

Application of Power Electronic Technologies For Wind Turbine System

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ABSTRACT

In this research work we found an application on trending technologies of Power Electronics for the generation of high power using wind turbine system. During the last two decades Power Electronics plays a vital role in many industrial applications for the generation of power from 1-10 kilowatt power. Now-a-days there are new upcoming technologies in power electronics which gives high efficiency, better reliability and good processing speed with less time consumption. In recent days there is widespread use of wind turbines in the transmission and distribution system. As the grid connection and power level of the wind turbines are increasing, there is a requirement to make advances in the generators, power electronics systems and control solutions for the improvement of characteristics of the power plant and make it more suitable to be integrated into power grid. The switching requirement in this application contains less power consumption which is nothing but Insulated Gate Bipolar Transistor (IGBT) as it was being replaced by Silicon Controlled Rectifier (SCR) for better controlling operations. As the characteristics of the plant are being improved then we need to face the challenges in the technologies.

Keywords: DFIG, IGBT, SCR, Generator and Motors.

I. INTRODUCTION

The advancement in power electronics engineering has a significant impact on wind turbine system. In this present technology a special kind of machines used which gives better power efficiency at a good rpm speed. In the 1980s, the power electronics for wind turbines was just a soft starter used to initially interconnect the squirrel-cage induction generator with the power grid, and only simple thyristors were applied and they did not need to carry the power continuously. In the year 2000, even more advanced back-to-back (BTB) power converters were introduced in large scale which started to regulate the generated power from the wind turbines. The scope of this paper is to give a status overview and discuss some technology trends of power electronics used for wind power application. Initially, the technology and market developments of wind power generation are generally introduced. Next two dominant wind turbine concepts as well as the potential converter topologies are addressed. Furthermore, the emerging challenges for future wind power generation are discussed and some final conclusions are given.

II. ABOUT DFIG

Doubly-fed electric machines are basically electric machines that are fed currents into both the stator and the rotor windings. Most doubly-fed

electric machines in industry today are three-phase wound-rotor induction machines. Although their principles of operation have been known for decades, doubly-fed electric machines have only recently entered into common use. This is due almost exclusively to the advent of wind power technologies for electricity generation. Doubly-fed induction generators (DFIGs) are by far the most widely used type of doubly-fed electric machine, and are one of the most common types of generator used to produce electricity in wind turbines. Doubly-fed induction generators have a number of advantages over other types of generators when used in wind turbines. The primary advantage of doubly-fed induction generators when used in wind turbines is that they allow the amplitude and frequency of their output voltages to be maintained at a constant value, no matter the speed of the wind blowing on the wind turbine rotor. Because of this, doubly-fed induction generators can be directly connected to the ac power network and remain synchronized at all times with the ac power network. This manual covers the operation of doubly-fed induction generators, as well as their use in wind turbines. Although it is possible to use these machines by themselves, they are primarily studied as a stepping stone to doubly-fed induction generators.

III. BLOCK DIAGRAM

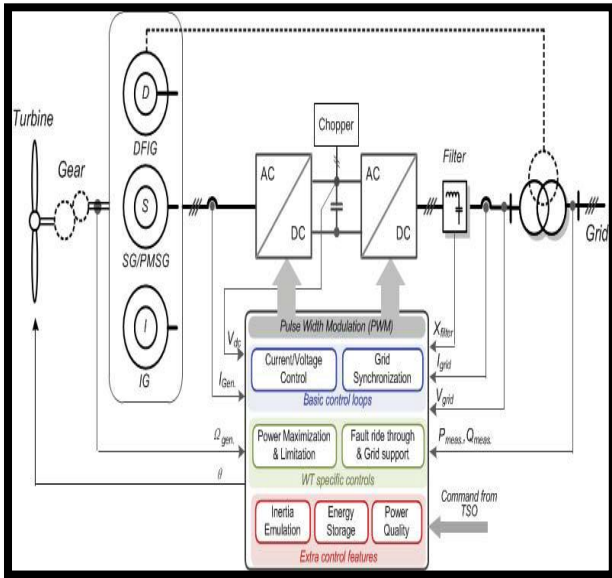


Figure 1: shows the block diagram of modern wind turbine system.

In the above figure shows the controlling section of DFIG based wind turbine system. Here the turbine converts wind energy to mechanical energy and this mechanical energy is converted to electrical energy by means of a rolling turbine. The electrical power generated goes to the converters where it converts an alternating current to direct current and again an inverter is used to convert the direct current to alternating current. Below maximum power production, the wind turbine will typically vary the rotational speed proportional with the wind speed and keep the pitch angle θ fixed. At very low wind speed, the rotational speed will be fixed at the maximum allowable slip to prevent over voltage of generator output.

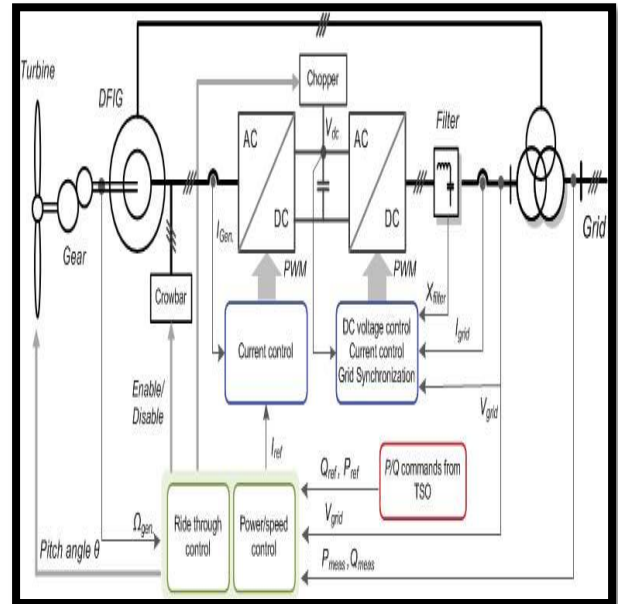


Figure 2: shows the control of wind turbine by using DFIG.

A pitch angle controller is used to limit the power when the turbine output is above the nominal power. The total electrical power of the WTS is regulated by controlling the DFIG through the rotor side converter. The control strategy of the grid side converter is simply just to keep the dc-link voltage fixed. It is noted that a trend is to use a crowbar connected to the rotor of DFIG to improve the control performance under grid faults.

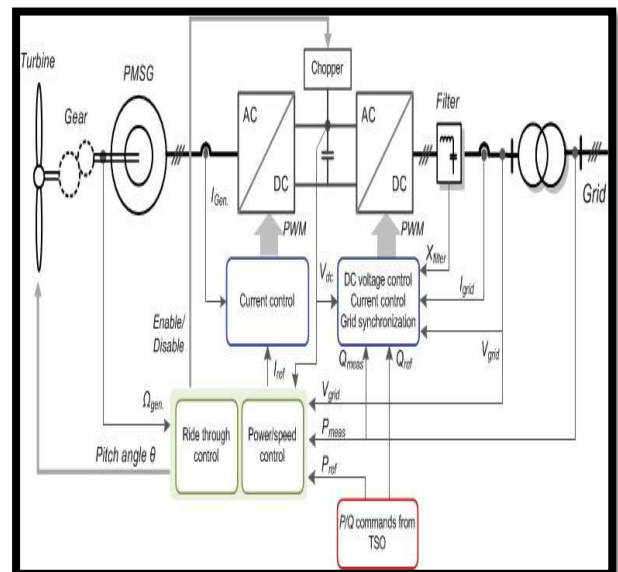


Figure 3: shows the control of Active and Reactive power in the wind turbine.

Another example for the control structure used for full-scale converter-based wind turbine concept is

shown in Fig 3. An advantage of this turbine system is that the dc link performs some kinds of control decoupling between the turbine and the grid. The dc link will also give an option for the wind turbines to be connected with energy storage units, which can better manage the active power flow into the grid system this feature will further improve the grid supporting abilities of the wind turbines. The generated active power of the WTS is controlled by the generator side converter, whereas the reactive power is controlled by the grid side converter. It is noted that a dc chopper is normally introduced to prevent overvoltage of dc link in case of grid faults, when the extra turbine power needs to be dissipated as the sudden drop of grid voltage.

IV. SIMULATION RESULTS

The doubly-fed induction generator rotates at the synchronous speed and the synchronous speed of the generator can be modified by adjusting the value of the rotor frequency.

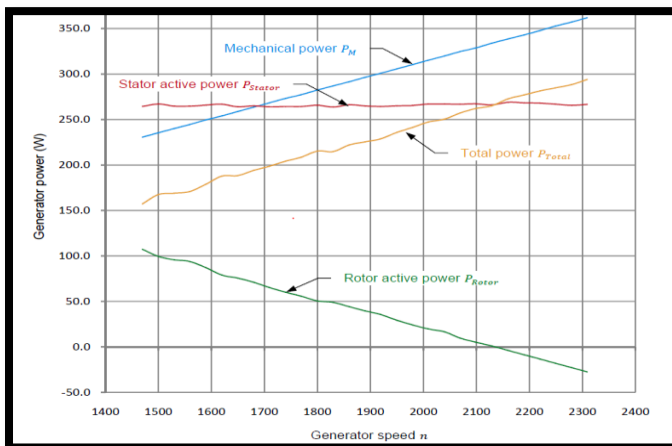


Figure 4: shows the simulation results of DFIG

As the doubly-fed induction generator speed increases and the magnetic flux in the generator is maintained at the optimal value, the active power at the stator remains constant, while the active power at the rotor decreases. Consequently, the generator total power increases. Furthermore, when the generator speed reaches a certain value in Hyper-synchronous operation the rotor begins supplying active power the polarity of active power at the rotor becomes negative which adds up to the active power supplied by the stator.

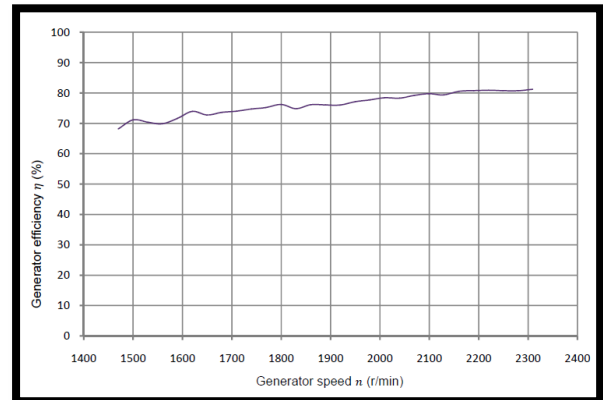


Figure 5: shows the Doubly-fed induction generator efficiency as a function of the generator synchronous speed.

The doubly-fed induction generator efficiency increases slightly with the generator speed. The relatively low efficiency of the doubly-fed induction generator is primarily due to its small size. In large doubly-fed induction generators such as the ones used in wind turbines, the generator efficiency is much higher. It is preferable for a doubly-fed induction generator to operate at hyper-synchronous speed as the generator efficiency increases with the generator speed of rotation.

The rotor speed of a doubly-fed induction generator can be varied by adjusting the frequency of the ac currents fed into the generator rotor, even though the amplitude and frequency of the ac power network to which the generator is connected remains constant. If the rotor of a doubly-fed induction generator rotates in the opposite direction to the magnetic field created in the rotor, the amplitude and frequency of the voltages produced by the generator will be lower than during normal singly-fed operation at the same rotor speed. The frequency of the ac currents that need to be fed into the doubly-fed induction generator rotor windings so that the generator is synchronized with the ac power network is calculated below:

$$f_{Rotor} = f_{Network} - \frac{n_{Rotor} \times N_{Poles}}{120}$$

$$= 50 \text{ Hz} - \frac{900 \text{ r/min} \times 8 \text{ poles}}{120}$$

$$= -10 \text{ Hz}$$

As the polarity of the rotor frequency is negative, the rotating magnetic field created by the ac currents fed into the generator rotor windings must rotate in the opposite direction to the generator rotor.

The frequency of the ac currents that need to be fed into the doubly-fed induction generator rotor windings so that the generator is synchronized with the ac power network is calculated below:

$$f_{Rotor} = f_{Network} - \frac{n_{Rotor} \times N_{Poles}}{120}$$

$$= 60 \text{ Hz} - \frac{1530 \text{ r/min} \times 4 \text{ poles}}{120}$$

$$= 9 \text{ Hz}$$

As the polarity of the rotor frequency is positive, the rotating magnetic field created by the ac currents fed into the generator rotor windings must rotate in the same direction as the generator rotor.

MERITS AND DEMERITS

Using doubly-fed induction generators in wind turbines instead of asynchronous generators offers the following advantages:

Below table 1, shows the silicon semiconductor devices for wind power applications:

	<i>IGBT module</i>	<i>IGBT Press-pack</i>	<i>IGCT Press-pack</i>	<i>SiC MOSFET module</i>
Power Density	Low	High	High	Low
Reliability	Moderate	High	High	Unknown
Cost	Moderate	High	High	High
Failure mode	Open circuit	Short circuit	Short circuit	Open circuit
Easy maintenance	+	-	-	+
Insulation of heat sink	+	-	-	+
Snubber requirement	-	-	+	-
Thermal resistance	Large	Small	Small	Moderate
Switching loss	Low	Moderate	Moderate	Low
Conduction loss	Moderate	Moderate	Moderate	Large
Gate driver	Moderate	Moderate	Large	Small
Major manufacturers	Infineon, Semikron, Mitsubishi, ABB, Fuji	Westcode, ABB	ABB	Cree, Rohm, Mitsubishi
Medium voltage ratings	3.3 kV / 4.5 kV / 6.5 kV	2.5 kV / 4.5 kV	4.5 kV / 6.5 kV / 10 kV	1.2 kV / 10 kV
Max. current ratings	1.5 kV / 1.2 kA / 750 A	2.3 kA / 2.4 kA	3.6 kA / 3.8 kA / 2 kA	180 A / 120 A

- 1) Operation at variable rotor speed while the amplitude and frequency of the generated voltages remain constant.
- 2) Optimization of the amount of power generated as a function of the wind available up to the nominal output power of the wind turbine generator.
- 3) Virtual elimination of sudden variations in the rotor torque and generator output power.
- 4) Generation of electrical power at lower wind speeds and

5) Control of the power factor in order to maintain the power factor at unity.

The disadvantages are high cost, high maintenance and high initial current.

CONCLUSIONS

The total installed and individual capacity of wind turbines have both been steadily increasing in the last four decade mainly driven by the needs for more renewable energies and also constantly to lower the cost of energy. The wind power

nowadays plays much more important role in the energy supply system. The state-of-the-art configurations and roles of power electronics in the wind turbine system show that the behavior performance of wind turbines can be significantly improved by introducing more advanced power electronic technologies. By proper controls and grid regulations, it is possible for the wind farms to act like conventional power plants and actively contribute to the frequency and voltage control in the grid system, thus the wind energy nowadays is more suitable to be integrated into the power grid. It is expected that even larger-scale integration of wind power will keep continuing in the near future. In the short term, the main focus of the power electronics technology in wind power application will be on the grid integration and compatibility of the wind power in the power system. In the long run, the challenges for lower energy cost, higher reliability, and better grid integration will push the technology developments in the WTS and enable many possibilities in respect to the power delivery structure, drive train, generator, PEC configurations, and the semiconductor devices.

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