

A Review on Power Electronic Application on Wind Turbines

Ms. Rinku Varghese¹ & Mr. Sankaran Nampoothiri K²

¹UG Scholar, ²Asst. Professor,

Department of Electrical & Electronics Engineering
Sree Buddha College of Engineering for women, Pathanamthitta, Kerala

Abstract: Wind power is still the most promising renewable energy in the year. The wind turbine system (WTS) started with a few tens of kilowatt power. There is a widespread use of wind turbines in the distribution networks and more and more wind power stations, acting as power plants, are connected directly to the transmission networks. As the grid penetration and power level of the wind turbines increase steadily. Therefore, more advanced generators, power electronic systems, and control solutions have to be introduced to improve the characteristics of the wind power plant and make it more suitable to be integrated into the power grid. This paper gives an overview and discusses some development trends in the technologies used for wind power systems. First, the developments of technology and market are generally discussed. Next, several state-of-the-art wind turbine concepts, as well as the corresponding power electronics.

I. INTRODUCTION

As fast growing capacity and more significant impacts to the power grid by wind turbine system (WTS), the power electronic technologies used of wind power application have changed dramatically during the last 30 years. Later 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 has to be applied and they did not need to carry the power continuously. In the 1990s the power electronics technology was mainly used for the rotor resistance control of wound-rotor induction generator. where more advanced diode bridges with a chopper were used to control the rotor resistance for generator especially at nominal power operation to reduce mechanical stress and loading. Since 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. First mostly in the partial-scale power capacity for the doubly fed induction generator (DFIG), then in the full-scale power capacity for the asynchronous/synchronous generator (A/SG). By introducing the BTB power electronics converters (PECs),. Power electronics gradually become more and more advanced and bring in significant performance improvements for the wind turbines not

only reducing the mechanical stress and increase the energy yield.

II. WIND ENERGY CONVERSION SYSTEM

Thermal in components of a wind turbine system are illustrated in Figure, including a turbine rotor, a gearbox, a generator, a power electronic system, and a transformer for grid connection. Wind turbines capture the power from wind by means of turbine blades and convert it to mechanical power. It is important to be able to control and limit the converted mechanical power during higher wind speeds. The power limitation may be done either by stall control, active stall, or pitch control whose power curves are shown in Figure. It can be seen that the power may be smoothly limited by rotating the blades either by pitch or active stall and a lower power output for higher wind speed. The common way to convert the low speed, high-torque mechanical power to electrical power is using a gearbox and a generator with standard speed. The gearbox adapts the low speed of the turbine rotor to the high speed of the generator, though the gearbox may not be necessary for multi pole generator systems. The generator converts the mechanical power into electrical power, which being fed into a grid possibly through power electronic converters, and a transformer with circuit breakers and electricity meters. The two most common types of electrical machines used in wind turbines are induction generators and synchronous generators.

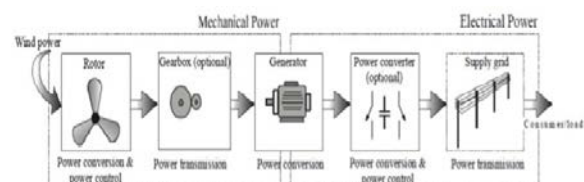


Fig. 1 Converting wind powers to electrical powers in a wind turbine

Induction generators with cage rotor can be used in the fixed speed wind turbines due to the damping effect. The reactive power necessary to energize the magnetic circuits must be supplied from

the network or parallel capacitor banks at the machine terminal that may have the danger of self-excitation, when connection to the network is lost. This type of system is an economical way to supply reactive power and obtain variable speed for increased energy yield at wind speeds below the rated speed. Synchronous generators are excited by an externally applied dc or by permanent magnets (PMs). There is considerable interest in the application of the multiple-pole synchronous generators driven by a wind-turbine rotor without a gearbox or with a low ratio gearbox. Synchronous machines powered by wind turbines may not be directly connected to the ac grid because of the requirement for significant damping in the drive train. The use of a synchronous generator leads to the requirement for a full rated power electronic conversion system to decouple the generator from the network.

III. VARIABLE SPEED WIND TURBINE WITH PARTIAL SCALE POWER CONVERTER

The most adopted partial scale frequency converter is adopted in conjunction with the DFIG concept, which gives a variable speed controlled wind turbine with a wound rotor induction generator and partial scale power converter on the rotor circuit. The topology is shown in Figure. The stator is directly connected to the grid, while a partial-scale power converter controls the rotor frequency and thus the rotor speed. The power rating of this partial-scale frequency converter defines speed range.

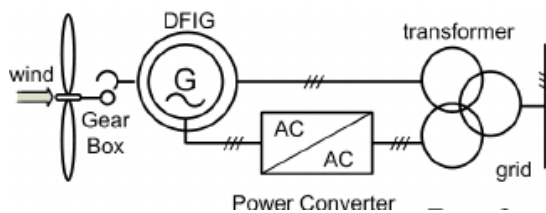


Fig. 2 Variable Speed Wind Turbines with Partial-Scale Power Converter

Moreover, this converter performs reactive power compensation and a smooth grid interconnection. The smaller frequency converter makes this concept attractive from an economical point of view. In this case, the power electronics is enabling the wind turbine to act as a dynamic power source to the grid. However, its main drawbacks are the use of slip rings and the protection schemes/controllability in the case of grid faults. If the generator is running super-synchronously electrical power is delivered through both the rotor and the stator. If the generator is running sub-synchronously electrical power is only delivered into the rotor from the grid. The third

category is wind turbines with a full-scale power converter between the generator and grid, which are the ultimate solutions technically. It gives extra losses in the power conversion but it may be gained by the added technical performance. These disadvantages may comprise the reliability and may be difficult to completely satisfy the future grid requirements.

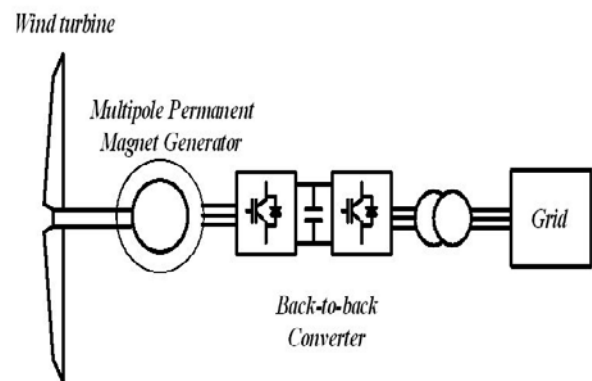


Fig. 3 Voltage source converters for wind turbines

IV. ASYNCHRONOUS / SYNCHRONOUS GENERATOR WITH FULL SCALE CONVERTER

The second important concept that is popular for the newly developed and installed wind turbines is shown in Fig 4. It introduces a full-scale power converter to interconnect the power grid and stator windings of the generator, thus all the generated power from the wind turbine can be regulated. The asynchronous generator, wound rotor SG (WRSG) or permanent magnets SG (PMSG) has been reported as solutions. The elimination of slip rings, simpler or even eliminated gearbox, full power and speed controllability as well as better grid support ability are the main advantages compared with the DFIG-based concept.

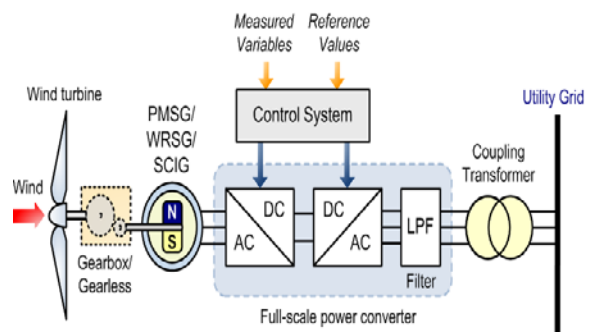


Fig. 4 A/SG with Full-Scale Power Converter

A variable speed wind turbine configuration with full-scale power conversion corresponds to the full variable speed controlled wind turbine, with the

generator connected to the grid through a power converter as shown in Figure. We can divide variable speed wind turbines into two main groups: direct driven and indirect driven turbines. Direct driven wind turbines consist of a SG with large number of poles, which enables them to operate in low speed. In this case the speed of the SG matches the turbine speed, so the gearbox is not needed for these types of wind turbines. Wound rotor and synchronous generators (WRSG) and permanent magnet synchronous generators (PMSG) with full-capacity power converter systems are widely used for direct-driven wind turbines. In indirect driven wind turbines the gearbox is used to match the low turbine speed portion of the rotor to the high rotational speed of the generator.

V. CONTROL STRUCTURE OF WIND TURBINE SYSTEM

The Controlling a wind turbine involves both fast and slow control dynamics as shown in where a general. Generally, the power flowing in and out of the generation system has to be managed carefully. The generated power by the turbines should be controlled by means of mechanical parts. Meanwhile, the whole control system has to follow the power production commands given by distribution system operator (DSO)/transmission system operator (TSO).

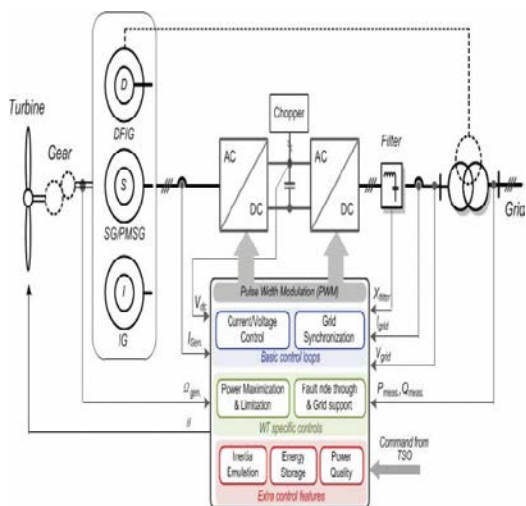


Fig. 5 General control structure for modern wind turbines

More advanced features of the wind turbine control may be considered such as the maximization of the generated power, ride through operation of the grid faults, and providing grid supporting functions in both normal and abnormal operations, and so on. In the variable-speed wind turbine concept, the current in the generator will typically be changed by controlling the generator side converter, and thereby the rotational speed of turbine can be adjusted to

achieve maximum power production. 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.

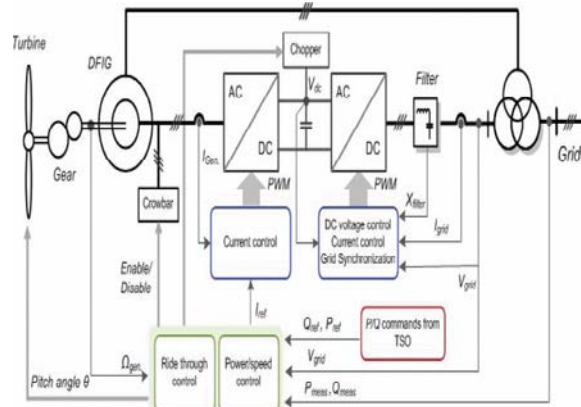


Fig. 6(a) Control of a wind turbine with DFIG

At very low wind speed, the rotational speed will be fixed at the maximum allowable slip to prevent over voltage of generator output. A pitch angle controller is used to limit the power when the turbine output is above of 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.

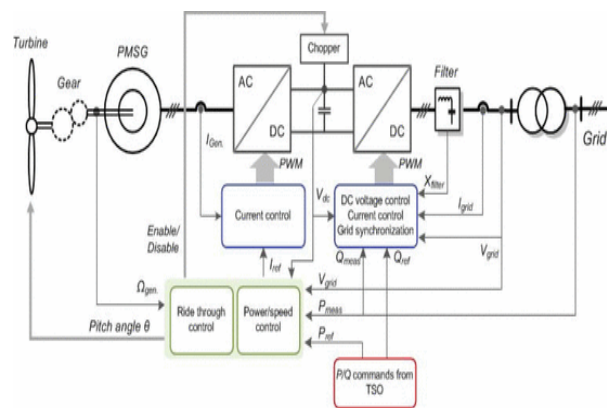


Fig. 6 (b) Control of active and reactive power in a wind turbine with multi pole PMSG

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.

VI. CONCLUSION

The various wind turbine systems with different generators and power electronic converters are described. Different types of wind turbine systems have quite different performances and controllability. The electrical topologies of wind Farms with different wind turbines are briefed. It has been shown that the wind farms consisting of different turbines may need different configurations for the best use of the technical merits. Furthermore, the possible methods of improving wind turbine performance in power systems to meet the main grid connection requirements have been discussed. The wind turbine size is still increasing. Both onshore and offshore wind farms are quickly developing in a global scale.

REFERENCES

1. M. Liserre, R. Cardenas, M. Molinas, and J. Rodriguez, "Overview of multi-MW wind turbines and wind parks," IEEE Trans. Ind. Electron. April 2011
2. S. Muller, M. Deicke, and R. W. De Doncker, "Doubly fed induction generator systems for wind turbines," IEEE " May/Jun. 2002.
3. F. K. A. Lima, A. Luna, P. Rodriguez, E. H. Watanabe, and F. Blaabjerg, "Rotor voltage dynamics in the doubly fed induction generator during grid faults," IEEE Trans. Power Electron., Jan. 2010.
4. K. Ma and F. Blaabjerg, "Multilevel converters for 10 MW wind turbines," in Proc. EPE, 2011, pp.
5. J. Rodriguez, S. Bernet, P. K. Steimer, and I. E. Lizama, "A survey on neutral-point-clamped inverters," IEEE Trans. Ind. Electron., vol. 57, no. 7, pp. 2219–2230, Jul. 2010.