MODELING AND SIMULATION PERFORMANCE OF DOUBLY FED INDUCTION GENERATOR (DFIG) FOR A TYPICAL 9MW WIND FARM

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Abstract:
The paper describes the modeling and simulation of a typical 9MW wind farm, consisting of six 1.5MW wind turbines connected to a 25KV distribution system to a 120KV grid through a 30KM short transmission line of 25KV feeder. An average model of a Doubly-Fed Induction Generator (DFIG) driven by a wind turbine model was utilized in the modeling. Steady-state operation of the (DFIG) and its dynamic response to voltage sag resulting from a fault on the 120KV system was analyzed. Various simulation results of the proposed system are also presented in this paper.

Keywords: *Doubly-Fed Induction Generator, Wind farm, Wind turbine and simulation model*

Introduction

Electricity has becomes part of life to the teeming population throughout the world. Conventional power supplies such as thermal, coal, gas, steam, nuclear are gradually becoming an old fashion of electricity generation to the consumers, this is because they are highly polluting source of energies. These conventional forms of energies have increased the global warming, and are treats to the human being and other Animals throughout the universe. Due to the adverse effects of this global warming, more attention and interest have been paid to the utilization of renewable energy sources such as Photovoltaic, fuel cell, biomass, tidal, and wind energy among others. The renewable energies have yields the green energy which reduces the carbon dioxide (CO_2) and pollution in power generations. However, wind energy is the pasted growing and most promising renewable energy source among them due to economically viable in nature (Muller, Deicke, Doncker, 2002). (Pena, Clare, Asher 1996). (Tapia, Tapia, G., Ostolaza, Saenz, 2003). (Yazhou, Mullane, Gordon, Robert, 2006). (Akhmatoy, Krudsen, 1999). (Li, Chen, 2008). (Mihet-Popa, Frede, 2004). (Chowary, Srinivas, 2006). Because of the popularity of wind energy, total installed capacity of wind energy in India and the rest countries in the world are estimated to be around 160GW(Muller, Deicke, Doncker, 2002). There were several attempts to build large scale wind powered system to generate electrical energy. For the last two decades, high penetration of wind turbines in the power system has been closely related to the advancement of the wind turbine technology and the way how to control them. Doubly-Fed induction generators (DFIG) wind turbines are increasingly receiving attention for wind energy conversion system during such situation of wind farms (Chitti Babu, Mohanty, 2010). DFIG, wind turbines are largely deployed due to their variable speed feature and hence influencing system dynamics. This has created an interest in developing suitable models for DFIG to be integrated into power system studies (Indrajit, Ghosh, Avishek, Pradip, Kr., Panda,). Modeled and simulated a doubly-fed Induction Generator and the fixe speed Induction generator with MATLAB Simpower system toolbox were developed. The system was made of a graphical model built under Simulink with already existing models for transmission line, loads, wind turbine and others. In this paper, a typical simulation of 9MW wind farm with Doubly-Fed Induction Generator (DFIG) was simulated via MATLAB soft ware. Simulation results under fault condition of the power line were also discussed in this work.

Concepts of Wind Turbine Modeling

Wind turbines convert kinetic energy into mechanical energy by means of producing torque. Since the energy in the wind is in the form of kinetic energy, its magnitude depends on the air density and the wind velocity. The wind power developed by the turbine is given by the equation (1) below.

$$P_m = C_p\left(\lambda, \beta\right)\rho A \frac{1}{2} V_{wind}^3 \qquad (1)$$

Where, C_p is the power Co-efficient, ρ is the air density in Kg/m^3, A is the area of the turbine blades in m^2 and V is the wind velocity in $m/\sec$. The power coefficient C_p gives the fraction of the kinetic energy that is converted into mechanical energy by the wind turbine. It is a function of the tip speed ratio λ

and depends on the blade pitch angle for pitch-controlled turbines. From equation (1), $C_p(\lambda,\beta)$ can be expressed by general equation (2).

$$C_p(\lambda,\beta) = C_1\left(\frac{C_2}{\lambda_i} - C_3\beta - C_4\right)e^{-\frac{C_5}{\lambda_i}} + C_6\lambda \qquad (2)$$

With, $\frac{C_1}{\lambda_i} = \frac{1}{\lambda_i} + 0.08\beta - \frac{0.035}{\beta^3+1}$ $\lambda_i = 1/\lambda + 0.08\beta - 0.035/\beta^3 + 1$ (3)

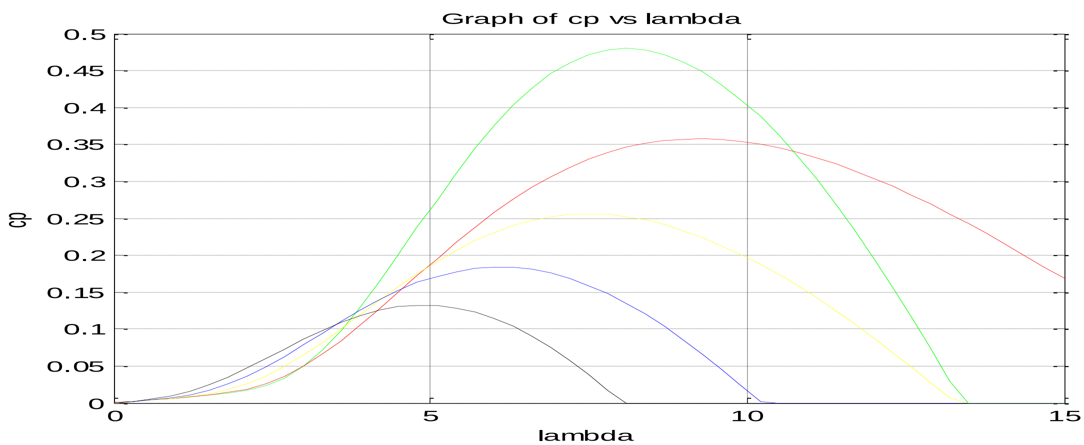

Figure 1. Performance coefficient and tip speed ratio.

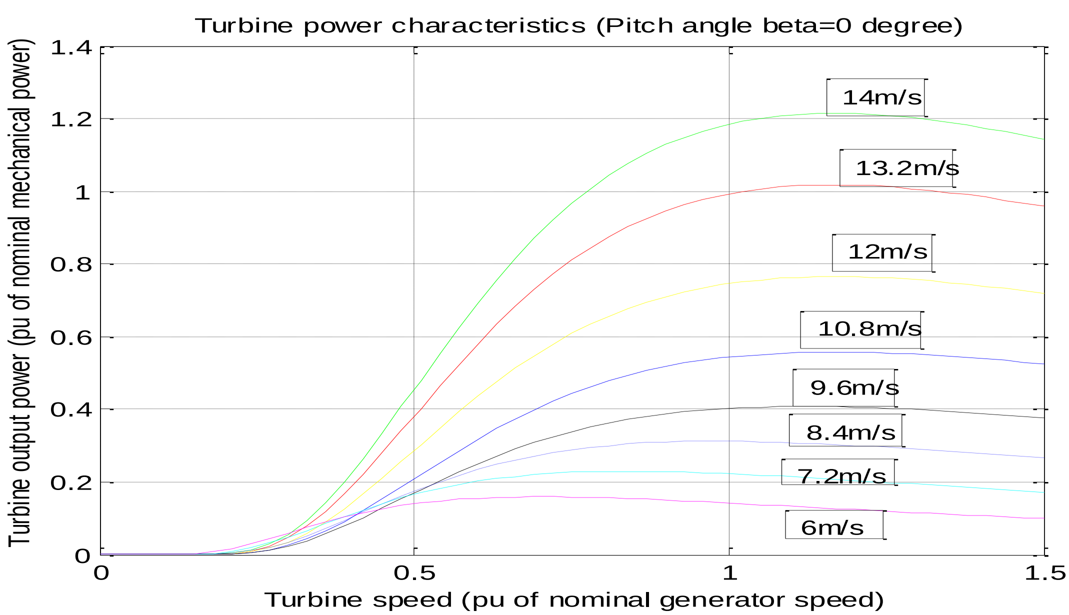

Figure 2. Turbine speed and turbine output power.

Figure 1 depicts the performance coefficient/tip speed ratio and Figure 2. Shows the turbine speed and turbine output power respectively, all the two Figures are due to equations (1) to (3). To limit the power extracted from the wind at high wind speeds, either pitches control or stall control can be applied. Many papers on modeling of a wind turbine with a directly grid coupled squirrel cage induction generator can be found in the literature, both in combination with pitch control and with stall control of the mechanical power, and Nowadays, a more modern variable speed wind turbine with a doubly fed induction generator has replaced the conventional constant speed wind turbine with a directly grid coupled squirrel cage induction generator. As the power developed is proportional to the cube of the wind speed it is obviously important to locate any electricity generating turbines in areas of high mean annual wind speed, and the available wind resource is an important factor in determining where the wind farms are sited. Wind turbine rotor of a given rating is much larger in size than a hydro-turbine.

Doubly-Fed Induction Generator

Must of wind turbines uses doubly-fed induction generators (DFIG) consisting of a wound rotor induction generator and an AC/DC insulated gate bipolar transistor (IGBT)-based pulse width modulation (PWM) converter. The stator winding is connected directly to the 50HZ frequency grid while the rotor is fed at variable frequency through the AC/DC converter. The DFIG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed producing maximum mechanical stresses on the turbine during gusts of wind. The optimum turbine speed producing maximum mechanical energy for a given wind speed is proportional to the wind speed. Another advantage of the DFIG technology is the ability for power electronic converters to generate or absorb reactive power, thus eliminating the need for installing capacitor banks as in the case of squirrel-cage induction generator. Figure 3, depicts the DFIG and its power flow.

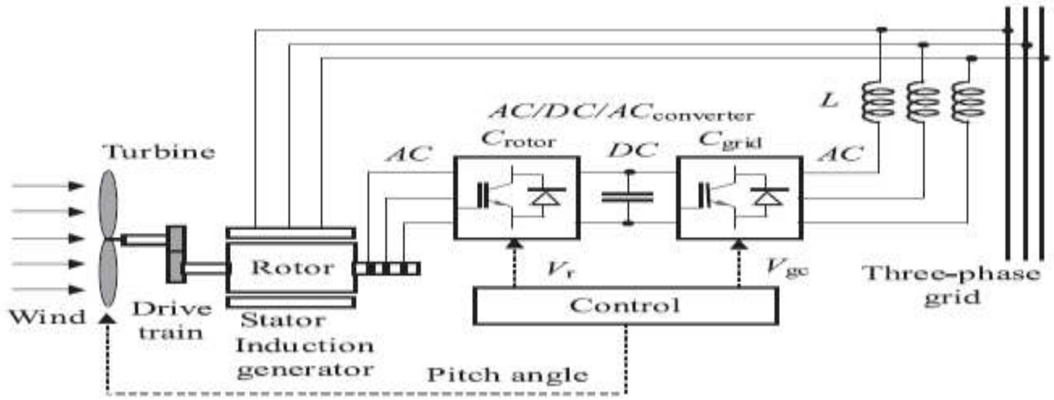

Figure 3. DFIG and its power flow

Simulation Model of 9MW wind Farm

The complete MATLAB/SIMULINK model of the 9MW wind farm is depicted by its simulation model of Figure 4. A doubly-fed induction generator (DFIG) is connected to grid side with wind turbine protection schemes involved for protection from single phase faults and ground faults. The system is connected to a 120KV, three-phase source which is also connected to a 9MW wind farm comprises of (6 number of 1.5MW each) via step-down transformers, faulty protection and pi-transmission line. The wind-turbine model is a Phasor model that allows transient stability type studies with long simulation time, the system is observed during 50s.

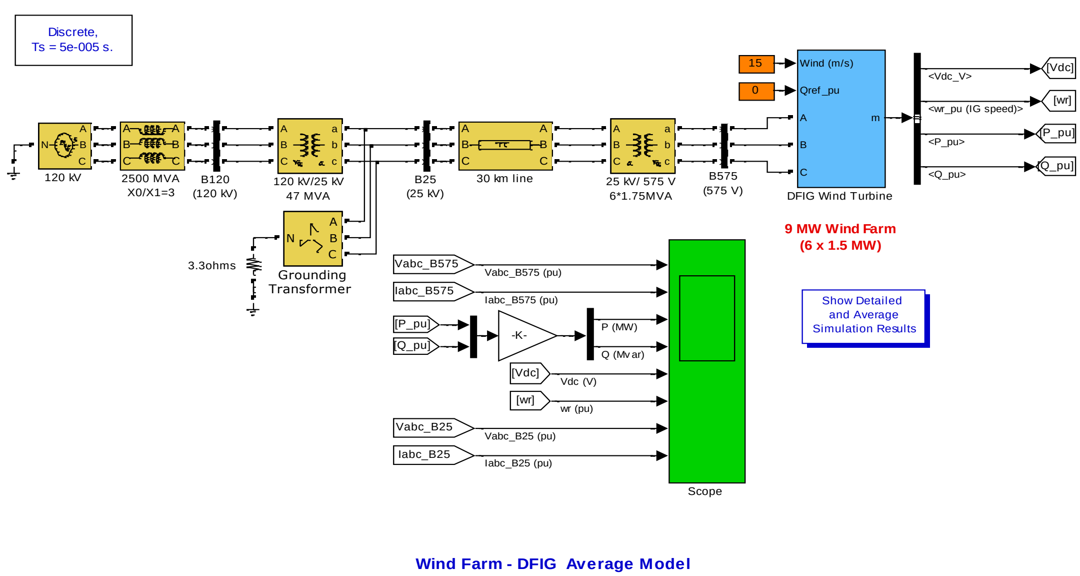

Figure 4. MATLAB/SIMULINK Model of 9MW Wind Farm using DFIG

Simulation Results and Discussions

In this section, simulations were performed to show the behavior of the Doubly-Fed Induction Generator connected to the grid by a bi-directional converter. The wind turbine is assumed to operate with variable speed so that it will operate in the peak power tracking mode. However, Figure 5, shows the various simulation results of the proposed model.

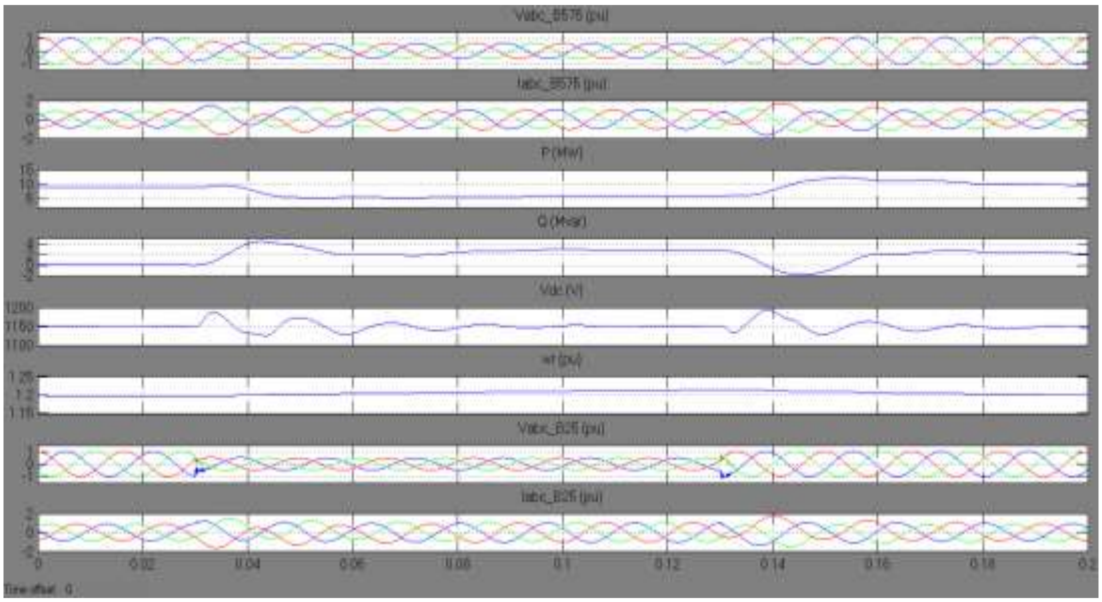

Figure 5. Feeder Voltage, Real Power, Imaginary power, DC Voltage, Reactive power and the distribution voltage respectively.

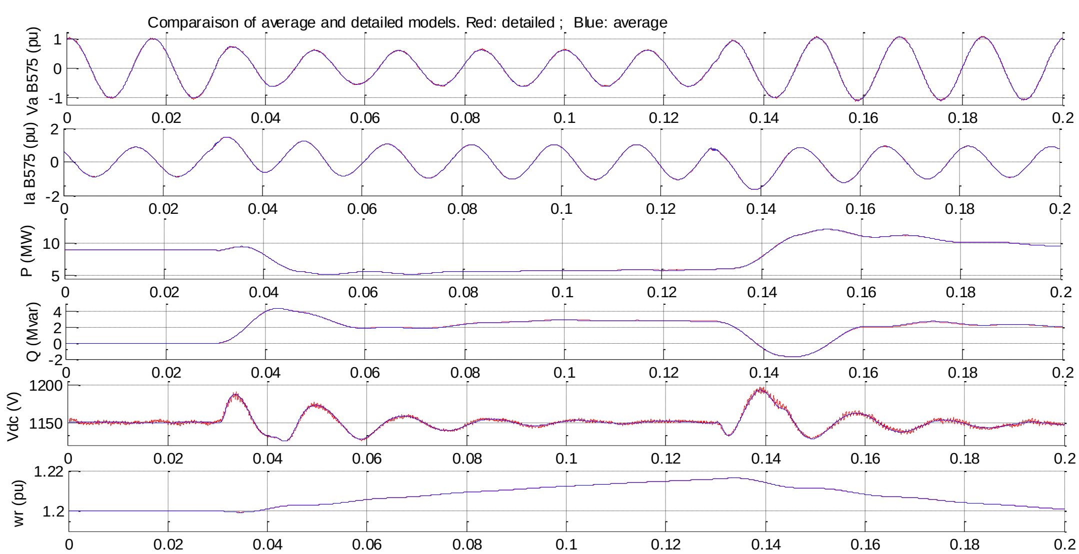

Figure 6. Comparison of the Average details model.

Conclusion

The paper presents the MATLAB modeling of 9MW wind farm, which comprises six number 1.5MW wind turbines. Doubly-Fed Induction Generator is utilized in the modeling that shows the best efficiency of the DFIG which was connected to the grid side and has better control. The rotor side converter (RSC) usually provides active and reactive power control of the machine while the grid-side converter (GSC) keeps the voltage of the DC-link constant. However, the DFIG has provides a considerable contribution to grid voltage support during short circuit periods. This implies that, Doubly-Fed Induction Generator has proven to be more reliable and stable system when connected to grid side with the proper converter control systems.

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