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POWER ELECTRONICS APPLICATION ON WIND TURBINES

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Abstract: This paper reviews the power electronic applications for wind energy systems. Various wind turbine systems with different generators and power electronic converters are described, and different technical features are compared. The electrical topologies of wind farms with different wind turbines are summarized and the possible uses of power electronic converters with wind farms are shown. Finally, the possible methods of using the power electronic technology for improving wind turbine performance in power systems to meet the main grid connection requirements are discussed.
Keywords—Fault ride-through, grid connection, power electronics converters, reactive power compensation, wind energy conversion, wind farms, wind turbine control.

I.INTRODUCTION

The last ten years, the global wind energy capacity has increased rapidly and became the fastest developing renewable energy technology. By the end of 2006, the global wind electricity-generating capacity has increased to 74 223 MW from 59 091 MW in 2005. The early technology used in wind turbines was based on squirrel-cage induction generators (SCIGs) directly connected to the grid. Recently, the technology has developed toward variable speed. The controllability of the wind turbines becomes more and more important as the power level of the turbines increases. Power electronic, being the technology of efficiently converting electric power, plays an important role in wind power systems. It is an essential part for integrating the variable-speed wind power generation units to achieve high efficiency and high performance in power systems. Even in a fixed-speed wind turbine system where wind power generators are directly connected to the grid, thyristors are used as soft starters. The power electronic converters are used to match the characteristics of wind turbines with the requirements of grid connections, including frequency, voltage, control of active and reactive power, harmonics, etc. This paper reviews the major applications of power electronics for wind power conversion systems, and it is organized as follows. Section II shows a brief review of the wind energy conversion systems and modern power electronics. Then, applications of power electronics for wind turbines are presented.

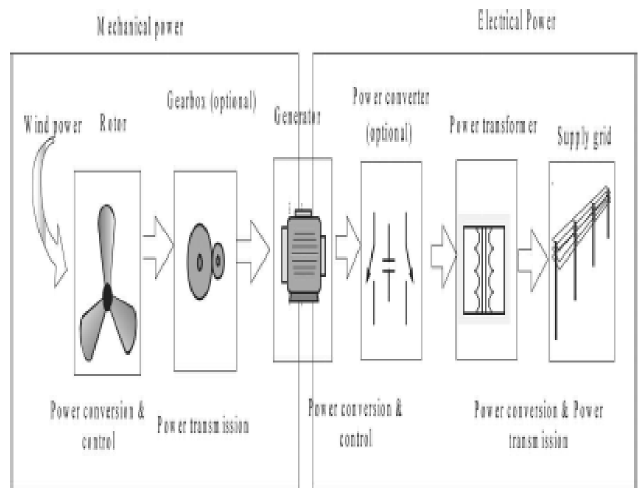


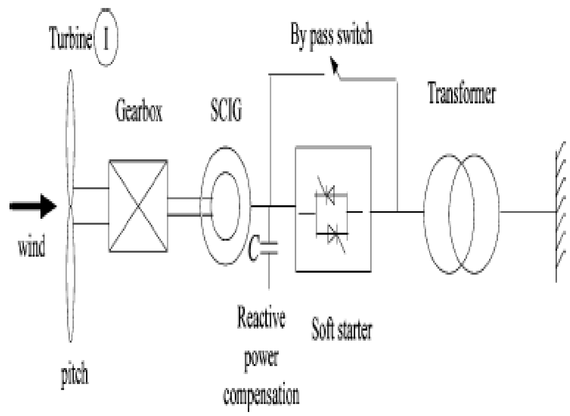
Fig. 1. Main components of a wind turbine system.

2. POWER ELECTRONICS FOR INTEGRATION AND CONTROL OF WIND TURBINES

Many possible technical solutions of wind turbine electrical systems are related to power electronics, since they can improve dynamic and steady-state performances, help to control the wind turbine generator, and decouple the generator from the electrical grid [2], [4]. Some major power electronic applications are described in this section.

2.1. Soft-Starter for Fixed-Speed Wind Turbines

The "Danish concept" [1] of directly connecting a wind turbine to the grid is widely used in early wind turbine systems. The scheme consists of an SCIG, connected via a transformer to the grid and operating at an almost fixed speed. The power can be limited aerodynamically either by stall control, active stall, or pitch control.



III POWER QUALITY IMPROVEMENT WITH POWER ELECTRONIC DEVICES

Large-scale integration of wind turbines may have significant impacts on the power quality and power system operation. Traditionally, wind turbines are not required to participate in frequency and voltage control. However, in recent years, attention has been increased on wind farm performance in power systems [1]–[2]. Consequently, some grid codes have been redefined to specify the requirements that wind turbines must meet in order to be connected to the grid. Examples of such requirements include the capabilities of contributing to frequency and voltage control by continuously adjusting active power and reactive power supplied to the transmission system, the power regulation rate that a wind farm must provide, flicker, harmonics, etc. Some of the requirements may be dealt with by power electronic technology, for example, reactive power control.

IV.SYSTEMS DYNAMIC STABILITY IMPROVEMENT WITH POWER ELECTRONICS

An important issue of integrating large-scale wind farms is the impact of the wind power technologies on the stability and transient behavior of the power systems [2]–[3]. The problem of network stability is often associated with different types of faults in the network, such as tripping of transmission lines (e.g., overload), loss of production capacity, and short circuits. Short circuits have a variety of forms, and most of them are cleared with relay protection systems either by disconnection.

4.1 Fault Ride-Through of DFIG with a Crowbar

As discussed previously, a voltage drop will spur an electromagnetic torque reduction that leads to the acceleration of the rotor. The grid voltage decreases rapidly to a low level and will cause high current transients in the generator stator and also in the rotor, due to the magnetic coupling between the stator and rotor [7]. The high current may damage the power electronics converter connected with the rotor winding of DFIGs. Therefore, protection measures are required for DFIG wind turbines during voltage dips. A reduction in mechanical torque is desired in order to avoid over speed. A pitch regulation, as explained before, can be used. To avoid damages in power electronics, the most common option is to block the rotor-side converter and short circuit the rotor winding by means of a so-called crowbar[8], [.9]. A crowbar is connected between the rotor of the DFIG and the rotor-side converter. The crowbar circuit may have various topologies, for example, Fig. 29 shows a crowbar consisting of a diode bridge that rectifies the rotor phase currents and a single thyristors in series with a resistor Rcrow. The thyristors is turned on when the dc-link voltage reaches its limit value or the rotor current reaches its limit value. Simultaneously, the rotor of the DFIG is disconnected from the rotor-side power electronic converter and connected to the crowbar. The rotor remains connected to the crowbar until the main circuit breaker disconnects the stator from the network. When the grid fault is cleared, the rotor-side converter is restarted, and after synchronization, the stator of the DFIG is connected back to the network. Rotor over current protection described before is called a passive crowbar.

V. CONCLUSIONS AND FUTURE TRENDS

This paper has reviewed the power electronic applications for wind energy systems. 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. While the wind turbine market continues to be

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dominated by conventional gear-driven wind turbine systems, the direct drive or one-stage gear, so-called multibrid-type wind system, is attracting attention. Variable-speed operation has many advantages. On the one hand, the DFIG dominates the current market for variable-speed gear-driven wind turbine systems, largely due to the fact that only the power generated in the generator rotor has to be fed through a power electronic converter system (25%–30%).On the other hand, variablespeed wind turbines with a full-scale power converter may be more effective and less complicated to deal with grid-related problems, including the possibility for active grid support, and the potential to operate wind turbines and wind farms as power plants. Therefore, variable speed wind turbine concepts with a full-scale power converter would become more attractive. Many power electronics configurations for wind turbine systems have been actively researched, mainly the VSCs, including Multi converter configurations, are used. Compared with geared drive wind generator systems, the main advantages of direct drive wind generator systems are higher overall efficiency, reliability, and availability due to omitting the gearbox.PM machines are more attractive and superior with higher efficiency and energy yield, higher reliability, and power-to-weight ratio compared with electricity-excited machines [2].With synchronous generators, diode rectifiers may be used as the machine-side converters [4]. Furthermore, studies on the use of current-source converters for grid converters are reported [3], [4]. Considering the performance of PMs is improving and their cost is decreasing over the recent years, combined with the fact that the cost of power electronics is decreasing, variable-speed direct drive PM machines with a full-scale power converter have become more attractive for offshore wind powers.

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