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# Investigation on PMSG based Variable Speed, Vertical axis Wind Energy Generating System to Enhance the Power Quality

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***Abstract***- This paper represents a investigation on variable speed wind energy generating systems using Permanent magnet synchronous generators (PMSG) and the investigation of reasons of poor power quality issues related with grid connected wind farm. Such issues can be Steady state voltage rise, voltage flicker, harmonics, frequency deviations, impact of low power factor. Also gives brief idea about power electronics converter topologies and its control techniques.

***Key words***- Wind energy generation, Power quality, Permanent Magnet Synchronous generator, Power Converters, Control

## I. INTRODUCTION

Today with the increasing demand of electrical power due to fast rise in Industry, IT sector etc need of pollution free and low cost energy source, lead to the use of renewable energy. Renewable energy resources such as solar, flowing water, biomass, wind etc are intermittent in nature. Among all the renewable sources, wind has been utilized as a source of power generation since it is being most economical, clean and emission free technology [1].Wind costs are much more competitive with other generating technologies because there is no fuel to purchase and minimal operating expenses. Essentially wind energy is a by-product of solar energy, available in the form of kinetic energy of air.

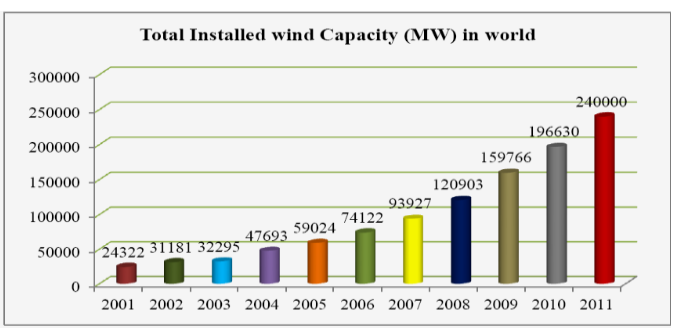


Fig 1 statistical data of wind capacity in the world

The statistical data[2] of installed capacity of wind in the world according GWEC is given in fig 1.The development of wind energy in India began in 1990's and significantly increased in the last few years. In the past 20 years the size of wind generators and the wind plant size increased significantly. The variability of wind power can create problems for the traditional grids in maintaining a supply and demand balance. Most of the wind farms in India are located in remote areas that are quite for away from load centers. This is one of the key constraints for the future of wind power development in the country. According to American Wind Energy Association 1MW of wind generated power can supply electricity to approximately 240, to 300 households per year.

This paper reviews the PMSG based Variable Speed, Vertical axis Wind Energy Generating System and it is organized as follows. Section II describes about wind energy conversion systems, Section III presents about power electronic converter topologies and its control strategies, Section IV describes about power quality issues, finally in Section V, and the conclusions are drawn.

## II. WIND ENERGY CONVERSION SYSTEMS

### A. Wind Power Characteristics.

The main component of wind energy conversion system is illustrated in Fig.2 including turbine blade, a gear box, PMSG, Converter, DC-DC converter, Inverter, Control circuits, Filters, Electrical cables, Ground support equipment and interconnection equipment, tower that supports the rotor and drive train. Wind turbine capture power from wind by means of turbine blades (which converts the energy in the wind to rotational shaft energy) and convert it to mechanical power. Wind at any speed can be captured and it is transformed into AC voltage with any frequency.

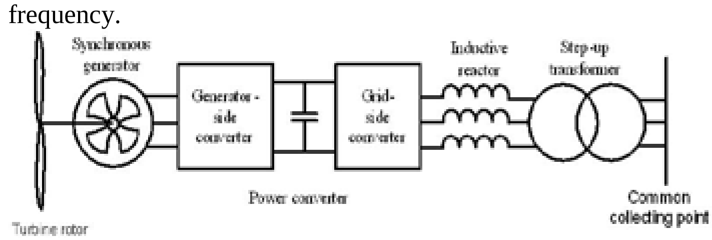


Fig 2.Main components of WECS

The ability of a wind turbine to extract power from wind is a function of three main factors:

- Wind power availability
- Power curve of the machine
- Ability of the machine to respond to wind perturbations.

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The power contained in wind is given by the kinetic energy of the flowing air mass per unit time as follows

$P_0$=1/2(air mass per unit time) X (wind velocity)$^2$

$=1/2\ \rho\ A\ V\infty^3$ (1) $P_0$: Power contained in wind (in watts),

ρ: Air density,

A: Rotor area in (square meter)

V∞: Wind velocity without rotor interference, ideally infinite distance from rotor in meter per second.

The factors affecting power output are wind speed, air density, altitude, Temperature, Tower height, Type of generator, number of blades, Blade size, Rotor efficiency, Gear box efficiency, wind speed distribution.

**B.Classification of wind energy conversion systems:**

**(i)According to Wind Speed:**
(1) Moderate: 6.4 to 7 m/sec (wind turbine class IV)
(2)Good: 7.5m/sec (wind turbine class III)
(3)Excellent: >7.5 m/sec (wind turbine class I or II, III)

**(ii)According to Output Power:**
(1) Small size: Up to 2 KW
(2)Medium Size: 2 -100KW
(3)Large size: 100KW and above.

**(iii)According to Rotational Speed of Aero turbines:**
While considering the rotational speed of Aerodynamics the wind energy generating systems can be classified as
(1)Fixed speed wind energy generating system
(2)Variable speed wind energy generating system
The wind energy generator design goes on changing from fixed speed to variable speed because of the higher energy gain and reduced stress [3], improve efficiency and power quality ,active and reactive power can be controlled easily and less rapid power fluctuations.

**(iv) According to the orientation of the wind turbine:**
While considering the orientation the wind turbines are classified into two types,
(1)Horizontal axis wind turbine (HAWT)
(2)Vertical axis wind turbine (VAWT).
A horizontal axis machine has its blades rotating on an axis parallel to the ground. A vertical axis machine has its blades rotating on an axis perpendicular to the ground. There are a number of available designs for both and each type has certain advantages and disadvantages. However, compared with the horizontal axis type, very few vertical axis machines are available commercially. Now days 95% of the existing turbines are horizontal axis wind turbines. The advantages of HAWT are able to produce more electricity, much lower cyclic stresses and yaw mechanism is not required. The disadvantages of vertical axis wind turbines are less efficiency, complicated maintenance, large land occupation.

**C.Generators in Wind Turbine Systems**
Four types of generators generally find application in wind power plants; Doubly-fed induction generator, geared/gearless squirrel gage induction generator, geared/gearless wound-rotor synchronous generator and Permanent magnet synchronous generator. Direct driven based multiple pole PMSG which are very suitable for large scale wind power plant because of its light weight and small size in construction, great yield, noise reduction, good reliability, low loss and higher efficiency, no additional power supply and no need of gear box [4].Such PMSG may be divided into several types, those with surface mounted magnets, those with buries magnets, and those with damper winding [5]

## III. CONVERTER TOPOLOGIES AND ITS CONTROL STRATEGIES

### A. Power Electronics for Variable Speed Wind Turbines

Wind power is characterized by its stochastic nature. Wind speed changes continuously along with it the energy flow. A Variable speed wind machine is able to extract significantly more energy than a constant speed machine. The grid connection of wind generators is essential to exploit their potential. However the generated power, voltage and frequency from variable speed wind machine changes with wind speed. The variable voltage variable frequency system requires efficient power electronic AC-DC-AC converters for interfacing with utility system, where AC-DC converter is used to convert AC voltage with variable amplitude variable frequency to constant DC voltage. This DC voltage is again converted into AC voltage with constant amplitude and constant frequency using DC-AC inverter. Thus a power electronic converter controls and shapes electrical output. Converters using power electronic devices have good dynamic performance, and can provide high quality sine wave current in the generator and the power network. They can also help to control real as well as the reactive power of the system. Furthermore when number of wind generators operates in parallel, the converters can optimize the output of each machine in order to increase the total power output by allowing different machines to operate at different speeds.
Power electronic converter systems [6] have different topologies shown in Fig 3,4,5,6. They are
(i)Thyristor grid side converter
1. Back to Back PWM,
2. Generator side uncontrolled rectifier with boost converter
(ii)Hard switched grid side converter

(iii)Matrix converter
1. Conventional matrix converter
2. Improved matrix converter
(iv)Multilevel power converter
1. Three level Neutral point diode clamped back to back converter
2. Three level H bridge back to back converter.

3. Five level H bridge back to back converter.
4. Three level Neutral point clamped converter.

(v)Resonant converters

(vi)B4 converters

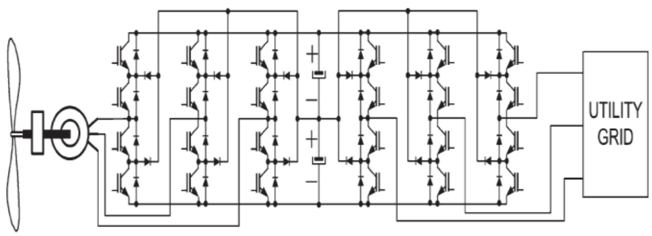


Fig 3 Multilevel back-to-back converter for direct connection to the grid

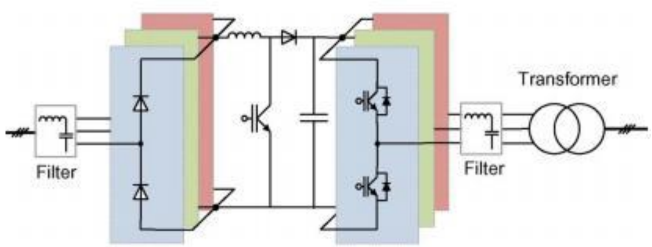


Fig 4 Two-level back-to-back converters with passive rectifier[9]

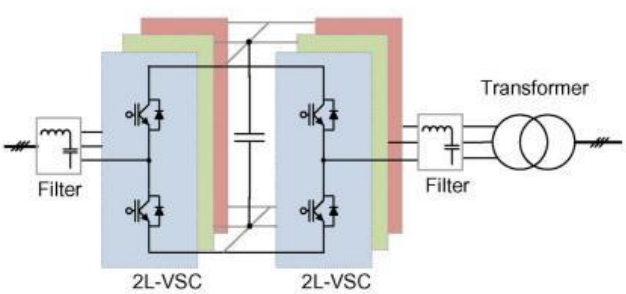


Fig 5 Two-level back-to-back converters with active rectifier [9]

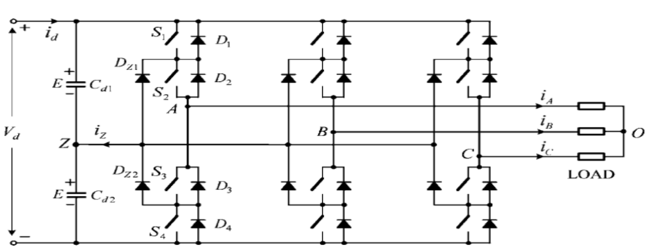


Fig 6 Topology of the NPC converter [9]

**B.Control strategies for wind energy systems**

The controllers which are used to control the switching characteristics of power electronic converters. The common methods used to control Power Electronic converter [7] are hard control such as PID control, Hysteresis control, sliding control and soft control such as Fuzzy and Neural network.

## IV. POWER QUALITY ISSUES

Electrical Power quality is the degree of any deviation from nominal values of the voltage magnitude and frequency. Power quality has become important issue over the last decade. It depends on connection of wind energy generating system with grid. Such issues can be Steady state voltage rise, voltage flicker, harmonics, frequency deviations; impact of low power factor. A wind turbine normally will not cause any interruptions on a high-voltage grid. The extensive use of power electronics based equipment and non linear loads at PCC generates harmonic currents.[8].

The machines and equipments that are affected by harmonic effects are capacitors, circuit breakers, conductors, electronic equipment, meters, protective relays, rotating machines etc. The devices used for eliminating power quality problem are known as the Custom power devices [10].They are Static Synchronous Compensator, Dynamic Voltage Restorer, and Unified Power Quality Conditioner etc. Filters are also integrated with power electronic converters to reduce the harmonics. Simple filter can be used is the passive filter (LC).Depending upon the order of harmonics present in the system the filters are tuned so that harmonics are eliminated.

## V. CONCLUSION

This survey paper has given an overview of different variable speed wind energy generating systems using Permanent magnet synchronous generators (PMSG) and the investigation of reasons of poor power quality issues related with grid connected wind farm and also presented about power electronics converter topologies and its control techniques.

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