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Wind Turbine Generators

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Abstract – There are various generators & control strategies used for wind turbines. The paper talks about various wind turbine generators & the power electronic circuits used for power generation by wind energy. The paper also deals with the present status of generator and power electronics circuits in wind turbine concepts. It shows that variable speed turbine driven by doubly fed induction generator controlled by back to back converter is most effective as compared to others.

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1. INTRODUCTION

Renewable energy sources have become more important in today's era because of lack & rising prices of fossil fuels. The renewable are considered imperative in improving the reliability of energy supplies by reducing the dependency on fossil fuels & emission of greenhouse gases. Amongst the renewable energy sources, the fastest growing source in the power industry is the wind power. Wind turbines can be either rotate at constant speed irrespective of wind speed or vary in accordance with the wind speed.

Fixed speed wind turbines are generally used with the induction generators, directly connected to the grid. Uncontrollability of reactive power & grid voltage level are the major drawbacks of fixed speed wind turbines. These drawbacks of fixed speed wind turbines are overcome by variable-speed wind turbine, which reduces noise at low wind speed & also improves the dynamic behavior of turbines.

Variable speed wind turbines needs the power electronic converters, to make variable speed operation possible. On the whole, a wind turbine is equipped with a three phase synchronous or asynchronous generator.

An asynchronous generator, Doubly Fed Induction generator, is more advantageous, since it offers extracting maximum wind energy for low wind speeds, by optimizing the turbine speed, at the same time as minimizing mechanical stresses on the turbine during gusts of wind. The optimum speed of turbine, for a given wind speed, the maximum mechanical energy extracted is proportional to the wind speed. Also, the power electronic converter used helps absorbing reactive power, thereby eliminating the need for installing capacitor banks.

2. TYPES OF WIND TURBINES

The fixed speed wind turbines are equipped with an induction generator directly connected to grid, with a capacitor bank for reactive power compensation & a soft- starter. These fixed speed wind turbines are designed to attain maximum efficiency at one particular wind speed. To facilitate the increased production of power, generators of some fixed speed wind turbine has two winding sets. Being simple, reliable & robust adds to the advantages of using fixed speed wind turbines.

Also, cost of its electrical parts is low. One of the disadvantages of fixed speed wind turbines is its uncontrollability of reactive power consumption. Because of its fixed speed operation, the fluctuations in the wind speed are projected as fluctuations in the mechanical torque & as a result, fluctuations in the electrical power on the grid.

Even though the electrical system of variable speed wind turbines is more complicated, the variable speed wind turbines are intended to attain utmost aerodynamic efficiency over a wide range of wind speeds. These are normally equipped with synchronous generator & through a power converter connected to the grid. The generator speed is controlled by the power converter.

Increased energy capture, reduced mechanical stress on the turbine, & improved power quality adds up to the advantages of variable speed wind turbines.

The disadvantage of variable speed wind turbines includes the losses in power electronics devices, use of more components & the increased cost of the equipment.

The introduction of variable speed wind turbines has increased the number of applicable generator types &

also several degrees of freedom in combination of generator & power converter circuits.

3. TYPES OF GENERATORS

A wind turbine can be operated with

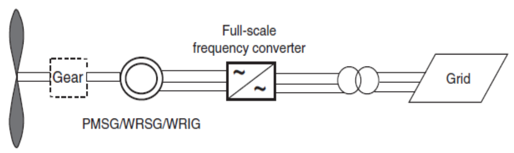
- Synchronous Generator
  - Wound Rotor Generator
  - Permanent Magnet Generator
- Asynchronous Induction Generator
  - Squirrel Cage Induction Generator
  - Wound Rotor Induction Generator

--Opti Slip Induction Generator

--Doubly Fed Induction Generator

3.1 Synchronous generator

A synchronous generator is electrically identical to a synchronous motor. In fact**,** a given synchronous machine may be used, at least theoretically as an alternator, when driven mechanically or s a motor, when driven electrically. AC voltage is induced in the stator windings due to the rotating Magnetic Field. The rotor's magnetic field may be produced by permanent magnets, or by a field coil electromagnet.



Synchronous generator has two types:

3.1.1 Wound rotor generator

The rotational speed of these generators is fixed by the frequency of the grid as the stator windings of WRSGs are directly connected to the grid. The rotor windings are excited by direct current using brushes & slip rings or with a rotating rectifier with a brushless exciter.

There is no need for any reactive power compensation system in case of synchronous generator. The rotor rotates at synchronous speed, & the direct current flows through the rotor windings. Number of poles & the frequency of the rotating field determine the speed of the synchronous generator.

3.1.2 Permanent magnet generator

As the excitation in permanent magnet machines is provided without any energy supply, as compared to induction machines, the efficiency of these machines is higher. The drawbacks of such machines are that, the resources used for manufacturing the permanent magnets are costly & complicated to work during manufacturing. Furthermore, full scale power converter is required for the excitation of permanent magnets so as to fine tune the voltage & frequency of transmission & generation, respectively. This is an added expense.

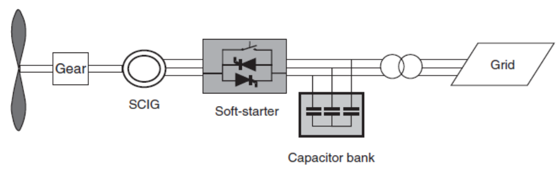
Anyhow the added advantage is that the PM machines can generate power at any speed, subsequently to fit the current conditions.

The stator of PMSGs is wound, and the rotor is offered with a permanent magnet pole. Because of the synchronous nature of these machines startup, synchronization & voltage regulation problems may occur. It does not supply a constant voltage. Another drawback of PMSGs is that the magnetic materials are sensitive to temperature, which needs to be taken care of & provided by a cooling system.

3.2. Asynchronous (induction) generator

Asynchronous generator has two types:

3.2.1 Squirrel cage induction generator



Unlike Synchronous generators the SCIGs are directly coupled to the grid. The SCIG speed varies by only a few percent for the reason that the generator slip changes with the changes in wind speed. Thus, the Squirrel Cage Induction Generator is used for constant-speed wind turbines. Gearbox forms the link between the generator & the wind turbine rotor. These SCIGs requires a soft starter & the arrangement for reactive power compensation.

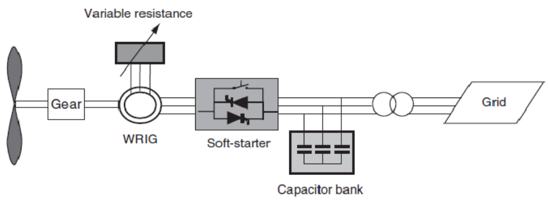
Because of steep torque speed characteristic of SCIGs, the fluctuations in wind power are directly sent out to the grid.

The connection of SCIG to the grid should be done carefully so as to limit the in rush current, since the transients are significant during the grid connection, especially when the in-rush current can be up to 7-8 times the rated current. Full load power factor is relatively low because of the magnetizing current. Hence, a capacitor bank is connected in parallel to compensate for low power factor.

SCIGs without the compensation capacitors can lead to voltage instability on the grid in case of a fault. When the fault occurs, the wind turbine speed may speed up, due to the imbalance between the electrical & mechanical torque. When the fault is cleared, the

SCIG draws large reactive power from the grid, leading to additional decrease in voltage.

3.2.2 Wound rotor induction generator



Wound rotor induction has two subtypes:

3.2.2.1 Optislip induction generator

The Optislip aspect permits generator to encompass variable slip and to choose the optimum slip, ensuing in smaller fluctuations in torque and power output. Variable slip offers simple, reliable & cost effective means to achieve load reduction. WRIG consists of the external variable rotor resistance, in order to control slip. Since, the converter is optically controlled; the need of slip rings is reduced.

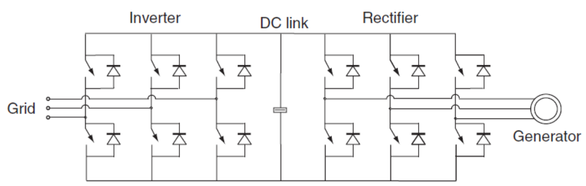
This generator configuration offers advantages such as, being simple in circuit topology, reduction of slip ring, & an enhanced operating speed range as compared to SCIG. This generator concept, to a certain extent helps reducing mechanical loads, & power fluctuations caused by gust of air. Yet, this still necessitates a system for reactive power compensation.

However, poor control of active & reactive power, slip power dissipated as variable resistance losses & limited speed range between 0-10 %, owns the disadvantages of this concept.

3.2.2.2 Doubly fed induction generator

One more interesting configuration of wind turbine generators is the concept of feeding the voltage from the stator to the grid, & feeding the voltage to rotor by the power converter. This type of generator is termed as Doubly Fed Induction Generator (DFIG).

This system also works for a wide but limited range of variable speed.



Here the converter is used to compensate the divergence between the mechanical and electrical frequency, by injecting a rotor current with a variable frequency. For both the durations, i.e during normal operation and during faults, the performance of the generator is monitored by the power converter and its controllers. The power converter essentially consists of two converters, the rotor-side converter and grid-side converter, each controlled independently. Active & reactive power components are controlled by the rotor side converter by controlling the rotor current components, at the same time; the line side converter controls the DC link voltage & ensures operation at unity power factor. This system offers several advantages.

The DFIG has several advantages. It has the ability to control reactive power and to decouple active and reactive power control by independently controlling the rotor excitation current. The DFIG need not necessarily be magnetized from the power grid; it can be magnetized from the rotor circuit, too. This system has the capability of generating, reactive power to be delivered to stator by the grid side converter. In case of a weak grid, including voltage fluctuations, the DFIG can be operated to produce or absorb reactive power to or from the grid to control voltage.

The back-to-back converter is exceedingly applicable to wind turbine, & this converter is used in DFIG.

The back-to-back converter is a bidirectional power converter, which consists of two conventional pulse-width modulated converters. The DC link voltage is boosted to a higher level, than the amplitude of the grid voltage, to achieve full control of the grid current. The capacitor connecting the rectifier & inverter helps decoupling the controls of the two the two without affecting the other side converter. To maintain the DC link voltage is maintained constant by controlling power flow at the grid side converter. Similarly, the magnetization requirement & the desired rotor speed are set by the control of generator side converter. Hence, the back-to-back converter is the scope for further studies, in various generator topologies.

4. CONCLUSION

The paper presents concise & comprehensive review of generator & power electronic devices concepts used by the current wind turbines. The paper also discusses basic wind turbine configurations, & control strategies, followed by the modern wind turbines. Promising concepts of generators & power electronics based on technical grounds & market trends are also discussed. The over view of generator combinations to provide variable speed option, is introduced for combination with converter type. Power electronic devices, are capable technical solutions, which provides wind power installations for power system control capabilities, & for power system stability.

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