Performance of Doubly-Fed Induction Generator by changing various system parameters

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Abstract—This paper describes the behaviour of a doubly-fed induction generator (DFIG) driven by wind turbine. The work has been carried out with the main objective to study dynamic performance of wind driven, grid connected doubly fed induction generator by formulating appropriate mathematical models. Further, performance of doubly fed induction generator is observed by changing various system parameters like base wind speed, line length and grid voltage. A MATLAB computer simulation study was undertaken and results on wind turbine are presented.

Index Terms*- Doubly-Fed Induction Generator (DFIG), Variable speed wind turbine, Dynamic Modelling.*

I. INTRODUCTION

For stand-alone or autonomous operation, mostly single induction generator or parallel operated induction generators are focused according to available analysed references. This induction generator driven by the individual prime movers Employed excitation capacitor bank to build up desired voltage via self-excited phenomena. Hence the value of the excitation capacitor bank and the rotor speed determine the magnitude of the generated voltage and its frequency. Both voltage and frequency need to be controlled to feed the power to the load. But for grid connected operation, there are two types of generators are used. (i.e., single output and double outputs).In order to feed the active power to the grid, the machine should run at a speed greater than the synchronous speed of the revolving magnetic field. (i.e. slip should be negative).The single output generator feeds active power to the grid via only stator side and double output generator feeds electrical power to the grid via both stator as well as rotor side.

The latter is also called static Kramer, double-fed or double outputs induction generators. This is only the generator which generates the power more than rated power without overheating. Besides, this kind of power generation usually causes problems in the utility grid system. Because the control on active and reactive power of the machine is complex one. Wind turbines often do not take part in voltage and frequency control and if a disturbance occurs, the wind turbines are disconnected and reconnected when normal operation has been resumed. As the wind power penetration continually increases, power utilities concerns are shifting focus from the power quality issue to the stability problem caused by the wind power connection. In such cases, it becomes important to consider the wind power impact properly in the power system planning and operation. This paper will focus on the grid-connected induction generator feeding power with DFIG during steady state and transient conditions. This paper describes the transient behaviour of a doubly-fed induction generator (DFIG) driven by wind turbine. The work has been carried out with the main objective to study dynamic performance of wind driven, grid connected doubly fed induction generator by formulating appropriate mathematical models. Further, performance of doubly fed induction generator is observed by changing various system parameters like base wind speed, line length and grid voltage. A MATLAB computer simulation study was undertaken and results on wind turbine are presented.

II. DFIG DYNAMIC MODELLING

A commonly used model for induction generator converting power from the wind to serve the electric grid is shown in Fig.1.The stator of the wound rotor induction machine is connected to the low voltage balanced three-phase grid and the rotor side is fed via the back-to-back IGBT voltage-source inverters with a common DC bus. The network side converter controls the power flow between the DC bus and the AC side and allows the system to be operated in sub synchronous and super synchronous speed. The proper rotor excitation is provided by the machine side power converter.

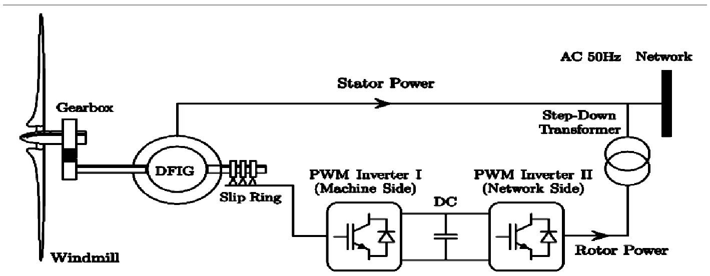

Fig. 1. Model of DFIG Wind Turbine

The general model for wound rotor induction machine is similar to any fixed-speed induction generator as follows.

A. Stator Voltage Equations

$$V_{qs} = p\lambda_{qs} + \omega\lambda_{ds} + r_s i_{qs}$$
$$V_{ds} = p\lambda_{ds} - \omega\lambda_{qs} + r_s i_{ds} \qquad (1)$$

B. Rotor Voltage Equations

$$V_{qr} = p\lambda_{qr} + (\omega - \omega_r)\lambda_{dr} + r_r i_{qr}$$
$$V_{dr} = p\lambda_{dr} - (\omega - \omega_r)\lambda_{qr} + r_r i_{dr} \qquad (2)$$

C. Power Equations

$$P_s = \frac{3}{2}\left(V_{ds} i_{ds} + V_{qs} i_{qs}\right)$$
$$Q_s = \frac{3}{2}\left(V_{qs} i_{ds} - V_{ds} i_{qs}\right) \qquad (3)$$

D. Torque Equation

$$T_e = -\frac{3}{2}\frac{P}{2}\left(\lambda_{ds} i_{qs} - \lambda_{qs} i_{ds}\right) \qquad (4)$$

E. Stator Flux Linkage Equations

$$\lambda_{qs} = \left(L_{ls} + L_m\right) i_{qs} + L_m i_{qr}$$
$$\lambda_{ds} = \left(L_{ls} + L_m\right) i_{ds} + L_m i_{dr} \qquad (5)$$

F. Rotor Flux Linkage Equations

$$\lambda_{qr} = \left(L_{lr} + L_m\right) i_{qr} + L_m i_{qs}$$
$$\lambda_{dr} = \left(L_{ls} + L_m\right) i_{dr} + L_m i_{ds} \qquad (6)$$

IV. DYNAMIC PERFORMANCE OF DFIG

The 9-MW wind farm comprises of six 1.5-MW wind turbines connected in parallel to a 25kV AC bus through a transmission line (30 km long) as shown in figure 2.

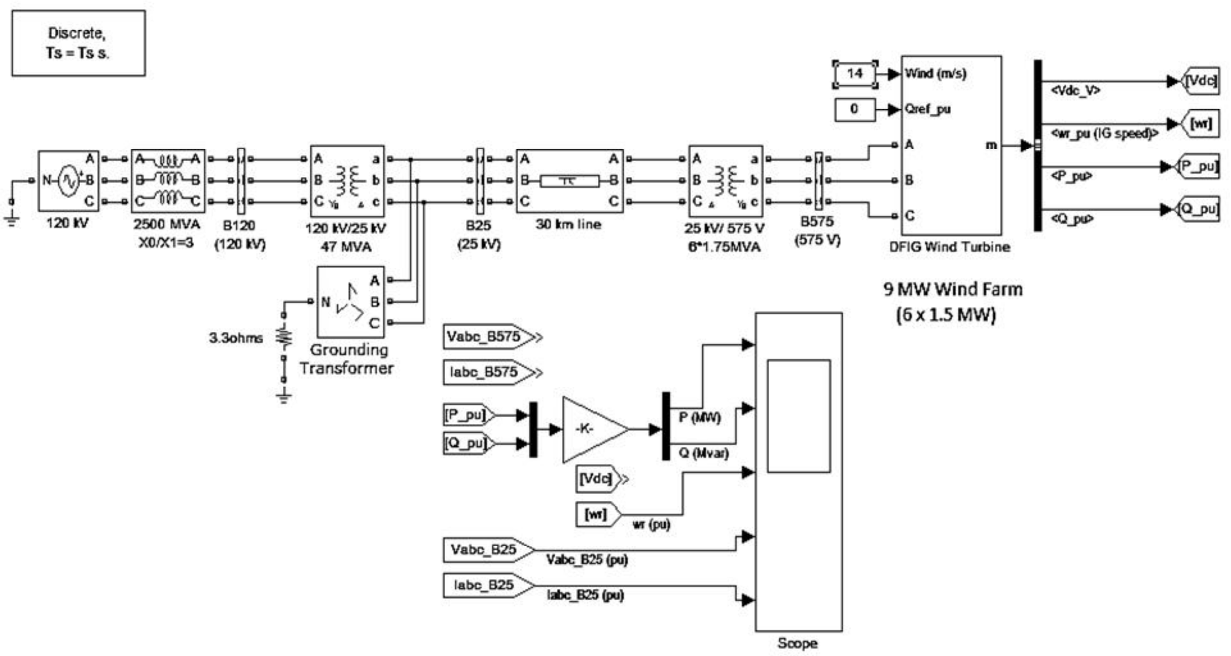

Fig 2

The doubly fed induction generator consists of a wound rotor induction generator and an AC/DC/AC IGBT-based PWM converter. Each of the 3-phase induction generators is rated with line to line voltage of 575V, frequency 60Hz. The equivalent generation has nominal base at 10 MVA, having inertia constant of 0.685 and friction factor 0.01pu. The stator winding is connected directly to 60 HZ grid and rotor is fed at variable frequency through the AC/DC/AC converter. The DFIG allows extracting maximum energy from wind for low wind speeds by regulating the turbine speed, while minimizing the mechanical stress on turbine during gusts of wind. For simulation, the base wind speed is taken as 14m/s, the active power, reactive power required by the DFIG, speed of wind turbine, voltage and current at 25kV bus B25 is shown in figure 3. The active power generated by DFIG increases to 11 MW and afterwards decreases to 9MW. This active power corresponds to maximum mechanical turbine output for 14m/s base wind speed minus electrical and mechanical losses.

There is an excessive demand of reactive power momentarily to 4Mvar which reduces to less than 1Mvar after few seconds. The reactive power is managed by filters and AC source. During this DC link voltage is maintained constant by converter. The turbine speed is maintained slightly higher at 1.1pu but lower than 1.2pu. The grid voltage observed at the AC b0us B25 is 1pu in time period of 360ms. The current at the grid has a value of 0.8pu at AC bus B25. This value is obtained after initial transients of decreasing magnitude.

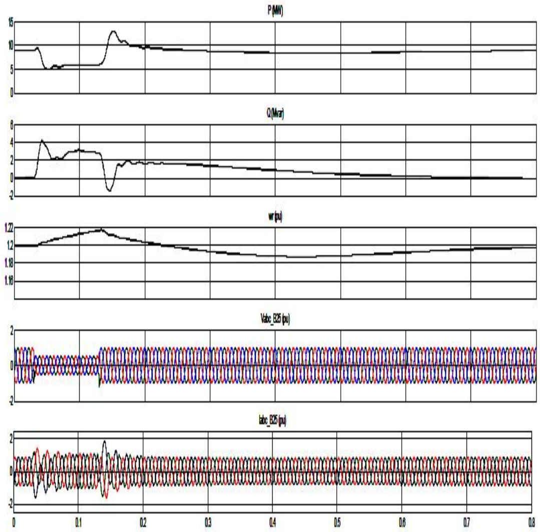

Fig 3 **Wind driven DFIG output**

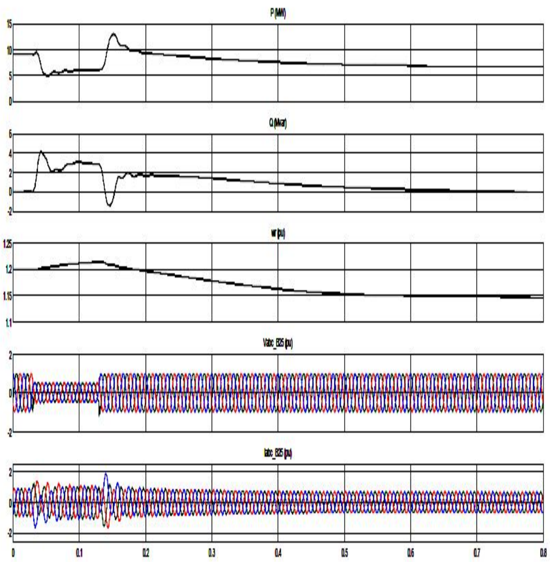

Fig 4 Effect of wind speed 8m/s

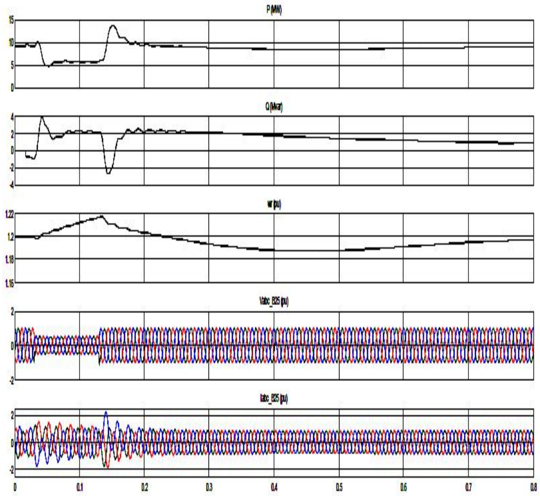

Fig 5 Effect of 10km line length

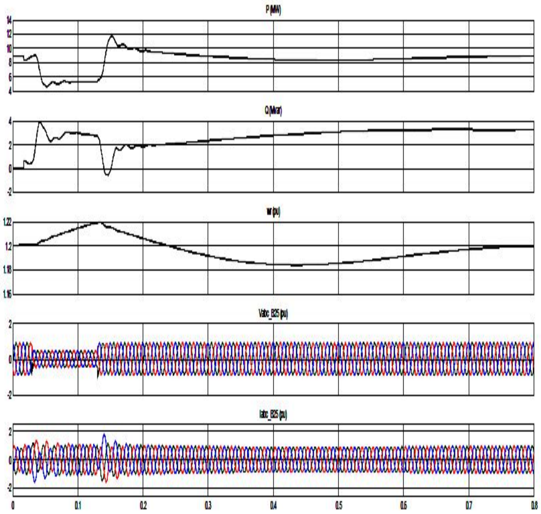

Fig 6 Effect of 108kV grid voltage

V CONCLUSION

The dynamic performance of wind driven doubly fed induction generator has been studied. The dynamic models have been derived and performance has been simulated using MATLAB/SIMULINK. Various parameters have been studied for observing the performance of doubly fed induction generator. The following conclusion is drawn from the study:
The real output power of turbine changes with the change in base wind speed.

With decrease in the length of transmission line, high amplitude transients in current are resulted.

Change in grid voltage is related to change in reactive power demand as at higher grid voltages, reactive power consumed by DFIG is less.

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