, a slip of -0.2 occurs with rated wind speed (12 ms-1). As wind speed drops, slip has to increase and in this case has a maximum value of 0.35.

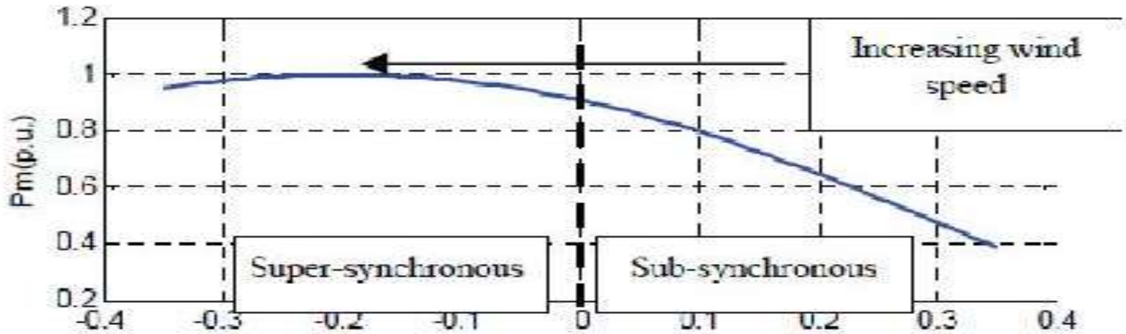

Fig.5 DFIG power flows [2]

When rotating at the synchronous speed ($s = 0$), the DFIG supplies all the power via the stator winding, with no active power flow in the rotor windings and their associated converters. Note that at $S = 0$, the stator power is maximum as shown in figure 6. As the wind speed increases, the rotational speed must also increase to maintain optimum tip-speed ratios. In such circumstances, the machine operates at super synchronous speeds ($s < 0$). The mechanical power flows to the grid through both the stator windings and the rotor windings and their converter. At lower wind speeds, the blades rotate at a sub-synchronous speed ($s > 0$). In such circumstances, the rotor converter system will absorb power from the grid connection to provide excitation for rotor winding. With such a control scheme it is possible to control the power extracted from the aerodynamic system such that the blade operates at the optimum aerodynamic efficiency (thereby extracting as much energy is as possible) by adjusting the speed of rotation according to the incident wind speed.

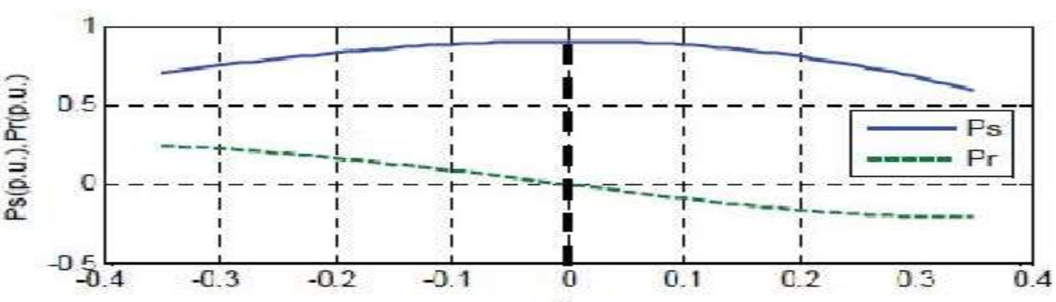

Fig. 6. DFIG power flows showing stator power (Ps) and rotor power (Pr)[2]

4. CONCLUSIONS

This paper gives idea about DFIG system. That costs more than fixed-speed induction generators without converters. However, the key points are the performance and controllability which are excellent in comparison with fixed speed induction generator systems; they capture more wind energy, they exhibit a higher reliability gear system, and high-quality power supplied to the grid. It saves investment on full-rated power converters, and soft-starter or reactive power compensation devices fixed-speed systems (2). In the case of a weak grid, where the voltage may fluctuate, the DFIG may be ordered to produce or absorb an amount of reactive power to or from the grid, with the purpose of voltage control.(7) Also because of its ability to control reactive power and to decouple active and reactive power control by independently controlling the rotor excitation current, DFIG is preferred in wind power generation.

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