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A Review on Comparison of Wind Energy Conversion Systems

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Abstract

This review paper is towards the comparison of the conversion used for variable speed wind electric generation system. In this paper we review the generators that are used for the variable speed generation. In variable speed wind energy conversion system (WECS), the frequency with which the rotor rotates varies and to keep the output of generator with fixed frequency load is fed through back to back converter. Variable speed wind turbine is required to track Maximum power point tracking so that maximum power can be extracted at all speed.

Keywords: DFIG, PMSG, variable speed wind turbine, wind energy conversion system

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INTRODUCTION

As we all know due to environment concern Wind based systems are mostly used in field of power generation. Hence a vast Research is going on to increase the power and efficiency of wind power plant and decrease the cost and losses of the system. In 1888 the first wind powered electricity was produced by a machine built by Charles F. Brush in Cleveland, Ohio. The rated power of machine is 12 KW (DC). Till 1930's direct current electricity production continued in the form of small scale, stand alone systems. In 1941 the first machine that feeds AC power to the grid is developed.[1–5]

Wind power mainly depends on the weather and geographic conditions and varies from time to time. Hence it is necessary to construct a system that can generate maximum power for all operating conditions.[6–9] Modern wind turbines are very advanced machine they can generate power for all the operating conditions. Two configurations used for wind energy conversion system (i) standalone system (ii) grid connected systems. In the standalone systems direct load is supplied it is mainly used in the remote areas and in grid connected systems power is fed to grid and then distributed to the load. Utility system guarantees a backup power in the situations where wind availability is insufficient. The acceptable power of wind turbines is also increasing and presently in the range of few MW. To increase the power level higher voltage generators are being proposed. Now the power rating of most popular large variable speed wind turbines are about 1.5–3 MW, recently 7 MW wind turbines has also appeared and 10 MW wind turbines are under development.[10,11]

WIND POWER GENERATION

The powers is captured from wind by wind turbines by means of its aerodynamically designed blades and convert it into rotating mechanical power. This rotating Mechanical power is used to drive generator, which will produce electrical power. The amount of power extracted from wind turbine is given by equation:[7]

$$P_M = \tfrac{1}{2} \rho A C_P V_W^3 \quad \text{Eq. (1)}$$

The mechanical torque in (N-m) is given by [7]

$T_M = P_M/W_M$ Eq. (2)

Where, A is the wind turbine rotor swept area in m^3, V_W is the speed of the wind in (m/s), W_M is the mechanical speed of the wind turbine in (rad/s), C_P is the turbine power coefficient and ρ is the air density in kg/m^3.(Figure 1)

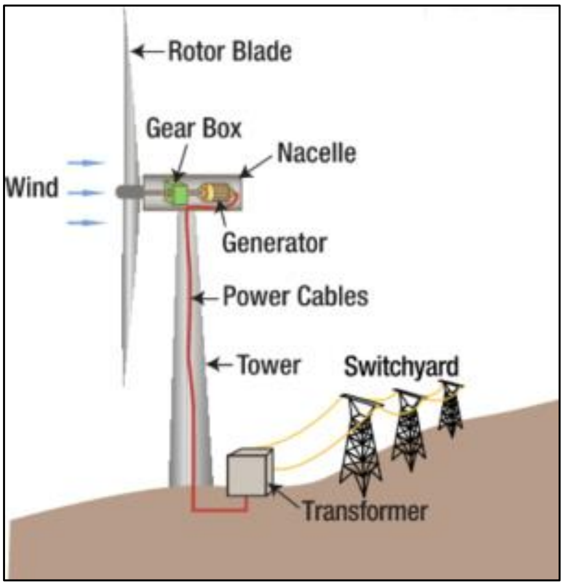


Fig 1. *Wind Energy Conversion System.*

When energy is extracted from air by the wind turbine, air gets slow down due to this some of air spread out and spread out and divert around the wind turbine to some extent without turning the rotor blades. This is the basis of Betz limit. In 1919 a German Physicist Albert Betz determined that at most 59% of energy in wind can be extracted by a wind turbine.[2] The most important parameter in the design and study of wind energy conversion devices is wind speed.

Conversion of mechanical energy into electrical energy involves many processes. In the first step energy is extracted from the wind and the kinetic energy of the wind is converted into mechanical energy via aerodynamic lift. The speed requirement of the generator is matched by gear ratio that increases the rotor speed. In the second step mechanical energy is converted into electrical energy through electrical generator. Shaft, gear box, and generator associated equipment are located at the top of the tower. In the bottom of the tower a transformer may be connected to increase the voltage level i.e. to reduce transmission losses and then it is fed to the grid or to the load.

DFIG Based Generation

The complete block diagram of DFIG based generation system is shown in Figure 2. A wound rotor induction machine can be used as DFIG and wind turbine is used with variable wind speed and blade pitch angle input. In doubly fed induction generator stator is directly connected to the grid while the rotor is connected via slip rings to the rectifier and the rectifier is connected to the inverter.

The operation of the induction generator in variable speed range is limited by rectifier and inverter. The output of the rectifier is constant irrespective of the fluctuations in the input and load. The multilevel inverter is used because of its ability to provide a better output quality and has lower switching losses and higher efficiency. The control voltage needed for controlling the output is generated by inverter controller based on vector control scheme that uses d-q axis control.

The torque reference (T_{ref}) is calculated by using maximum power point tracking technique. By calculating the difference between reference and actual torques the q-axis reference current (I_{qref}) is calculated whereas the voltage of the stator side is controlled to generate d-axis reference current (I_{dref}).

The control voltage is provided by d-q axis reference rotor currents and this control voltage is used to generate gate pulses for the 12 switches of the inverter.[4]

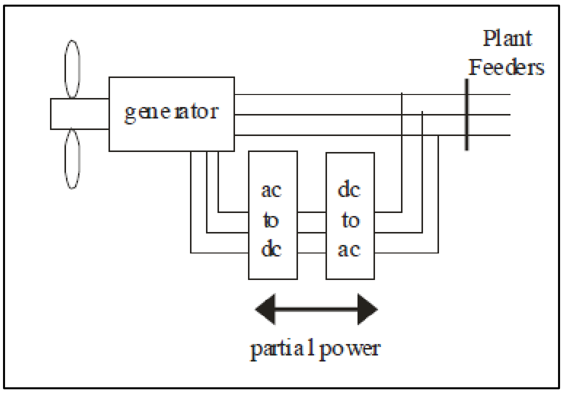


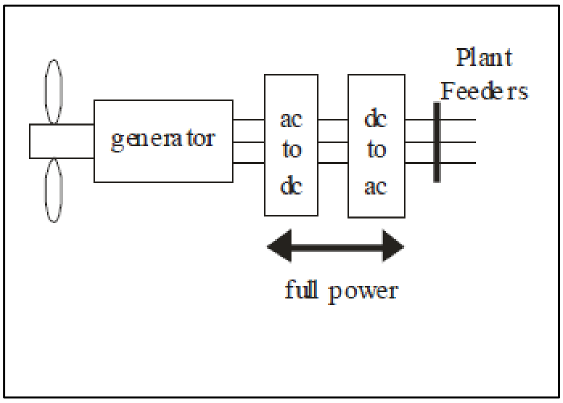
Fig. 2. *Block Diagram of DFIG Based Generation System.*

PMSG Based Generation

The block diagram of PMSG based wind energy conversion system is shown in fig. It consists of the wind turbine, gear box, permanent magnet synchronous generator, rectifier and inverter. Wind turbine is used to capture wind energy, it converts K.E. of the wind to rotational M.E. which is used to drive generator.

By using PMSG a wide range of speed is possible to maintain maximum tip speed ratio so that maximum power can be extracted from the wind turbine to the generator.[7] But with PMSG we need a full rated power electronic converter to provide fixed voltage and fixed frequency supply to the loads. The variable voltage and variable frequency AC is converted into constant DC by rectifier. If uncontrolled rectifier is used then a DC-DC converter must be used to get constant DC voltage.

A DC link capacitor is used filter out ripples at the output stage of the rectifier. Cascaded H bridge inverter convert DC to fixed voltage and fixed frequency AC. As the power level of the WECS are increasing it is not possible to use PWM inverters in such systems, so multilevel inverters are used in large wind energy conversion systems. The multilevel inverter provides staircase output and reduce the THD of the output and also reduces electro-magnetic interference.



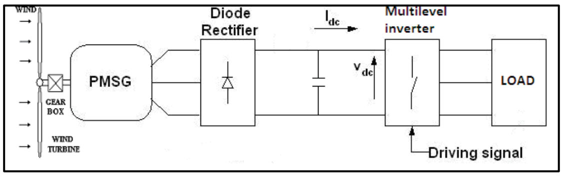


Fig. 3. *Block Diagram of PMSG Based Wind Energy Conversion System.*[9]

CONCLUSION

A Permanent Magnet Synchronous Generator is interfaced to the grid through a full power converter whereas in Doubly Fed Induction Generator only partial power is fed through converter. Hence the ratings of the converter used in DFIG are low in comparison to PMSG. PMSG has better controllability and reliability, high power density. PMSG are also performing better than DFIG in the fault conditions. Hence PMSG is increasingly adopted in variable speed wind generation system. In PMSG full Speed range is possible to produce output and maximum tip speed ratio is possible at all speed.

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