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Research Paper Engineering

Control Stretagy for Microgrid connected Induction Generator for wind energy conversion system

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ABSTRACT

The Microgrid power generation containing wind and Solar, given the variable nature of its sources, raises a number of difficulties when it is integrated into the Grid. The aim of the work is to study the present issues and to analyze the relation between the Microgrid integration and Generation for a particular wind farm or PV generation. To get this objective we will be modelled the wind park which will be integrated with the microgrid. From this model we will see the dynamic behavior of the Microgrid response to disturbances, voltage dips, etc. The simulations will be carried out to show the raised problem of the integration of Microgrid to renewable sources like wind farm. This paper considers the Simulink/matlab simulation for Microgrid connected Fixed Speed Induction Generator with its corresponding results and waveforms.

Key word : Wind Energy, Microgrid, Fixed Speed Induction Generator

INTRODUCTION

The Renewable energy sources presently provide significant amount of energy in many countries. Energy Information Administration estimates that about 21% of world electricity generation was from renewable energy in 2011, with a projection for nearly 25% in 2040. These energy sources will become increasingly important in the recent future. There are many types of renewable energy in a good situation among the energy types like Wind Energy Systems, Biomass Energy System, Hydro Energy Systems and Photovoltaic Energy Systems. But much more experience is needed to predict the future economics and markets for emerging technologies.

The renewable energy has many other benefits such as: Create significant new employment opportunities in energy infrastructure, manufacturing, installation and etc., Contribute to the securing of long term, cost-effective environmentally sustainable energy supplies and offer low operating costs.

Renewable energy sources and distributed generation (DG) have attracted attention world-wide due to high prices of fossil fuels. Wind power is sometimes considered to be DG, because the size and location of some wind farms make it suitable for connection at distribution voltages.

However, in the case of wind farms that are integrated into the electric power system, a number of peculiarities that characterize such systems must be taken into account: (1) under the current legislation, the entire electricity production of this type is injected into the power system, (2) the electric system is operated by calculating the electric generation with a day in advance, in view of the planned consumption, randomness of the wind poses serious problems in regard to this anticipated prediction, (3) as a result of the previous wind farms cannot be used as an slack bus, (4) there is no temporal correlation between wind generation and consumption, i.e. at times of peak generation demand can be minimal, (5) is necessary supply voltage drops of wind farms "instantly" (increasing the production of thermal power), otherwise could happen electrical blackouts of the system, and (6) the so-called voltage dip is one of the biggest drawbacks of wind turbines. When this phenomena occurs in the system, the wind turbines with Squirrel Cage Induction Machines (SCIM) are disconnected from the electrical grid to avoid being damaged and thus causing further disruptions in the system, in this case, lack of supply.

MICROGRID

The Microgrid concept assumes a cluster of loads and microsources operating as a single controllable system that provides both power and heat to its local area. This concept provides new paradigm for defining the operation of distributed generation.

FIXED SPEED INDUCTION GENERATOR (IG)

The power curve of a specific wind turbine gives the electrical power output as a function of wind speed at hub height (i.e. rotation centre of the rotor). It is the most important characteristic of a specific turbine.

The exact appearance of the power curve depends on the wind turbine technology and control options, more precisely:

- Fixed Speed or Variable Speed;
- Pitch, Active-stall or Passive-stall Controlled;
- Operational Settings.

For a long time, the squirrel cage induction generator (SCIG) or Fixed Sped IG has been the most used generator type for wind turbines.

The generator is mostly directly grid connected, as in Figure1. The motor or generator operation is only stable in the narrow range around the synchronous speed Ns. In this zone, the machine speed N varies only very little with varying torque, and cannot be controlled. Turbines equipped with this generator type are often called fixed-speed systems, although the speed slightly varies over a narrow range. The range becomes broader with increasing rotor resistance.

The induced rotor currents cause dissipation of electrical energy in the rotor bars. It can be proven that this dissipated rotor power PR obeys the following equation:

$$P_R = {}_sPd \qquad \text{Eq. (1)}$$

Where,

Pd =the air-gap power: the electromagnetic power crossing the air gap from stator to rotor or vice versa;

S the slip, being equal to $N – N_s$ [p.u.], with N the synchronous speed. The slip is mostly not higher than 5% for SCIGs.

Generator operation only occurs for speeds higher than N_s (equal to 1 p.u. if Ns is chosen as the base speed). As the pole pair number p_p is mostly equal to 2 or 3 in commercial wind turbine generators with SCIGs, the synchronous speed in a 50Hz-grid is equal to 1500 Or 1000 rpm.

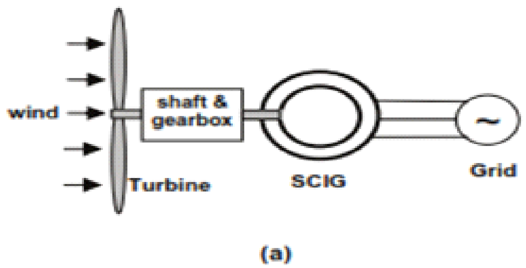

Fig. 1 Grid connection scheme of squirrel cage induction generator

WIND FARM MODELLING

The main objective of the work is to study the behaviour of a wind park of small power (1.5 MW) connected to a distribution network. The developed electromagnetic transient simulation model of the wind farm allows to predict its behaviour under normal operating conditions and also under electrical disturbances.

Some of the machine inductances in the voltage equations that describe the performance of induction machines are function of the rotor speed, whereupon the coefficients of the differential equations (voltage equations) that describe the behaviour of these machines are time varying except when the rotor is stalled. A variable change is often used to reduce the complexity of these differential equations. This general transformation refers machine variables to a frame of reference that rotates at an arbitrary velocity w_g [12]. As a consequence, stator and rotor variables will be expressed in the *dq0* reference frame fixed in the rotor, so $w_g = w_r$. The electric model will be expressed through following Equations with i_{sd}, i_{sq}, i_{s0} for stator side and i_{rd}, i_{rq}, i_{ro} for the rotor side, as electrical state variables of electromagnetic transient model.

$$\frac{di_{sd}}{dt} = \frac{L_m(R_r i_{rd} - u_{rd}) + L_r[\omega_r(L_s i_{sq} + L_m i_{rq}) + u_{sd} - R_s i_{sd}]}{L_s L_r - L_m^2}$$

$$\frac{di_{sq}}{dt} = \frac{L_m(R_r i_{rq} - u_{rq}) + L_r[\omega_r(L_s i_{sd} + L_m i_{rd}) + u_{sq} - R_s i_{sq}]}{L_s L_r - L_m^2}$$

$$\frac{di_{so}}{dt} = \frac{u_{so} - R_s i_{so}}{L_{ls}}$$

$$\frac{di_{rd}}{dt} = \frac{L_s(u_{rd} - R_r i_{rd}) - L_m[\omega_r(L_s i_{sq} + L_m i_{rq}) + u_{sd} - R_s i_{sd}]}{L_s L_r - L_m^2}$$

$$\frac{di_{rq}}{dt} = \frac{L_s(u_{rq} - R_r i_{rq}) - L_m[\omega_r(L_s i_{sd} + L_m i_{rd}) + u_{sq} - R_s i_{sq}]}{L_s L_r - L_m^2}$$

$$\frac{di_{ro}}{dt} = \frac{u_{ro} - R_r i_{ro}}{L_{lr}}$$

Where, L_s and L_r are the stator and rotor side inductances, L_m is the magnetizing inductance, R_s and R_r are the stator and rotor resistances, and w_r is the rotor electrical speed.

The expression for the electromagnetic torque in terms of arbitrary reference-frame variables may be obtained in terms of currents as:

$$T_e = \frac{3}{2} P L_m (i_{sq} i_{rd} - i_{sd} i_{rq})$$

The differential equations that describe the mechanical dynamics of the rotor are:

$$\frac{d\theta}{dt} = \omega_r$$

$$\frac{d\omega_r}{dt} = \frac{1}{J}[P(T_e + T_w) - D\omega_r]$$

Where, T_e is the electromagnetic torque, T_w is the torque due to the wind, J is the inertia of the rotor, D is the damping coefficient, and P is the number of pole pairs of the generator.

SIMULATION RESULTS

This example shown in the simulation is of a 1.5-MW wind farm using Induction Generators (IG) driven by variable-pitch wind turbines. Figure 2 shows grid connected wind farm of a 1.5 MW.

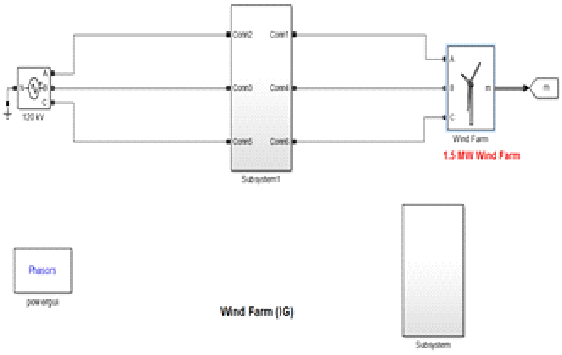

Fig. 2 Model of Microgrid connected Wind Farm

A wind farm consisting of one 1.5-MW wind turbines is connected to a 33-kV distribution system exports power to a 120-kV grid through a 25-km 33-kV feeder as shown in model of wind farm figure 2.

The stator winding is connected directly to the 50 Hz grid and the rotor is driven by a variable-pitch wind turbine. The pitch angle is controlled in order to limit the generator output power at its nominal value for winds exceeding the nominal speed (9 m/s). In order to generate power the IG speed must be slightly above the synchronous speed. Speed varies approximately between 1 pu at no load and 1.005 pu at full load. Reactive power absorbed by the IGs is partly compensated by capacitor banks connected at each wind turbine low voltage bus (400 kvar for 1.5 MW turbine).The rest of reactive power is taken from bus B33. The turbine mechanical power as function of turbine speed is displayed for wind speeds ranging from 4 m/s to 10 m/s. The nominal wind speed yielding the nominal mechanical power (1pu=1.5 MW) is 9 m/s. The wind speed applied to turbine is initially, is set at 8 m/s, then at t=8s Wind turbine wind speed is rammed to 10 m/s in 3 seconds. This is all shown in a Figure 3 below.

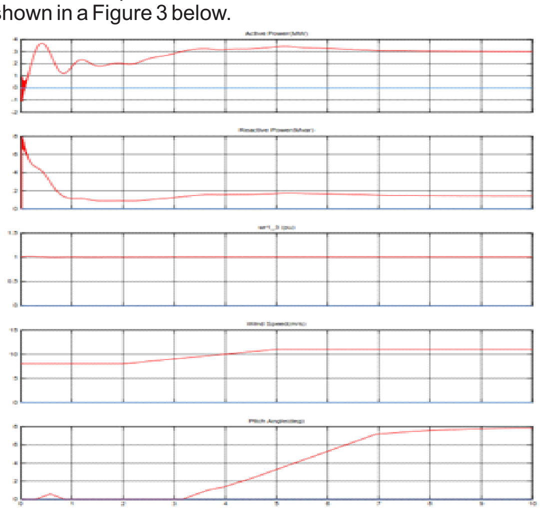

Fig. 3 Graph of Active power, Reactive power, Wind Rating, Wind Speed and Pitch angle with respect to time at Wind Farm Side

The generated active power starts increasing smoothly (together with the wind speed) to reach its rated value of 1.5 MW, over that time frame the turbine speed will have increased from 1.0029 pu to 1.0045 pu. Initially, the pitch angle of the turbine blades is zero degree. When the output power exceed 1.5 MW, the pitch angle is increased from 0 deg to 2 deg in order to bring output power back to its nominal value.

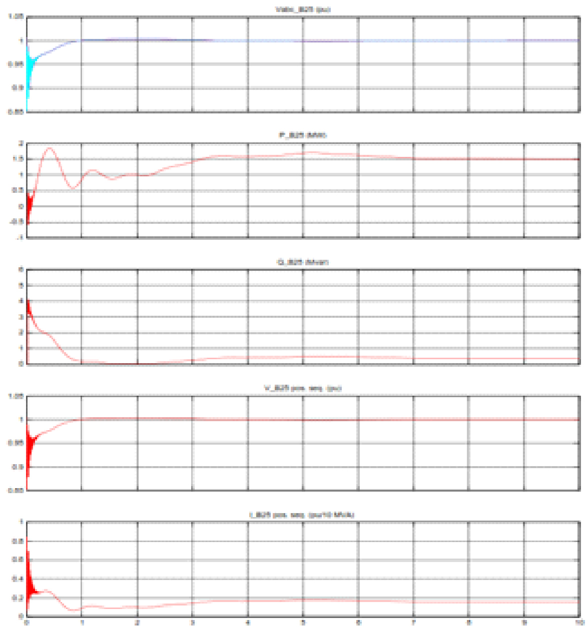

Fig. 4 Graph of Bus Voltage, Active power, Reactive power, Bus Voltage (Positive Sequence) and Bus Current (Positive Sequence) with respect to time at Grid Side

We can see the graph of Wind speed, Bus Voltage, Active power, Reactive power, and Bus Current with respect to time in Figure 4. Observe that the absorbed reactive power increases as the generated active power increases. At nominal power wind turbine absorbs 0.7156 Mvar. For a 10m/s wind speed, the total exported power measured at the B33 bus is 1.5 MW and absorbs 0.7156 Mvar. This are the results and values obtained from wind farm simulation with the grid.

CONCLUSION

From the above simulation results we got all the values like Active power, Reactive Power, Bus voltage and current with relation with time and wind speed in wind farm. We also came know reactive power required by wind farm which will be given by capacitor bank. From this work, we came to know the stochastic nature of wind farm which will be integrated with microgrid.

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