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Analysis And Comparative Study Of Induction Generators For Wind Power Plants

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ABSTRACT*- Induction generator is an important part of wind power plants. It converts mechanical energy into electrical energy. The introduction of variable-speed options in wind turbines increases the number of applicable generator types and further introduces freedom in the combination of generator type and power converter type. Power electronic devices provide promising technical solutions to provide wind power installations with efficient power system control capabilities and to improve power system stability.*

KEYWORDS-Induction Generator, SCIG WRIG

INTRODUCTION

Wind power plants consists of Induction generator as one of the major part. Mechanical energy is converted into electrical energy when the shaft is rotated faster than the synchronous frequency of the equivalent induction motor The most popular type A WPPs employ squirrel cage Induction generators which are constant speed induction generators. Type B induction generators then developed which are known as wound rotor induction generators. Induction generators are mechanically and electrically simpler than other generator types. They are more rugged in construction and require no brushes or commutator.

WORKING PRINCIPLE

Induction generators produces electrical power when their rotor is rotated faster than the synchronous frequency.

In normal motor operation, rotating flux of stator is faster than the rotor rotation. This initiates stator flux to induce rotor currents, which creates rotor flux with magnetically opposite polarity to stator. Hence rotor is dragged behind stator flux, by value equal to slip. In generator operation, a prime mover, drives the rotor above the synchronous speed. Stator flux induces currents in the rotor, but since the opposing rotor flux is now cutting the stator coils, active current is produced in stator coils, and motor then operates as a generator sending power back to the electrical grid.

DIFFERENT TYPES OF INDUCTION GENERATORS

Grid and stand-alone connections:

a) For a grid connected system, frequency and voltage of the machine will be dictated by the electric grid.

b) For stand-alone systems, frequency and voltage are complex function of machine parameters such as capacitance used for excitation, and load value.

FIXED SPEED SQUIRREL CAGE INDUCTION GENERATOR

The Squirrel Cage Induction Generator (SCIG) is simple and robust in construction. The stator winding of the generator is connected to the load and is insulated. The rotor is provided with an uninsulated winding, resistant to the effects of dirt ingress, and vibrations.

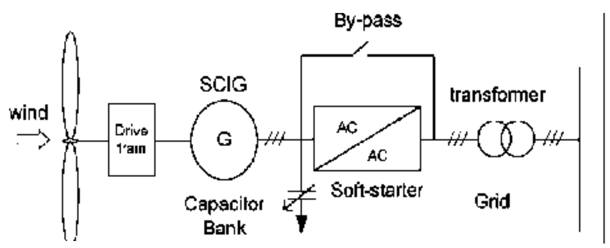

Figure 1 Fixed speed wind turbine with directly grid connected squirrel-cage induction generator

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VARIABLE SPEED WIND TURBINE GENERATOR.

Variable speed turbines have become the most common type of wind turbines as they can store some of the power fluctuations due to heavy wind by increasing the rotor speed, and pitching the rotor blades Fig. shows a variable speed turbine connected to a Squirrel- Cage Induction Generator SCIG.

WOUND ROTOR INDUCTION GENERATOR

It has been found useful to apply the wound rotor Induction Machine as a Wind Power Generator. In wound rotor type the rotor is provided with 3 phase insulated winding very similar to that of the stator. In traditional method rotating winding may be connected to the stationary supply circuits via a set of slip rings and brushes but an alternate is to use a power electronic converter, which may or may not require slip rings.

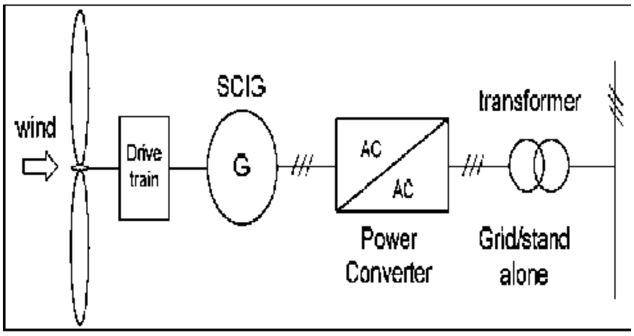

Figure 2 Variable speed wind turbine with squirrel-cage induction generator

Another method is using Doubly Fed Induction Generator DFIG, as shown in Fig. 3. It consists of a stator connected directly to grid and a rotor through slip rings through four-quadrant ac-to-ac converter based on insulated gate bipolar transistors (IGBTs)

This system offers the following advantages:

1. Reduced inverter cost
2. Improved system efficiency.
3. Power-factor control can be implemented at lower cost.
4. Active and reactive power can be controlled.

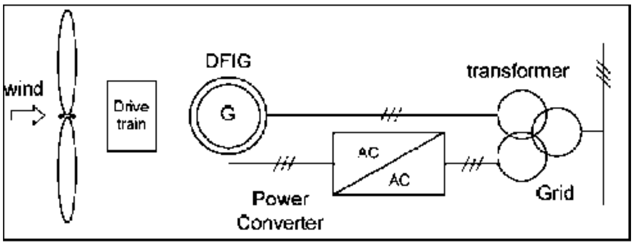

Figure 3 Variable Speed Wind Turbine with Doubly-Fed Induction Generator

Conventional wind turbines are equipped with induction generators due to its qualities like inexpensive, rugged and requires little maintenance. But induction generators requires reactive power for excitation to produce active power. This reactive component causes low power factor, Transmission and distribution losses, reduced voltage stability and poor voltage profile. The interactions between wind turbine and power system network are important aspect of wind generation system. If wind turbine is equipped with an induction generator and fixed capacitor are used for reactive compensation, then self excitation risk may occur during off grid operation. then other sensitive equipments subject to under and over voltage. , hence injection or absorption of Var can stabilise the voltage.

PERFORMANCE OF SQUIRREL CAGE INDUCTION GENERATOR IN WPPs

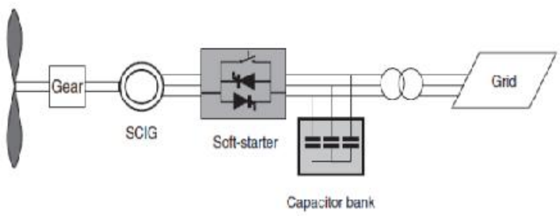

Figure 4 Squirrel Cage Induction Generator

It can be started as a induction motor and then connected with the grid when reached the synchronous speed. Or else it can be started by pitching and when near synchronous speed connected to the grid. During this connection and disconnection, transient occurs which causes jerks on the gear box. To minimize this effects soft starters are used. As in the figure 1 soft starter and capacitor

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bank is provided when wind turbine is connected with the grid. As illustrated in Figure (a) the SCIG is directly grid coupled. The SCIG speed changes by only a few percent because of the generator slip caused by changes in wind speed. Therefore, this generator is used for constant-speed wind turbines.

Gearbox couples the generator and the wind turbine rotor. Wind turbines based on a SCIG are typically equipped with a soft-starter mechanism and an installation for reactive power compensation, as SCIGs consume reactive power. Since SCIGs possess a steep torque speed characteristic the fluctuations in wind power are transmitted directly to the grid. These transients are especially critical during the grid connection of the wind turbine, where the in-rush current can be up to 7–8 times the rated current. Therefore, the connection of the SCIG to the grid should be made gradually in order to limit the in-rush current. Because of the magnetizing current the full load power factor is relatively low which is a major problem.

Very low power factor is compensated by connecting capacitors in parallel to the generator. In the case of a fault, SCIGs without any reactive power compensation system can lead to voltage instability on the grid. When a fault occurs the speed may be too high, owing to the imbalance between the electrical and mechanical torque. Thus, when the fault is cleared, SCIGs draw a large amount of reactive power from the grid, which leads to a further decrease in voltage.

PERFORMANCE OF WOUND ROTOR INDUCTION GENERATOR IN WPPs

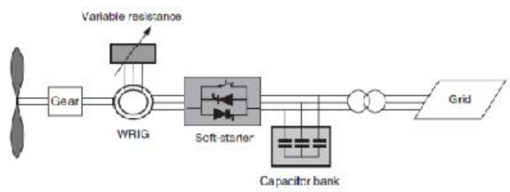

Figure 5 Wound Rotor Induction Generators

In the type B WPP heat losses are high due to external resistances. The magnitude and frequency of the output voltage can be controlled by varying the effective rotor resistance of induction generator (WRIG). without changing the excitation capacitance ,for a given stator load impedance, both the frequency and the voltage can be maintained constant as the speed is varied,. When the stator load is variable, simultaneous voltage and frequency control requires the excitation capacitance to be changed as the rotor resistance is varied. The Optislip feature allows generator to have a variable slip and to choose the optimum slip, resulting in smaller fluctuations in torque and power output. The variable slip method is a simple, reliable and cost-effective way to achieve load reductions. WRIG includes a variable external rotor resistance by means of which slip can be controlled. The converter is optically controlled, which means that no slip rings are necessary. The stator of the generator is connected directly to the grid which has advantages of the concept of simple circuit topology, no need for slip rings and an improved operating speed range compared with the SCIG. To a certain extent, this concept can reduce the mechanical loads and power fluctuations .But still it requires a reactive power compensation system. The disadvantages include the speed range is typically limited to 0–10 %, poor control of active and reactive power is achieved and the slip power is dissipated in the variable resistance as losses.

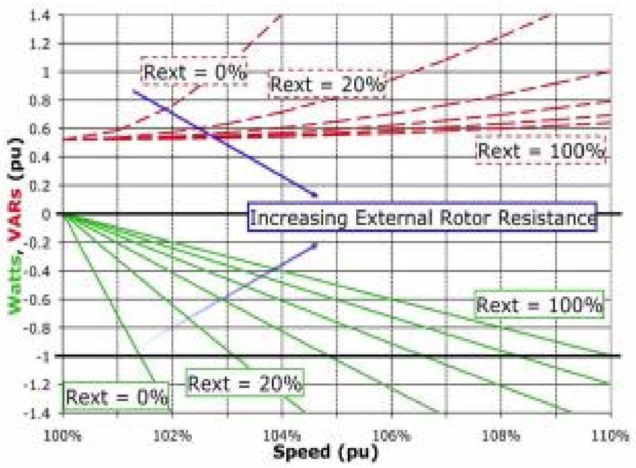

Figure 6 Variation of Real and Reactive Power with External Rotor Resistor

ISSUES REGARDING CONNECTION WITH GRID

The impacts on the transmission and distribution network are not only viewed as an obstacle to development, but rather as obstacles which must be overcome. High penetration of intermittent wind

power and may affect the network in the following ways and has to be studied.

ISSUES OF INDUCTION GENERATORS FOR WPPS

1.POOR GRID STABILITY

For economic exploitation of wind energy, a grid reliability is as important as availability of strong winds. The loss of generation for stable grid can be 10% to 20% and this deficiency may perhaps be the main reasons for low actual energy output of WEGs compared to the predicted output in known windy areas with adequate wind data.

2.LOW-FREQUENCY OPERATION

Low frequency operation affects the output of WEGs in two ways. Many WEGs do not get cut-in, when the frequency is less than 48 Hz (for standard frequency of 50 Hz) through wind conditions are favourable, with consequent loss in output .This deficiency apart, the output of WEGs at low frequency operation is considerably reduced, due to reduced speed of the rotor. The loss in output could be about 5 to 10% on the account of low frequency

3.IMPACT OF LOW POWER FACTOR

WEGs fitted with induction generators need reactive power for magnetizing. Normally in conventional systems, apart from supplying active power generators will be supplying a reactive power. But in case of WEGs fitted with induction generators, they absorb reactive power from grid instead of supplying reactive power to the grid, which indeed is a strain on the grid. Hence Suitable reactive power compensation is required to reduce the reactive power burden on the grid.

4.POWER FLOW

It is to be ensured that the interconnecting transmission or distribution lines will not be over-loaded. This type of analysis is needed to ensure that the introduction of additional generation will not overload the lines and other electrical equipment. Active and reactive power requirements should be investigated.

5.SHORT CIRCUIT

It is required to determine the impact of additional generation sources to the short circuit current ratings of existing electrical equipment on the network.

6.POWER QUALITY

Fluctuations in the wind power have direct impact on the quality of the supply. As a result, large voltage fluctuations occur in voltages as well as power quality standards such as flicker etc are violated.

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