IJRDET

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 5, May 2014)

Modeling and Simulation of Fixed and Variable Speed of DFIG Wind System

Rakesh Sharma[1], Kuldeep Sahay[2], Sateyndra Singh[3]
[1]*M. Tech. (Student), UP Technical University, Lucknow*
[2,3]*Department of Electrical Engineering, Institute of Engineering & Technology, Lucknow*

***Abstract*— The wind power is a pollution free source of energy. In this paper we have focused on analyzing the performance of wind power in conventional system under various scenarios. Here we have introduced a wind power in a power generation and transmission system alongside the conventional 3-phase sources and have simulated its working and performance. The wind power is made to work in tandem with the regular supply. In case of faults occurring in the system wind power is used to act as backup for the original supply. Also in case of extra power demand in peak time periods, it has been used to complement the power sources there by maintaining the power quality and frequency in the system. To analysis the performance of DFIG wind system during three phase fault there is two cases (i) Performance analysis of DFIG during fault at fixed wind speed (ii) Performance analysis of DFIG during fault at variable wind speed. All these scenarios have been simulated with the help of the simulation program using MATLAB and its inbuilt components provided in SIMULINK library**.

***Keywords*—Doubly Fed Induction Generator (DFIG), Rotor Side Converter (RSC), Stator Side Converter (SSC), Pulse Width Modulation (PWM), Wound Rotor Induction Generator (WRIG), Voltage Source Converter (VSC).**

I. Introduction

In last some years more attention has been focused on induction generators for low and medium power application because they have attractive advantages over conventional generators such as low unit cost, less maintenance robust construction etc. One way of generating electricity from renewable sources is to use wind turbines. The most common type of wind turbine is the fixed-speed wind turbine with the induction generator directly connected to the grid. This system has a number of drawbacks, however. The reactive power and, therefore, the grid voltage level cannot be controlled .The DFIG is the same as the WRIG system except that variable resistance in the rotor circuit is replaced by a grid-connected power converter system &there is no need for the soft starter or reactive power compensation and also the power factor is adjusted by power converter itself [1].

The use of convertors also allows bidirectional power flow in the rotor circuit & increase the speed range of the generator (extended generator speed range ±30%), also improved the overall power conversion efficiency. Doubly-Fed Induction Generators (DFIG) are particularly suitable for isolated operation like wind developments. The wind generation includes fixed-speed system as well as variable-speed system [2]. The variable-speed wind power generation is mostly used in wind power generation development because it can operate on the maximum power point of the machine [3, 4]. This system include synchronous and asynchronous generator. In wind turbines based on DFIG, the induction generator stator-side is directly connected to the grid-side and the rotor-side is excited by three phase converter which can regulate both active and reactive power of stator machine through control of *dq*-axis rotor currents. The rated power of the back-to-back converter is smaller than the induction generator rated power, so that back-to-back converter always specified by the slip power, which is approximately 25% of the rated power of the generator.

II. Wind Energy

Wind energy comes from wind turbine blades and then transferred to a gear box (to match the high speed generator with low speed turbine blades) & the rotor hub to provide mechanical energy to the shaft. The shaft drives the generator to converts the mechanical energy in to electrical energy. The power of an air mass flowing at speed v_W through an area A can be calculated by

$$\text{Power} = \frac{\text{density of air} * \text{swept area} * \text{velocity cubed}}{2}$$

$$P = \frac{1}{2}\rho A v_w^3 \qquad (1)$$

Where, P is power in watts (W), ρ is the air density in kilograms per cubic meter (kg/m^3),A is the swept rotor area in square meter (m^2),V is the wind speed in meter per second (m/s).But the turbine model is based on the power captured by the blade &converted into mechanical energy.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 5, May 2014)

$$P_m = C_p\ (\lambda, \beta).\frac{1}{2}\ \rho\ Av_w^3 \qquad (2)$$

$$\lambda = (R_{blade}\omega_r)/v_w$$

$$c_p\ (\lambda, \beta) = c_1\left(c_2 - c_3\beta - c_4\beta^2 - c_5\right)e^{-c_6} \quad (3)$$

Where, c_1=0.5, c_2=116/ λi, c_3=0.4, c_4=0, c_5=5, c_6=21/ λi,

$$\frac{1}{\lambda i} = \frac{1}{\lambda + 0.08\,\beta} - \frac{0.035}{\beta^3 + 1} \qquad (4)$$

Where P_M is the mechanical power output power in watts & C_p is the power coefficient of the blade which depends on the tip speed ratio (λ) & blade pitch angle (β).C_P decides how much energy can be captured by wind turbine system.

To get maximum Cp, in this paper turbine system, for different wind speeds the pitch angle β=0 is fixed.

III. DFIG Wind Model And Equations

The DFIG typically operates about 30% above & below synchronous speed, sufficient for most wind speed conditions. It also enables generator side active power control & grid side active power control. In the DFIG model of wind system controlling techniques of power converters (wind energy power converters) in which the real and reactive power are controlled separately. The wind turbine drives DFIG wind system consists of an Induction generator (WRIG) and an AC/DC/AC IGBT based pulse width modulated(PWM) converter (back-to-back converter with dc-link capacitor) or we can say that two levels IGBT voltage source converter (VSC) system in a back to back configuration is normally used [3,5]. Since both stator and rotor can feed power to gird, the generator is known as doubly fed induction generator (DFIG).It has two main parts ,the rotor side converter control (RSC), which controls the torque or active/reactive power of the generator and, grid side converter controls (GSC), which controls the DC link voltage and its AC-side reactive power[6,7]. An equivalent circuit of DFIG wind system in Fig.1 & Fig. 2a, 2b and relation equations [8] to voltage V, current I, flux linkage Ψ, and electro-magnetic torque T_{em} are as fallows. Fig. 3 & 4 shows the rotor-side converter control of voltage block diagram and simulink model respectively and Fig. 5 shows the equivalent circuit of stator-side converter choke.

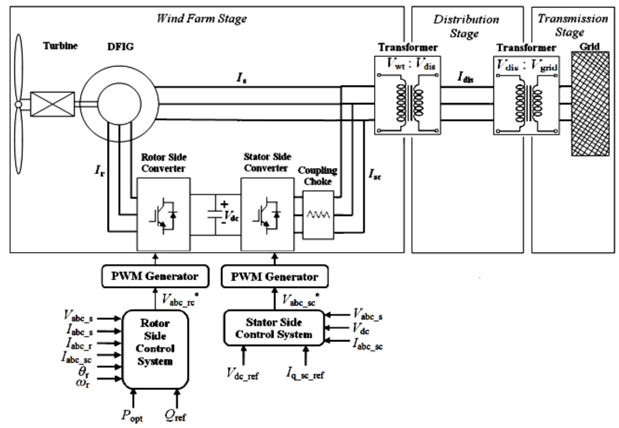

Fig.1 Wind Turbine DFIG System Configuration

d-q Reference frame model

Voltage equations

V_s=V_{ds}+j V_{qs} (5)

I_s= I_{ds}+jI_{qs} (6)

Ψ_s=Ψ_{ds}+jΨ_{qs} (7)

V_r=V_{dr}+j V_{qr} (8)

I_r= I_{dr}+jI_{qr} (9)

Ψ_r=Ψ_{dr}+jΨ_{qr} (10)

$$V_{ds}= R_sI_{ds}-\omega_s\Psi_{qs}+\frac{d\Psi ds}{dt} \qquad (11)$$

$$V_{qs}=R_sI_{qs}+\omega s\ \Psi_{ds}+\frac{d\Psi qs}{dt} \qquad (12)$$

$$V_{dr}=R_rI_{dr}-s\omega_s\Psi_{ds}+\frac{d\Psi dr}{dt} \qquad (13)$$

$$V_{qr}=R_rIq_r+s\omega_s\Psi_{dr}+\frac{d\Psi ds}{dt} \qquad (14)$$

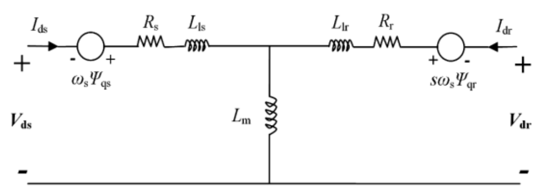

Fig.2a d-axis Model

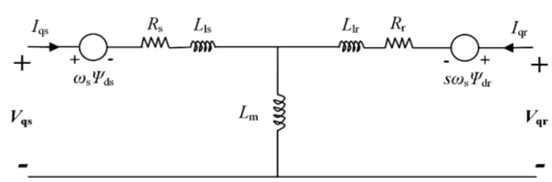

Fig.2b q-axis Model

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 5, May 2014)

$\Psi_{ds}=L_sI_{ds}+L_mI_d$ (15)

$\Psi_{qs}=L_sI_{qs}+L_mI_{qr}$ (16)

$\Psi_{dr}=L_rId_r+L_mI_{ds}$ (17)

$\Psi_{qr}=L_rI_{qr}+L_mI_q$ (18)

Electro-magnetic torque equation

$T_{em}=3n_p/2\ (\Psi_{ds}I_{qs}-\Psi_{qs}I_{ds})$ (19)

Where $L_s=L_{ls}+L_m$ (20)

$L_r=L_{lr}+L_m$ (21)

$s\omega_s=\omega_s-\omega_r$ (22)

$\Psi_{ds}=(V_{qs}-R_sI_{qs})/\omega_s$ (23)

$\Psi_{qs}=(V_{ds}-R_sI_{ds})/(-\omega_s)$ (24)

$\Psi_s=\sqrt{\Psi_{ds}^2}+\sqrt{\Psi_{qs}^2}$ (25)

The subscripts r, s and q, d represents the rotor stator, q-axis, d- axis components respectively, T_{em} is electro-mechanical torque, L_m & J are generator mutual inductance, and the inertia coefficient, respective.

$I_{dr\_ref}=-\frac{2LsTe}{3npLm\Psi s}$ (26)

$P_{\_ref}=P_{opt}-P_{loss}=T_e\ \omega_r$ (27)

$P_{loss}=R_sI_s^2+R_r\ I_r^2+R_c\ I_{sc}^2+F\ \omega_r^2$ (28)

Where R_c, F and I_{sc}, are choke resistance and friction factor, stator-side converter current. $P_{\_ref}$, P_{opt} and P_{loss} are reference active power, desired optimal output active power and system power loss.

$Q_o=-V_{ds}(\Psi_s-L_mI_{qr})/L_s$ (29)

$Q_o=-V_{ds}I_{qs}$ (30)

$V_{dr}^2=R_rI_{dr}-s\omega_s\,(L_rI_{qr}+L_mI_{qs})$ (31)

$V_{qr}^2=R_rI_{qr}+s\omega_s\,(L_rI_{dr}+L_mI_{ds})$ (32)

$V_{drc}=V_{dr}=V_{dr}^1+V_{dr}^2$ (33)

$V_{qrc}=V_{qr}=V_{qr}^1+V_{qr}^2$ (34)

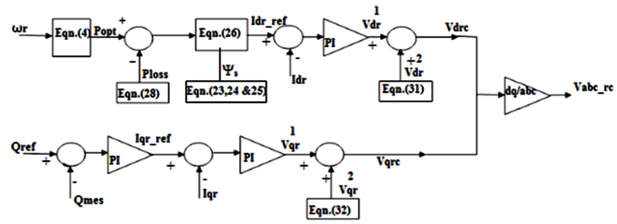

Fig. 3 Rotor-Side Converter Control Scheme (V_{abc_rc})

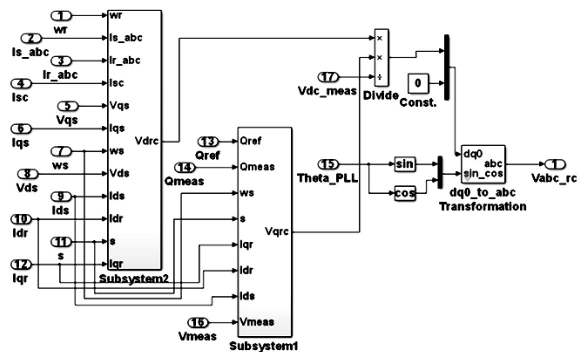

Fig.4 Simulink Model of Rotor-Side Converter Voltage (V_{abc_rc})

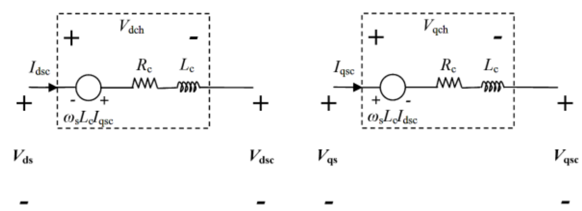

Fig.5 Equivalent Circuit of Stator Side Converter Choke

$V_{dsc}=V_{ds}-V_{dch}$ (35)

$V_{qsc}=V_{qs}-V_{qch}$ (36)

$V_{dch}^2=R_cI_{dsc}-\omega_sL_cI_{qsc}$ (37)

$V_{qch}^2=R_cI_{qsc}+\omega_sL_cI_{dsc}$ (31) (38)

$V_{dsc}=V_{ds}-V_{dch}^1-V_{dch}^2$ (39)

$V_{qsc}=V_{qs}-V_{qch}^1-V_{qch}^2$ (33) (40)

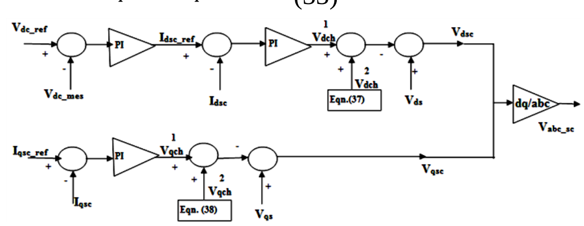

Fig.6 Stator-Side Converter Control Scheme

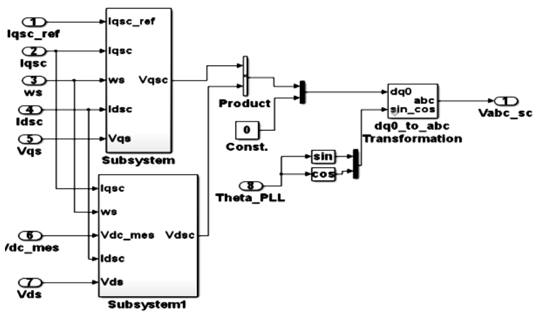

Fig.7 Simulink Model of Stator Side Converter Voltage V_{abc_sc}

Where the rotor-side converter voltage signals at q-axis V_{qr}^{1} and V_{qr}^{1} & at d-axis V_{dr}^{1} and V_{dr}^{2} are generated through the regulation of currents and cross-coupling parts. I_{dr_ref} is the rotor-side converter reference current signals, V_{dch}^{2} and V_{qch}^{2} is the coupling part of voltage, V_{dch}^{1} and V_{qch}^{1} are determined by regulation of current I_{dsc} and I_{qsc} in which the I_{qsc_ref} (current reference) is given directly and I_{dsc_ref} is calculated through the regulation of dc-link voltage V_{dc}. V_{qsc} and V_{dsc} is stator-side converter voltage signals. Fig. 6 & 7 shows the stator-side converter control of voltage block diagram of control blocks and simulink model respectively. Fig. 8 show the complete connection diagram of control blocks (rotor-side control and stator-side control).

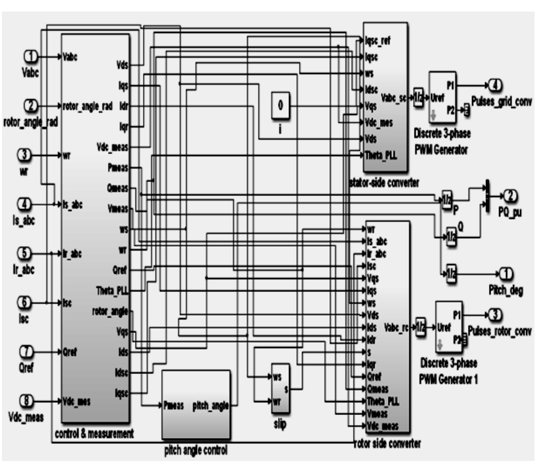

Fig. 8 Connection Diagram of Control Blocks (RSC and SSC)

A. Two–Level voltage Source converter

The convertor has been widely used in industry for many applications. When the convertor transforms a fixed DC voltage to a three phase AC voltage with variable magnitude and frequency for an AC load, it is often called inverter.

When the converter transforms an AC grid voltage with fixed magnitude and frequency to an adjustable DC voltage for a DC load, it is normally known as an active rectifier or PWM rectifier [9]. Whether it serves as an inverter or a rectifier the power flow in the converter circuit is bidirectional the power can flow from its dc side to ac side and vice versa. In wind energy conversion systems, the converter is often connected to an electric grid and delivers the power generated from the generator to the grid the converter in this applications is referred to a grid connected or grid tied converter. It is also called an inverter since the converter normally delivers power from its dc side to the ac side .The PWM schemes for two level voltage source converters since the modulation schemes are applicable to the converter that may be operated as an inverter or a rectifier. The simulink blocks of discrete three phase PWM generator of stator and rotor side are shown in Fig. 9 & 10 respectively.

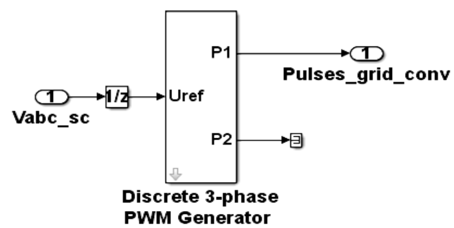

Fig. 9 Discrete 3 Phase PWM Generator of Stator-Side

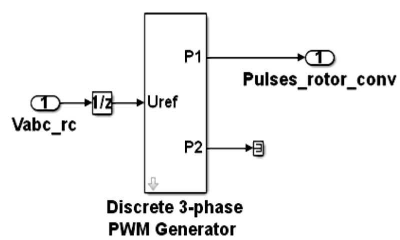

Fig. 10 Discrete 3 Phase PWM Generator of Rotor-Side

The vector-form reference signal used to generate the output pulses and connect this to a 3-Φ sinusoidal signal when the discrete PWM Generator block is controlling a 3-Φ bridge converter. For linear operation of discrete 3-Φ PWM Generator, the magnitude of U_{ref} must be between −1 and +1.The output gives six pulse signals which is used to fire the self-commutated devices IGBTs of a three-arm converter. Fig. 11 shows simulink diagram of the universal bridge connection in DFIG system.

IJRDET
International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 5, May 2014)

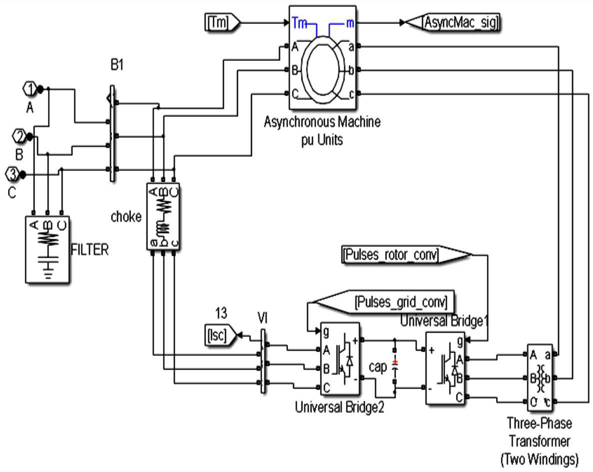

Fig. 11 Simulink Diagram of the Universal Bridge Connection in DFIG System

B. Pitch Angle Control

The pitch angle is calculated by an open loop control of regulated output real power. Due to the big size of turbine blades so the pitch angle; inertia has to change to a smooth rate and a reasonable range. Here Pmeas and Pref. are connected with summer block then the signal pass to the discrete type PI controller after that it passes through the saturation and change rate limiter block then it gives pitch angle β.The simulink model of pitch angle control are shown in Fig. 12.

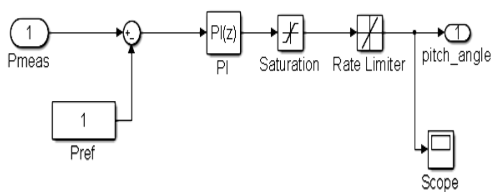

Fig. 12 Simulink block diagram of pitch angle control

IV. SIMULINK MODELING OF DFIG WIND SYSTEM

Fig. 13 shows DFIG wind model simulation in MATLAB/SIM-POWER SIMULINK. The three phase programmable source is generating power at 120 kV, which is stepped down to 25 kV by the two winding transformer and then transmitted by the 30 km long transmission line for further stepping down the voltage level to the 575 V at point of common coupling between grid and DFIG wind energy conversion system. The DFIG wind energy conversion system is generating power of 1.5 MW.

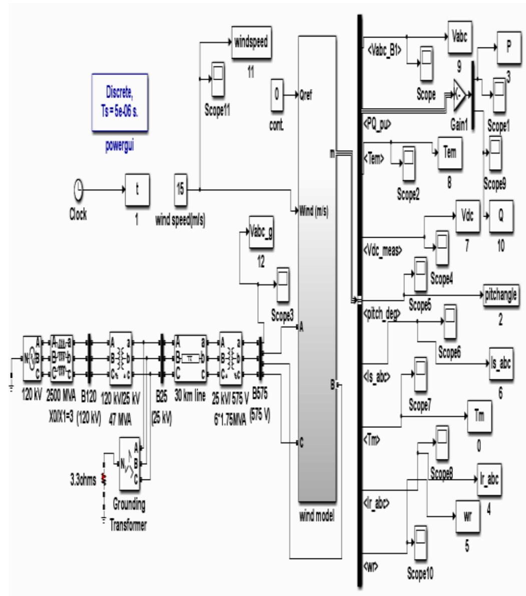

Fig. 13 Development Test Model for DFIG Wind System

In this, the wind turbine uses a doubly-fed induction generator (DFIG), which consists of an AC/DC/AC IGBT-based PWM converter and a wound rotor induction generator. The dc voltage is applied to IGBT/Diode‛s of two level inverter. The pulse width modulation technique has been used in this inverter, in order to achieve higher accuracy , the carrier frequency or switching frequency is 1620 Hz, discrete sample time is, Ts =5 microseconds. The stator of Induction generator is connected directly to the 60 Hz grid system whereas the rotor is providing at variable frequency through the AC/DC/AC converter. The DFIG wind model allows capturing maximum power to the wind for low wind speeds through maintaining the turbine speed, while minimize mechanical stresses on the wind turbine during the gusts of wind. In this, the reactive power is kept at 0 Mvar & DC voltage is regulated at 1200 V. When we double click on wind model block then it shows a generator, a converter, a turbine, & a drive train and the control system block.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 5, May 2014)

A. Case:-1 Performance Analysis of DFIG during Fault at Fixed Wind Speed

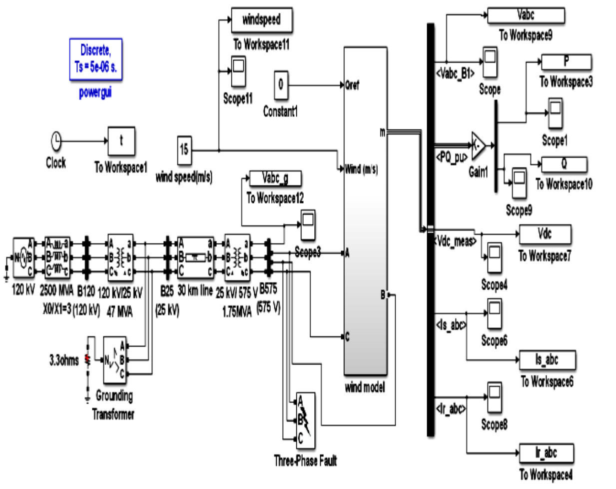

Fig. 14 Simulink Diagram of DFIG Wind System during Fault at Fixed Speed

The DFIG wind energy system Fig. 14 connected to grid via transformer and transmission line the DFIG rating is 1.5 MW a three phase short circuit fault (three phase fault element from Simscape) occur at bus B575 for 0.2 sec between 0.4 to 0.6 sec and simulated MATLAB simulink model for 1.2 sec.

B. Effect of Fault on Active Power

Fig. 15 shows that the active power (P) at fault condition under fixed speed. It can be seen that at the time of fault the active power becomes zero between 0.4 to 0.6 sec. after that the active power increasing up to rated value which are 1.5 MW.

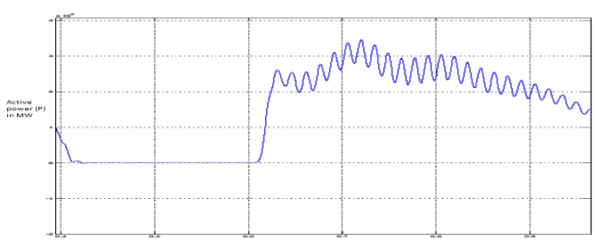

Fig. 15 Active Power (P) Versus Time at Fault Condition

C. Effect of Fault on Reactive Power

Fig. 16 shows that the reactive power (Q) at fault condition under fixed speed.

It can be seen that at the time of fault the reactive power becomes zero between 0.4 to 0.6 sec. after the fault clearance reactive power requirement increases up to 0.25 MW and comes in normal state within 0.3 seconds.

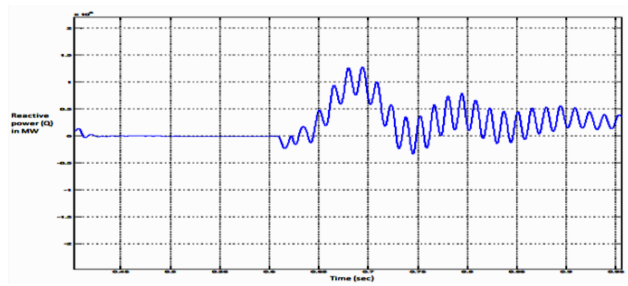

Fig. 16 Reactive Power (Q) versus Time at Fault Condition

D. Effect of Fault of Rotor and Stator Current of DFIG Wind System

Fig. 17 & Fig. 18 shows that the rotor and stator current of DFIG wind system at fault condition under fixed speed. It can be seen that at the time of fault between 0.4 sec. to 0.6 sec., both become almost zero (but not zero), before and after the fault both will become stable.

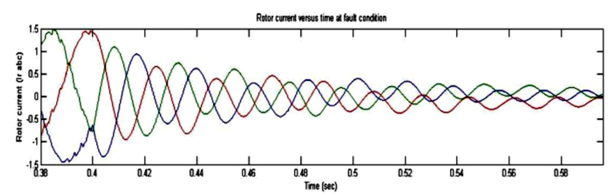

Fig. 17 Rotor Current of DFIG Wind System at Fault Condition

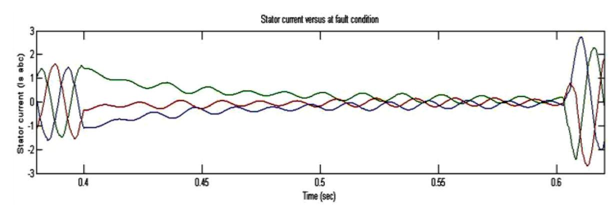

Fig. 18 Stator Current of DFIG Wind System at Fault Condition

E. Effect of Fault on Grid Side voltage without and with Filter, DC link Voltage (V_{abc}, V_{dc}, V_{abc_g})

Fig. 19, 20 & Fig. 21 shows that the Grid Side voltage without and with Filter, DC link Voltage, (V_{abc}, V_{abc_g}, V_{dc},**)** of DFIG Wind energy System at fault condition under fixed speed. It can be seen that at the time of fault between 0.4 sec. to 0.6 sec., both become almost zero (but not zero), before and after the fault both will become stable. It becomes almost zero (but not exactly zero).

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 5, May 2014)

Before and after the fault they give their regular value at fix speed, and dc link voltage V_{dc} remains constant at fault time 0.4 sec to 0.6 sec before and after.

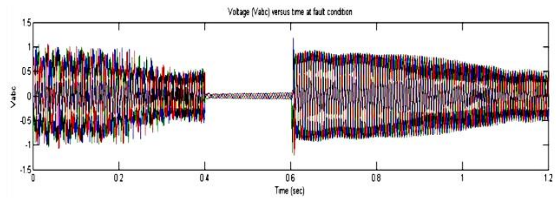

Fig. 19 Grid Side Voltage with Filter (V_{abc}) versus Time at Fault Condition

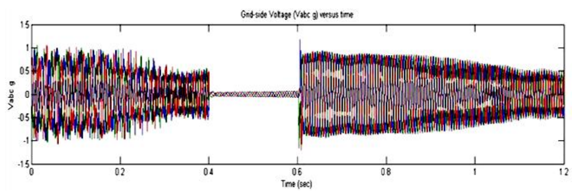

Fig. 20 Grid Side Voltage without Filter (V_{abc_g}) versus Time at Fault Condition

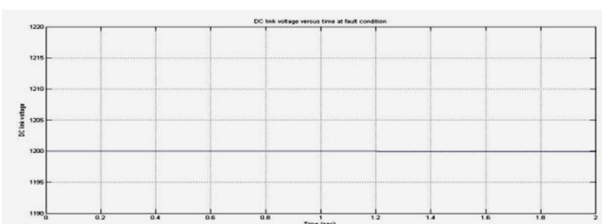

Fig. 21 DC Link Voltage (V_{dc}) versus Time at Fault Condition

F. Case:-2 Performance Analysis of DFIG during Fault at Variable Wind Speed

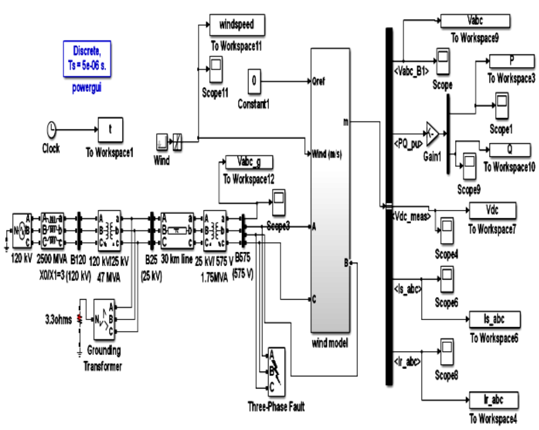

Fig. 22 Simulink Diagram of DFIG Wind System during Fault at Variable Speed

The DFIG wind energy system Fig. 22 connected to grid via transformer and transmission line the DFIG rating is 1.5 MW a three phase short circuit fault occur at bus B575 for 0.2 sec between 0.4 to 0.6 sec and simulated MATLAB simulink model for 1.2 sec.

G. Effect of Fault on Active Power

Fig. 23 shows that the active power (P) at fault condition under variable wind speed. It can be seen that at the time of fault the active power becomes zero between 0.4 to 0.6 sec., after that the active power increasing up to rated value which are 1.5 MW.

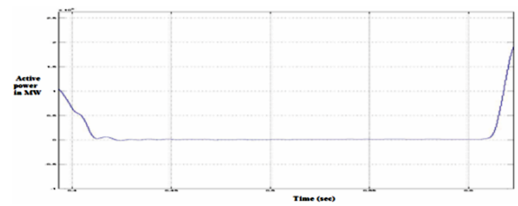

Fig. 23 Active Power (P) Versus Time at Fault Condition

H. Effect of Fault on Reactive Power

Fig. 24 shows that the reactive power (Q) at fault condition under Variable wind speed. It can be seen that there is no effect of variable wind speed at fault time. At the time of fault the reactive power becomes zero between 0.4 to 0.6 sec., after the fault clearance system comes in normal state within 0.02 second (*able to provide required reactive power*).

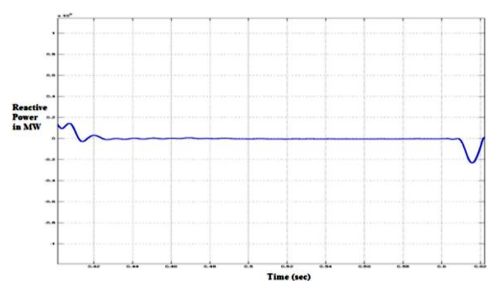

Fig. 24 Reactive Power (Q) versus Time at Fault Condition

I. Effect of Fault of Rotor and Stator Current of DFIG Wind System

Fig. 25 & Fig. 26 show that the Rotor and Stator Current of DFIG Wind System at fault condition under Variable wind speed. It can be seen that there is no effect of variable wind speed at fault time. At the time of fault between 0.4 sec. to 0.6 sec., both become almost zero (but not zero), before and after the fault both will become stable.

IJRDET
International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 5, May 2014)

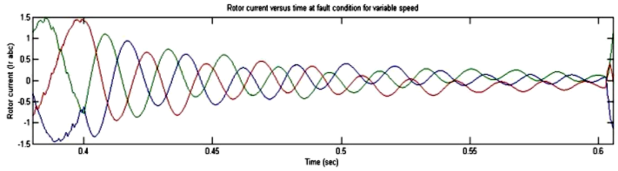

Fig. 25 Rotor Current of DFIG Wind System at Fault Condition

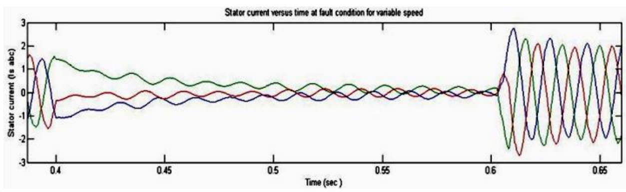

Fig. 26 Stator Current of DFIG Wind System at Fault Condition

J. Effect of Fault on Grid Side voltage without and with Filter, DC link Voltage (V_{abc}, V_{dc}, V_{abc_g})

Fig. 27, 28 & Fig. 29 shows that the Grid Side voltage without and with Filter, DC link Voltage, (V_{abc}, V_{abc_g}, V_{dc}**,)** of DFIG Wind energy System at fault condition under fixed speed. It can be seen that there is no effect of variable wind speed at fault time. At the time of fault between 0.4 sec. to 0.6 sec., both become almost zero (but not zero), before and after the fault both will become stable. It becomes almost zero (but not exactly zero). Before and after the fault they give their regular value at fix speed, and dc link voltage V_{dc} remains constant at fault time 0.4 sec. to 0.6 sec. before and after.

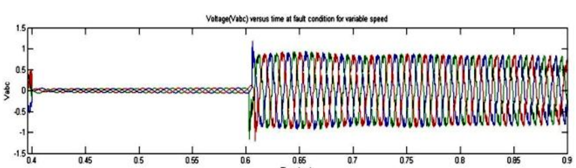

Fig. 27 Grid Side Voltage with Filter (V_{abc}) versus Time at Fault Condition

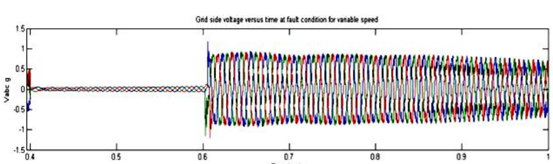

Fig. 28 Grid Side Voltage without Filter (V_{abc_g}) versus Time at Fault Condition

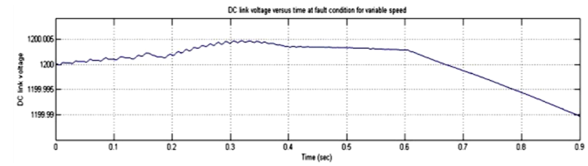

Fig. 29 DC Link Voltage (V_{dc}) versus Time at Fault Condition

V. CONCLUSION

A DFIG wind system are modeled and simulated in MATLAB software .An active power versus rotor speed relationship is analyses for the wind turbine model, In SCIG we know that requires external reactive power to support gird side voltage and it can maintain the real power at nominal level by pitch control but cannot vary the rotor speed to get maximum wind power at different wind speed .In our DFIG wind system there is no need to reactive power compensators to maintained the distribution line voltage and make optimal active power controlling. Here we employed both side (stator-side & rotor-side) voltage control techniques .The steady state and dynamic response of the DFIG wind system are calculated .It is concluded that the variable speed wind energy system has ability of optimal active power control & the efficiency became much higher of that system. It can be seen that the dc-link voltage maintain constant during fault.

REFERENCES

[1] Pehosh M., Putnam R., "Interconnection Of Large Wind Turbines To Electric Cooperative Distribution Grids", Rural Electric Power Conference (REPC), IEEE 2010.

[2] R. Datta and V. T. Ranganathan, "Variable-Speed Wind Power Generation Using Doubly Fed Wound Rotor Induction – A Comparison with Alternative Schemes," IEEE Trans. Energy Conversion, vol. 17, no. 3, pp. 414-421, Sept. 2002.

[3] R.Pena, J.C. Clare and G.M.Asher, "Doubly Fed Induction Generator Using Back To Back PWM Converters And Its Application To Variable Speed Wind Energy Generation" ,IEE Proc.-Electr.Power Appl. Vol. 143 ,no.3, pp. 231-241,May 1996.

[4] B.H. Chowdhury and S. Chellapilla, "Double-Fed Induction Generator Control for Variable Speed Wind Power Generation," Electric Power Systems Research, vol. 76, iss. 9-10, pp. 786-800, June 2006.

[5] Bharat Singh, S.N. Singh," Wind Power Interconnection into the Power System: A Review of Grid Code Requirements", the electricity journal, Science direct, vol 22, issue 5, June 2009.

[6] Mustafa Kayıkc and Jovica V. Milanovi´," "Reactive Power Control Strategies for DFIG-Based Plants", IEEE transactions on energy conversion, vol. 22, no. 2, June 2007.

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 2, Issue 5, May 2014)

[7] S. N. Singh, Jacob Østergaard, and Bharat Singh, "Reactive Power Capability of Unified DFIG for Wind Power Generation",IEEE 2010.

[8] Rakesh Sharma, Kuldeep Sahay, Satyendra Singh, "Effects of Varying Load on DC-Link Voltage in DFIG Wind Energy Conversion System", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 3, Issue 5, May 2014.

[9] J. Carrasco, L. Franquelo, J. Bialasiewicz, E. Galvan, R. Guisado, M. Prats, J. Leon, and N. Moreno-Alfonso, "Power-electronic systems for the grid integration of renewable energy sources: A survey," IEEE Trans. Industrial Electronics, vol. 53, no. 4, pp. 1002–1016, Jun. 2006.

BIOGRAPHY

Rakesh Sharma is a M. Tech student in the Department of Electrical Engineering, IET, and Lucknow. He received his B.Tech degree in Electrical Engineering from UP Technical University, Lucknow, India. He has total 04 years of teaching experience in IET, Lucknow, His research area of interest includes DFIG wind energy conversion system, fault analysis and performance enhancement.

Kuldeep Sahay, Ph.D. is associated with Institute of Engineering & Technology, Lucknow since 1996, where, he is presently Professor in the Department of Electrical Engineering, An Autonomous Constituent College of Gautam Buddh Technical University (Formerly Uttar Pradesh Technical University), and Lucknow. He has authored numbers of research paper in National and International Journal having good citation and published a book. His research interests are in the area of Mathematical Modeling of Energy Storage System, Integration of Renewable Energy System with Grid. Prof. Sahay for his overall contribution in research and academics has been awarded "Shiksha Rattan Puraskar" and "Rashtriya Gaurav Award" by India International Friendship Society, New Delhi in 2011.

Sateyndra Singh, M. Tech. is associated with Institute of Engineering & Technology, Lucknow since 2008, where, he is presently Assistant Professor in the Department of Electrical Engineering, An Autonomous Constituent College of Gautam Buddh Technical University (Formerly Uttar Pradesh Technical University), and Lucknow. He has authored numbers of research paper in National and International Journal having good citation. His research interests are in the area of power systems.