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A Review on Power Converter Topology for Wind Energy System for Permanent Magnet Synchronous Generator

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Abstract **— This paper is a review on different converter topology with PMSG for wind energy conversion system. In the area of renewable energy resources, wind energy conversion system is becoming popular. Four main type of generator used in wind energy conversion system (WECS) are Squirrel Cage Induction Generator (SCIG), Doubly Fed Induction Generator (DFIG), Wound Field Synchronous Generator (WFSG), and Permanent Magnet Synchronous Generator (PMSG). Currently PMSG is more popular due to many advantages over other. PMSG is directly coupled to wind turbine that's why it is called Direct Driven Generator. The paper mainly discuss Power converter topologies in use with Permanent Magnet Synchronous Generator for stand-alone and grid connected wind energy conversion system.**

Keywords **— Permanent Magnet Synchronous Generator, Wind Energy Conversion System, Multiple Converters, Matrix Converter, Z- Source Inverter, Wind Power Plants.**

I. INTRODUCTION

The renewable energy sources are mostly used in the world wise. The cost of oils is increasing day by day and fossil fuels are very less, and less solution is attracted. The wind energy is free and not pollution. Wind energy is quite attractive among other sources because of its commercial potential [72 TW] that is five times higher than world energy demand in all forms. However, the installed capacity in 2009 was only 159GW [1] and [2]. The dynamic growth of wind power directly pushes the wind technology into a more competitive area. The variable nature of wind energy sources (in Terms of the real power, reactive power, output voltage, and frequency) is a major challenging issue. The conversion of an input AC power at a given frequency and voltage to an output power at different frequency and voltage can be obtained with static circuits called power converters, containing controllable power electronic devices. Various power converters have been developed to fulfill the requirements of the wind power generation. Each of them has some advantages and some disadvantages. New expertise in converter design together with the large-scale implementation of wind power plants (WPP) increases the capacity factor of wind farm substantially. Some new wind farms require capacity factor higher than 50% [3], [4], [5]. In the near future, new grid scale energy storage technologies potentially can bring the capacity factor to even higher. For example, Ocean Renewable Energy Storage from MIT [6], Wind Hydrogen Storage Systems are very promising in this aspect. In addition, today's advanced technologies have made WPP perform as good as conventional fossil fuel or nuclear power plants in keeping the grid stable. Gigantic WPP nowadays can actively participate in grid voltage/frequency regulation on both primary and secondary control, eliminate all the anxiety about high wind energy penetration might make the grid become unstable. With these advantages, wind energy will be involved to be an important source of energy for the world, contribute to the solution for our climate and energy problems.

II. WIND ENERGY CONVERSION SYSTEM

Blades of the wind turbines designed aerodynamically, they capture power from the wind and convert wind power into the mechanical power [7]. A gear box is used to match the speed of wind turbine and generator. PMSG is a direct-drive type system so it's used to eliminate the gear box and reduces the size of wind energy conversion system [8]. After converting the mechanical wind energy into electrical energy by the generator, power converters are included for conversions of generated AC power into DC power (either for storing energy in battery or supplying dc power to resistive loads) or in AC/DC/AC system supplying AC power grid coupled systems. Various topologies of converter used with PMSG base wind energy conversion system for high efficiency and low cost [9].

III. POWER CONVERTERS

Power converters are used in WECS for converting generated power. The development of power electronics and their applicability in wind energy extraction allowed for variable speed operation of the wind turbine. Two main converter topologies of power converter with PMSG are Standalone topology and Grid connected topology.

A. Grid side Converter:

Converters used in grid side are thyristor converters. They have high power capacity and mainly used in high power applications.

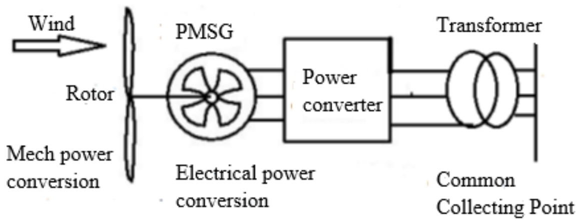

Fig. 1 Wind energy conversion system for PMSG

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B. Standalone Converter:

Standalone converter system used PWM control method general. IGBT is mainly used semi-conductor because of turn- off capability. PWM converter may produce harmonics and interharmonics due to high frequency switching. Filters are connected to remove harmonics [8].

✓ Grid connected topologies with PMSG are classified on the basis of Grid side converters:

1. Thyristor grid side converter
2. Hard switched grid side converter
3. Matrix converter
4. Multilevel converter
5. Z-source inverter

1. Thyristor grid side converter:

A thyristor grid side inverter allows continuous control of inverter firing angle [10]. To obtain the optimum energy thyristor grid side inverters regulate turbine speed by the DC link voltage. A voltage source converter (VSC) is used for the compensator and the error signal between the reference and actual compensator current is used to drive the pulse width modulated (PWM) control [11].

Advantages:

1. Lesser cost and greater power rating.

Disadvantages:

1. Need of an active compensator for reactive power demand and reduction in total harmonic distortion

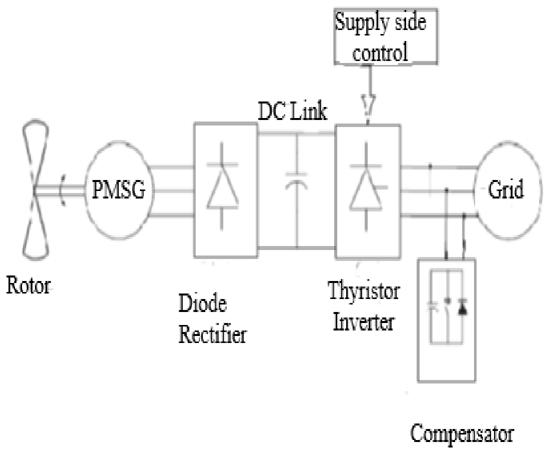

Fig. 2 Thyristor grid side converter

2. Hard switched grid side converter:

To maximize the system's power output a power mapping technique is used to match the Maximum Power to the DC-link voltage. Furthermore, a derivative control is also used to control the stator frequency as it changes with the DC-linked voltage. The control system is like the MPPT (Maximum Power Point Tracking) which maps the Power generated to a reference power so as to set the operating DC voltage.

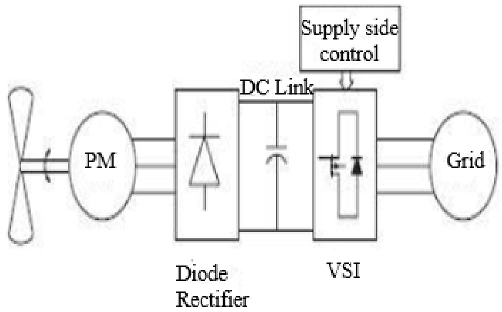

Fig.3 Hard Switching Supply side Inverter with Voltage Source Inverter (VSI)

Following topologies are being use with grid side PWM converters:

a) Back to back PWMVSI:

Back to back PWM converter is the most conventional type converter. It is referred as two levels PWM-VSI converter because two voltage source inverter (VSI) are connected in generator side and grid side. A DC link capacitor is connected between two PWM-VSI. DC link capacitor is also called decoupling capacitor and provide a separate control in the inverter on the generator side and grid side [12].

Advantages:

Lower cost

Disadvantages:

1. Switching losses and emission of high frequency harmonics.
2. Decoupling capacitor reduces life of the system.

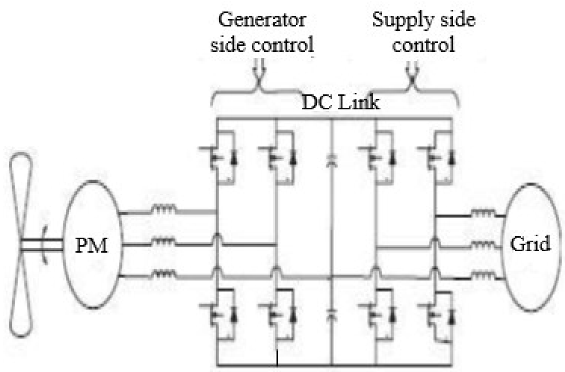

Fig. 4 Back to back PWM VSI converter

b) Generator side uncontrolled rectifier with boost converter:

In this topology, output of PMSG is rectified by an uncontrolled rectifier and MPPT is achieved by a boost converter.

Advantages:

1. No need of wind measurement.
2. Controller adapts to the parameter variations of the PMSG.

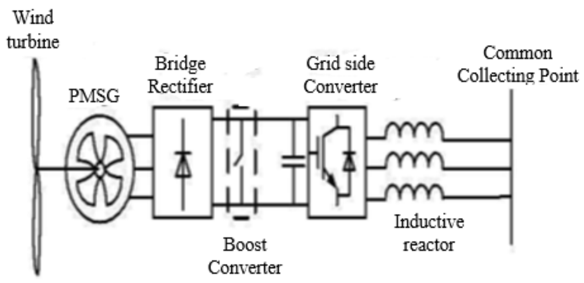

Fig. 5 Generator side uncontrolled rectifier with boost converter

c) Generator Side Phase Shifting Transformer feeding Series Type 12 Pulse Uncontrolled Rectifier:

This type of inverter used to a novel and simple MPPT control strategy. In generator terminal a passive filter is connected to reduce harmonics and improve efficiency.

Advantages:

Provide high efficiency and suppress distortions presents in the PMSG voltage and current.

d) Generator Side semi controlled Rectifier:

The main advantages of the topology are following:

1. Simple circuit design, no complexity.
2. No possible shoot through fault.
3. High efficiency.
4. Low cost.

3. Matrix converter:

Matrix converter is an AC-AC converter and an alternative of the DC link voltage-sourced converter. A matrix converter provides a large no. of control levers that allows for independent control on the output voltage magnitude, frequency, phase angle and input power factor [13].

Advantages:

1. Eliminate DC link reactive element, e.g. bulky capacitor and / or inductors.
2. No need of any large energy storage element.
3. High efficiency.
4. Harmonic emission.

Disadvantages:

1. Lack of decoupling between the two sides of the converter.
2. Low voltage gain.
3. Higher conducting losses
4. Due to complex control it has not accepted in industrial application.

Some different types of matrix converter are following:

a) Conventional matrix converter:

The conventional matrix converter is composed with nine bi-directional commanded insulated gate bipolar transistors (IGBT) [14]. Proper operation of switches in the matrix control on the output of magnitude, frequency, phase angle and input displacement angle.

Disadvantages:

1. Commutation problem associated during the operation of the switches.
2. Safe operation of the switches requires complicated switching.

b) Improved matrix converter:

Improved matrix converter is based on the concept “Fictitious DC link” used in controlling the matrix converter. There is no energy storage element between line side and load side converter [13]. The matrix convert is connected between two filters and PMSG is connected with first order type filter and second order type filter is connected with an electric network [14].

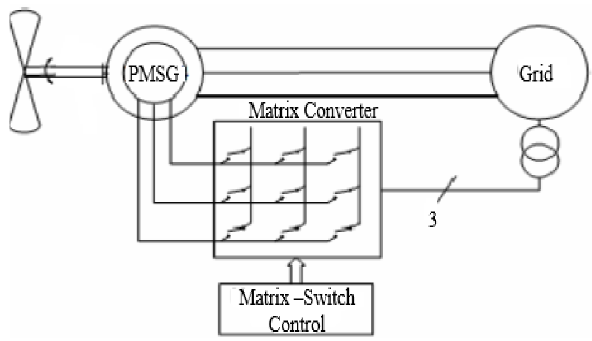

Fig. 6 Conventional matrix converter

Advantages:

1. Commutation problem associated with the switches have been solved.
2. All the switches at the line-side turn-on and turn-off at Zero current.

IV. CONCLUSION

Wind energy conversion system (WECS) are becoming more and more popular in the renewable energy resources system. Power converter plays a important role in WECS. In this paper, different popular converter topologise used in PMSG based WECS has been studied. By studying and comparing the various converter topology of grid side and standalone system based on PMSG WECS, it is found that the Thyristor grid side inverter is cheap but generates lot of harmonics in the generatoe current which increased losses and reduces generator current which reduces generators life. Thyristor is not able to take out power under low wind speed condition. In hard switched inverter topology back to back PWM VSI is the most popular but it is costly solution for smaller capacity. Multilevel converter reduces the weight but they commonly used for offsher wind farms. Matrix converter eliminate the DC-link stage and provide a more reliable system comparing to other. Matrix converter has disadvantage of complicated control and cost,due to this backdraw this topology has not yet been accepted in the industrial application. Z-source inverter improves the relaibilty of the system as it is able to escape the shoot through fault. Standalone side system is used for small wind energy applications so converters used in standalone side are boost converter and buck-boost converter. Boost conveter is used to convert low generted voltage into high genrate voltage from small wind turbines. Buck-boost converter has cascade connection of the buck and boost converter and it is used to control the rotor speed.

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