OVERVIEW OF DIFFERENT WIND GENERATOR SYSTEMS AND THEIR COMPARISONS

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Abstract

Presently the major energy requirements are catered by using conventional sources out of which coal based thermal generation is having major contribution. Considering the rate at which conventional sources are being consumed and their impact on environments it is necessary to adopt alternate energy technologies for sustainable development. Out of various renewable energy sources, wind generation is most cost effective in addition to its various advantages. Worldwide the share of wind generation connected to grid is increasing at faster rate and in near future will become one of the major sources of renewable energy. With rapid development of wind power technologies and significant growth of wind power capacity installed worldwide, various wind turbine concepts have been developed.

Considering the increasing share of wind generation interfaced to grid it is necessary to study the power quality and reactive power issues considering voltage quality and stability issues. In case of Induction type wind energy converter reactive power management in cost effective way is essential. In many wind farm wind energy converter using Synchronous generator and Induction generator are used. Use of Synchronous generator leads to distortion of wave shape and are sensitive to grid disturbances. Considering the challenges to be faced related to interfacing of large wind farms using Induction and Synchronous generators, it is necessary to study the different wind generator systems and their comparisons. The wind energy conversion system is demanded to be more cost-competitive, so that comparisons of different wind generator systems are necessary. An overview of different wind generator systems and their comparisons are presented. Also Critical Power Quality issues & Problems related with Grid connections are also discussed.

Keywords- *Wind farm, Wind generator, Power Quality issues, Grid connection.*

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1. INTRODUCTION

The research and development of modern wind power conversion technology has been going on since 1970s, and the rapid development has been seen from 1990s onwards. The average annual growth rate of wind energy converter installation is around 26.6% during last 10 years. The global wind generation installed capacity is around 74,223 MW till March 31st 2008. By the end of 2020, which is expected to cross 12, 60,000 MW i.e. 12% of the world's electricity consumption [12].

Wind energy in India came in the early 1980s with the establishment of the Ministry of Non-conventional Energy Sources (MNES), now renamed as Ministry of New and Renewable Energy (MNRE). Its purpose is to encourage a diversification of fuel sources away from the growing demand for coal, oil and gas required to feed the country's rapid economic growth. The Centre for wind Energy Technology (C-WET) first estimated the total potential for wind power in India at around 45,000 MW. This figure was also adopted by the MNRE as the official estimate of the wind power potential in the country. The Indian Wind Turbine Manufacturers Association (IWTMA) estimated the potential to be of the order of 65,000 MW.

Wind electricity installed capacity in India is around 8757.2 MW till March 31st 2008 and gross potential is 45,000 MW. Wind generation installed capacity in Maharashtra state is 1,755.9 MW and a gross potential is 3,650 MW. It ranks 2nd after Tamilnadu having capacity 3,873.4 MW in India. Today India is a major player in the global wind energy [11].

Considering the increasing share of wind generation interfaced to grid it is necessary to study an overall perspective on various types of existing wind generator systems and possible generator configurations, critical power quality issues, problems related with grid connections and some comparisons of different wind generator systems.

2. WIND TURBINE CONCEPTS AND GENERATOR TYPES

Wind turbine concepts and generator types are as follows.

2.1 Classification Of Induction Generators

Induction generators can be classified by different ways as rotor construction, excitation process, and prime movers.

2.1.1 Classification On The Basis Of Their Rotor Construction

- Squirrel cage induction generator
- Wound rotor induction generator

[A] Squirrel Cage Induction Generator (SCIG)

For the squirrel cage type induction generator, the rotor winding consists of un-insulated conductors; in the form of copper and aluminum bars embedded in the semi closed slots. These solid bars are short circuited at both ends by end rings of the same material. Without the rotor core, the rotor bars and end rings look like the cage of a squirrel. The rotor bars form a uniformly distributed winding in the rotor slots.

[B] Wound Rotor Induction Generator (WRIG)

In the wound rotor type induction generator, the rotor slots accommodate an insulated distributed winding similar to that used on the stator. The wound rotor type of induction generator costs more and requires increased maintenance.

2.1.2 Classification On The Basis Of Their Excitement Process

- Grid connected induction generator
- Self-excited induction generator

[A] Grid Connected Induction Generator (GCIG)

The grid-connected induction generator (GCIG) takes the reactive power from the grid, and generates real power via slip control when driven above the synchronous speed, so it is called grid connected induction generator. It is also called autonomous system. The operation is relatively simple as voltage and frequency are governed by the grid voltage and grid frequency respectively. The GCIG results in large inrush and voltage drop at the time of connection, and its operation makes the grid weak. The excessive VAR drain from the grid can be compensated by the shunt capacitors, but it cause large over voltage during disconnection. Therefore, the operation of GCIG should be carefully chalked out from the planning stage itself. The performance of the GCIG under balanced and unbalanced faults should be thoroughly investigated to ensure good quality and reliable power supply.

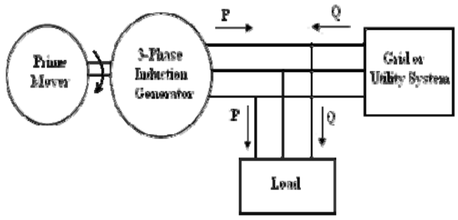

Figure: 1. Grid Connected Induction Generator

[B] Self-Excited Induction Generator (SEIG)

The self-excited induction generator takes the power for excitation process from a capacitor bank, connected across the stator terminals of the induction generator. This capacitor bank also supplies the reactive power to the load. The excitation capacitance serves a dual purpose for stand alone induction generator: first ringing with the machine inductance in a negatively damped, resonant circuit to build up the terminal voltage from zero using only the permanent magnetism of the machine, and then correcting the power factor of the machine by supplying the generator reactive power [2] & [1].

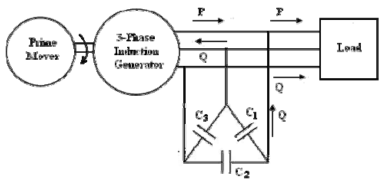

Figure: 2. Self-Excited Induction Generator

2.1.3 Classification On The Basis Of Prime Movers Used, And Their Locations

[A] Fixed speed concept using a multistage gearbox

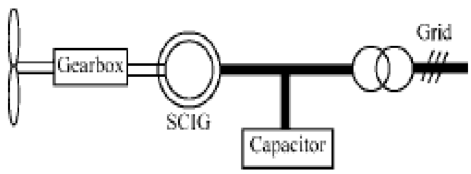

Figure: 3. Fixed speed concept using a multistage gearbox

Rotor of SCIG is directly connected to the hub of turbine through multistage gearbox. Stator is connected to the grid through coupling transformer. The wind turbine equipped with this type of generator is often called the fixed-speed wind generator system. This is the conventional concept applied by many Danish wind turbine manufacturers during the 1980s and 1990s. The SCIG always draws reactive power from the grid, during the 1980s. This concept was extended with a capacitor bank for reactive power compensation [5].

Advantages:
1) Smoother grid connection is possible by using soft starter.
2) Pole changeable SCIG used, which gives two rotation speeds.
3) It is robust, cheap, and easy.
4) It is used to operate at a constant speed which provides stable control frequency.

Disadvantages:
1) The speed is not controllable & variable only over a very narrow range, in which only speeds higher than synchronous speed are possible.
2) Fixed speed concept means that wind speed fluctuations are directly translated into electromechanical torque variations this causes high mechanical & fatigue stresses on the system & result in swing oscillations between turbine & generator shaft.
3) Periodical torque dips arises & results in higher flicker.
4) Pole changeable SCIG does not provide continuous speed variation.
5) Due to gearbox, cost increases.
6) It is necessary to obtain excitation current from the stator terminals of SCIG. This makes it impossible to support grid voltage control.
7) Reactive power compensation & soft starter required.

[B] Limited Variable speed concept using a multistage gearbox

This wind turbine concept uses a wound rotor induction generator (WRIG) with variable rotor resistance by means of a power electronic converter. The stator of WRIG is directly connected to the grid, whereas the rotor winding is connected in series with a controlled resistor [5].

Advantages:
1) Variable speed operation can be achieved by controlling the energy extracted from the WRIG rotor. The power is dissipated in the external resistor.
2) A typical limited variable speed range is less than 10% above the synchronous speed.

Disadvantages:
1) Reactive power compensation & soft starter required.
2) Due to gearbox & converter system, cost increases.

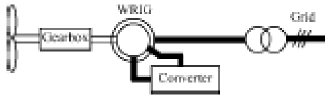

Figure: 4. Limited Variable speed concept using a multistage gearbox

[C] Variable speed concept with a partial scale power converter

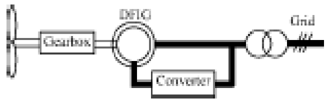

Figure: 5. Variable speed concept with a partial scale power converter

This configuration is known as the DFIG concept, which corresponds to a variable speed wind turbine with a WRIG and a partial-scale power converter on the rotor circuit. The stator is directly connected to the grid, whereas the rotor is connected through a power electronic converter. The power converter controls the rotor frequency and thus the rotor speed [10].

Advantages:
1) The rotor energy, instead of being dissipated, can be fed into the grid by the power electronic converter.
2) Grid side power converter system can perform reactive power compensation & smooth grid connection.

Disadvantages:
1) A multi-stage gearbox required. So there will be heat dissipation from friction, require regular maintenance, audible noise occurs, costs also increases.
2) The slip ring is used to transfer the rotor power by means of a partial scale converter, which requires a regular maintenance, & may be result in machines failures & electrical losses.
3) Under grid fault conditions, large stator currents result in large rotor currents, so that power electronic converter needs to be protected from destroy.
4) According to grid connection requirements for wind turbines, in case of grid disturbances, ride through capability of DFIG is also required, so that the corresponding control strategies may be complicated.

[D] Variable speed direct drive concept with a full-scale power converter

Types of Variable speed direct drive concept with a full-scale power converter
1) Electrically excited Synchronous generator
2) PM Synchronous generator

1) Electrically excited Synchronous generator (EESG)
Advantages:
1) The direct drive generator rotates at a low speed, because the generator is directly connected on the hub of the turbine rotor. No gearbox, so costs also decrease.
2) It does not require the use of PM, which is, might suffer from performance loss in harsh atmospheric condition. So generator costs also decreases.

Disadvantages:
1) In order to arrange space for excitation windings & pole shoes, it requires a large diameter. So a large number of parts & windings make it a heavy weight & becomes a expensive.
2) It is necessary to excite the rotor windings with DC using slip rings & brushes or brush less exciter, employing a rotating rectifier & the field losses are inevitable.

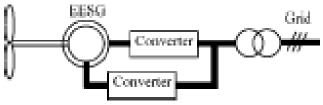

Figure: 6. Electrically excited Synchronous generator

2) PM Synchronous generator (PMSG)

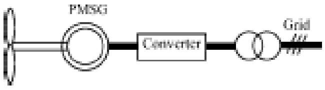

Figure: 7. PM Synchronous generator

Advantages:
1) Higher efficiency & energy yield.
2) No additional power supply for the magnet field excitation.
3) Improvement in the thermal characteristics of the PM machine due to the absence of the field losses.
4) Higher reliability due to the absence of mechanical components such as slip rings.
5) Lighter & so higher power to weight ratio.

Disadvantages:
1) High cost of PM material.
2) Difficulties to handle in manufacture.
3) Demagnetization of PM at high temperature.
Types of PM:
1) Axial-Flux PM Machines: Produces magnetic flux in axial direction.
2) Radial-Flux PM Machines: Produces magnetic flux in radial direction.
3) Transversal-Flux PM Machines: Produces magnetic flux is perpendicular to the direction of rotor rotation.

[E] Variable speed single stage geared concept with a full-scale power converter

1) PM Synchronous generator (PMSG)
Advantages:
1) It has a higher speed than the direct drive concept & a lower mechanical component than a multiple stage gearbox concept.

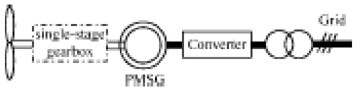

Figure: 8. PM Synchronous generator

[F] Variable speed multiple stage geared concept with a full scale power converter
Types of Variable speed multiple stage-geared concepts with a full-scale power converter
1) PM Synchronous generator (PMSG)
2) Squirrel cage Induction Generator (SCIG)

1) PM Synchronous generator (PMSG)

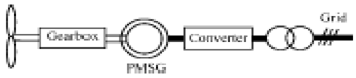

Figure: 9. PM Synchronous generator

Advantages:
Compared with DFIG system, it has the following advantages.
1) It has a better efficiency.
2) The generator can be brush less.
3) The grid fault ride through capability is less complex.

Disadvantages:
1) Larger, more expensive converter.
2) The losses in the converter are higher because the power electronic converter processes all powers.

2) Squirrel cage Induction Generator (SCIG)

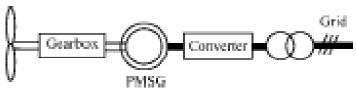

Figure: 10. Squirrel cage Induction generator

Advantages:
1) Flexible control with a full-scale power, such as variable speed operation, better performances of reactive power compensation & smooth grid connection.
Disadvantages:
1) High cost & losses of the full-scale converter, the efficiency of the total system may be low.

3. CRITICAL POWER QUALITY ISSUES

Critical power quality issues related to integration of wind farms in weak grids in India is as follows to characterize the power quality:
1. Grid availability and capacity
2. Reactive power
3. Voltage unbalance
4. Voltage ranges
5. Frequency range
6. Harmonics and interharmonics
7. Voltage fluctuations
8. Islanding and overcompensation

Of these, reactive power is at present the most important parameter for the electricity boards in India, while grid availability, frequency range, voltage unbalance and voltage range are the primary parameters influencing the wind turbine operation [7].

4. PROBLEMS RELATED WITH GRID CONNECTIONS

1) Poor grid stability
2) Low frequency operation
3) Impact of low power factor
4) Power flow
5) Short circuit
6) Power Quality
7) Power system Faults
a) Symmetrical Faults (Three Phase fault L-L-L, Short Circuit Fault L-L-L-G)
b) Unsymmetrical Faults (L-L, L-G, L-L-G Fault) [8].

CONCLUSION

The paper provides an overview of different wind turbine concepts and possible generator types. The basic configurations and characteristics of various wind generator systems based on contemporary wind turbine concepts are described with their advantages and disadvantages. Also Critical Power Quality issues & problems related with Grid connections are also discussed.

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