International Journal of Electrical, Electronics and Data Communication, ISSN: 2320-2084 Volume-2, Issue-5, May-2014

A REVIEW ON POWER-ELECTRONIC SYSTEMS FOR WIND ENERGY CONVERSION SYSTEM

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Abstract- This paper aims to give a basic idea of wind energy conversion system with the power electronics systems. In future, the whole world will look for renew able and alternative energy sources with modern control techniques Modern wind turbines with high rating are possible only with the help of power electronics.

Keywords-Wind energy conversion system (WECS), Voltage source converter (VSC), H-bridge converter, Neutral-Point Clamped (NPC).

I. INTRODUCTION

Wind is one of the most abundant renewable sources of energy in nature. The economical environmental advantages offered by wind energy are the most important reasons why electrical systems based on wind energy are receiving widespread global attention. The research for wind power industry started to be improved in the last century, mainly due to the oil crisis and natural resources ripening. By increasing the wind turbine size the electrical power production is also increased. Conventional electrical energy sources depend heavily on fossil fuels burning. However, burning of the fossil fuels causes environmental issues such as global warming, acid rain and urban smog, etc. by releasing pollutant s like carbon dioxide, sulphur dioxide etc. Into the atmosphere. Based on the issue, the renewable energy, which includes photovoltaic energy, wind energy, and geothermal energy, etc., has been heavily investigated and rapidly developing. Renewable energy has the advantages that it is abundant, clean, and becoming increasingly economical. In fact, renewable energy sources help in reducing about 70 million metric tons of carbon emissions per year that would have been produced by fossil fuels .Among various types of renewable energy sources, wind energy is among the fastest growing renewable energy sources.

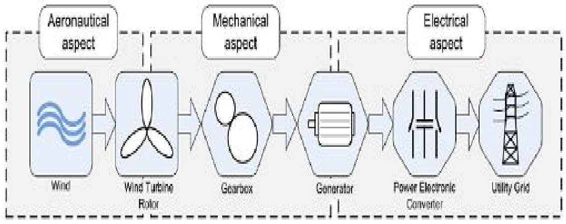

Figure 1. Wind Energy Conversion System (WECS) (based on [6],[7])

In wind energy conversion systems (WECSs), the key technologies include wind turbine technology, power electronics technology, and system control technology. For the wind turbines, based on the orientation of the rotation axis of the wind turbine, there are vertical and horizontal axis wind turbines. In the horizontal-axis wind turbines, the rotation axis of the wind turbine is parallel to the ground, while in the vertical-axis wind turbines, the rotation axis is perpendicular to the ground. Compared to the vertical-axis wind turbines, horizontal-axis wind turbines have higher wind energy conversion efficiency, which are widely applied in the wind energy industry. The wind turbines can also be classified as fixed-speed wind turbines and variable-speed wind turbines based on whether the operation speed is controllable. The fixed-speed wind turbines possess the merits that they are simple, robust, and require lower construction and maintenance cost. However, their operation speed is fixed and cannot be controlled with the variation of the wind speed, which results in lower energy conversion efficiency compared to the variable speed wind turbines. Nowadays, most of the wind turbines applied in industry are variable-speed wind turbines. Among various types of variable speed WECSs, three kinds are most widely applied in industry:

(1) doubly-fed induction generator (DFIG) WECSs with reduced-capacity power converters,

(2) geared/gearless squirrel-cage induction generator (SCIG) WECSs with full-capacity power converters, and

(3) geared/gearless wound-rotor synchronous generator (WRSG)/permanent magnet synchronous generator (PMSG) WECSs with full-capacity power converters. In the DFIG WECSs, only 30% of the rated power is processed by the power converters, which greatly reduces the cost of the converters while preserving the capability to control the speed of the generator in the range of about of its rated speed. In SCIG, WRSG and PMSG WECSs, full-capacity power converters are needed to process the power generated by the generators up to the rated power of the systems. With the application of the full-capacity power converters, the generators are fully decoupled from the grid, and are able to operate in the full speed range.

II. POWER CONVERTERS FOR WECSS

Power electronics devices have been applied in WECSs since the 1980s, when a thyristor based soft-starter was applied to a SCIG system which was directly connected to the grid. The thyristor based soft-starter was used for limiting the current surge during start up. In the 1990s, the emergence of the rotor resistance control approach made it possible that the WRSG can be controlled to operate at variable speed. Although the speed range is only limited to 10% above the synchronous speed of the generator, this progress has improved the energy capture efficiency of the wind turbine due to the application of the converter controlled variable resistance. Nowadays, backto-back converters are widely used in WECSs, either in reduced power (reduced power means that only the 30% of the rated power is processed by the power converters) for DFIG systems shown in Figure 2, or in full power (full power means that the power generated by the generator up to its rated power is processed by the power converters) for PMSG/SCIG/WRSG systems which can be seen in Figure

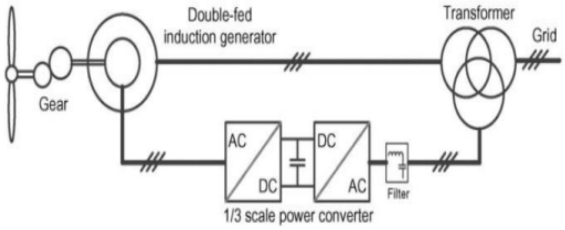

Figure 2. DFIG with partial-scale power converters

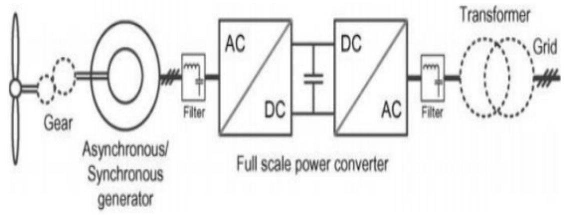

Figure 3. Wind turbine generators with full-scale power converters

The back-to-back power converters, which decouple the wind turbine from the grid, possess the capability to regulate the operation speed of such wind turbine generators, control the active and reactive powers injected into the grid, and improve the power quality. Conventional two-level back-to-back power converters have been widely applied in wind power industry and their reliability has been well proved. With the development of the semiconductor devices and the digital control technology, multilevel converters were investigated and commercialized during recent years, which helps in improving the power level and the power quality of the wind energy generation systems. The most widely applied power converters for the best seller range 1.5-3.0 MW WECSs are the two-level back-to-back voltage source converters (VSCs). Figure 4. And figure 5 are showing two typical two-level back-toback VSCs.

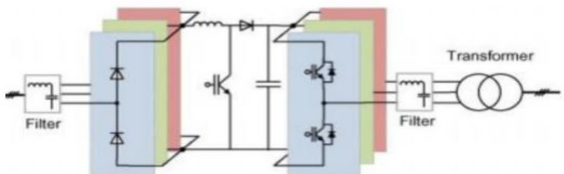

Figure 4. Two-level back-to-back converters with passive rectifier

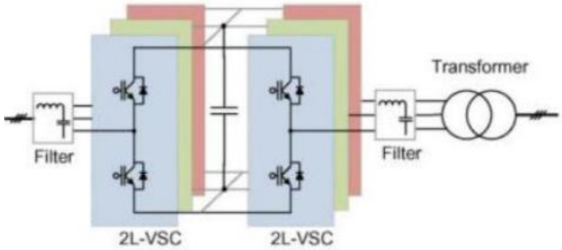

Figure 5. Two-level back-to-back converters with active rectifier

Shown in Figure 4 is a two-level back-to-back converter with a passive diode rectifier and a DC chopper. Figure 5 shows a two-level back-to-back converter with an active rectifier and inverter connected to the grid. As can be seen in Figure 4 and 5, the insulated gate bipolar transistors (IGBTs) are used as the power switches. Although recent developments have make the IGBT with higher-voltage blocking capability closer to the integrated gate-commutated thyristor (IGCT), the IGBT based twolevel back-to-back VSCs are applied mainly in the lowvoltage, low/medium power drive industries . As introduced in, to increase the voltage level, as well as the power level of the conventional two -level back-to-back VSCs, series-connected power switches can be applied as shown in Figure 6. Based on this topology of power switches connection, the series connected IGBTs distribute the voltage and power stress on the single IGBT in the conventional two-level VSCs, which improves the voltage and power level of the two-level VSCs. With the application of the series-connected IGBT two-level high power inverters, the multi-pulse rectifiers become attractive selections for the high power back-to-back VSCs. These types of rectifiers help in reducing the input current harmonics which is beneficial for the generators in wind turbine systems. Figure 7 shows the 12, 18, and 24 pulse rectifier circuit configurations.

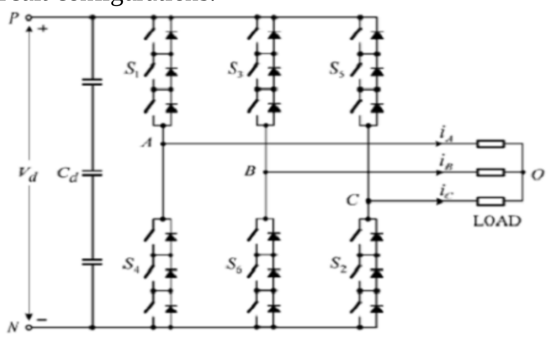

Figure 6. Two-level VSC with series-connected power switches

Although the series-connected IGBT VSC has greatly improved the voltage and power level of the twolevel VSC, it contributes nothing to reduce the dv/dt (the voltage change, dv, within the time interval, dt), or to improve the power quality. Based on this concern, the multilevel converters were investigated and commercialized. Among various types of multilevel converters, the neutral-point clamped (NPC) converters, cascaded H-bridge (CHB) converters, flying capacitor converters, and Active NPC converters are the most studied ones. Here, the research on NPC and CHB converters which are the most widely applied types of multilevel converters will be reviewed.

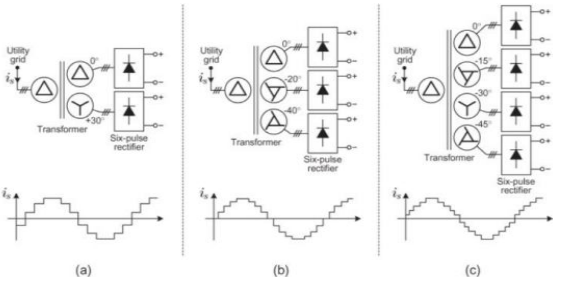

Figure 7 Multi-pulse diode rectifier circuit configuration and input current: (a) 12 pulse, (b) 18 pulse, and (c) 24 pulse

A. Neutral-Point Clamped Multilevel Converters

The NPC multilevel converter was proposed in in the early 1980s. It can be structured as three level, five level, and even seven level or more. However, the three level NPC converters is the most applied type in industry. In each leg of the three-level NPC converter, there are four power switches which are clamped with diodes to a midpoint of the capacitor bank as shown in Figure 8. To this converter, all conventional pulse width modulation (PWM) approaches are applicable. Since the commutation voltage of all the power switches in the NPC converter is only half of the DC bus voltage, the NPC converter is very suitable for the high power, medium voltage drives (2.3-4.16 kV) . What is more, since the conduction of the power switches only shares half of the DC bus voltage, the dv/dt is greatly reduced. The output line-to-line voltages of the NPC converter consists of three voltage levels, which result in reduced harmonics in the output voltages and improved power quality. The main drawback of the NPC converter is that the power losses on the power switches are unevenly distributed, which reduces the reliability of the NPC converters.

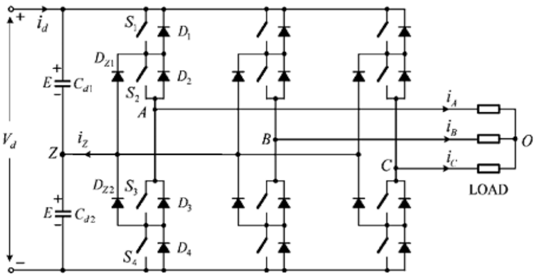

Figure 8. Topology of the NPC converter

B. Cascaded H-Bridge Converters

The concept of cascaded H-bridge (CHB) converter was first introduced in. After that in the late 1990s, the CHB converter was further studied and tested in. The CHB converter consists of series connected Hbridge power cells. A typical H-bridge power cell is shown in Figure 9. The series-connected power cells naturally increase the voltage and power level of the CHB converters. The number of the power cell mainly depends on the operation voltage, the harmonic requirements, and the budget for the system. What is more, for a CHB multilevel converter with 2k+1 power cells, it will be able to generate level output voltages, which results in reduced harmonics in the output voltages and improved power quality . The main drawback of the CHB converter is that it requires large number of dc sources for the H -bridge, which increases the cost.

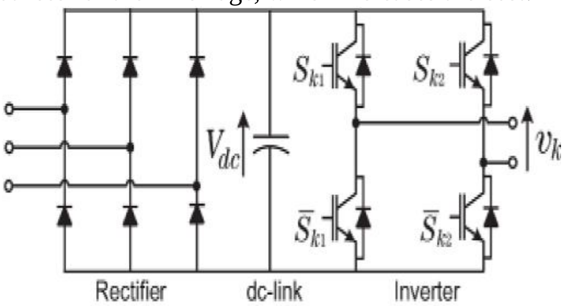

Figure 9. CHB power cell

CONCLUSION

This paper has reviewed the power electronic applications for wind energy systems. Wind turbine systems with different generators and power electronic converters are described. Different types of wind turbine systems have quite different performances and controllability. In this paper the main trends of the power electronics used in WT applications are presented. Due to the high demand for renewable energy sources applications, there is a continuing research for improving the total efficiency of these applications and by improving each electronic part included. Power electronics technology for WECSs have been actively researched, mainly the VSCs, including multiconverter configurations, are used. Compared with geared-drive WECSs, the main advantages of direct-drive WECSs are increased overall efficiency, reliability, and availability due to omitting the gearbox. PM machines are more attractive and superior with higher efficiency and energy give up, higher reliability, andpower-to-weight ratio compared with electricity-excited machines .

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