STUDY OF FAULT ANALYSIS IN A DOUBLY FED INDUCTION GENERATOR WIND ENERGY CONVERSION SYSTEM

B.K.Prusty[1], C.K.Panigrahi[2], S.M.Ali[3]
[1]Research Scholar, [2]Professor, [3]Associate Professor
School of Electrical Engineering, KIIT University, Bhubaneswar, Odisha, India
binodprusty@rediffmail.com, panigrahichinmoy@gmail.com, drsma786@gmail.com

ABSTRACT

In recent years, wind energy has become one of the most important and promising sources of renewable energy, which demands additional transmission capacity and better means of maintaining system reliability. The evolution of technology related to wind systems industry leaded to the development of a generation of variable speed wind turbines that present many advantages compared to the fixed speed wind turbines. These wind energy conversion systems are connected to the grid through Voltage Source Converters (VSC) to make variable speed operation possible. The studied system here is a variable speed wind generation system based on Doubly Fed Induction Generator (DFIG). The stator of the generator is directly connected to the grid while the rotor is connected through a back-to-back converter which is dimensioned to stand only a fraction of the generator rated power. To harness the wind power efficiently the most reliable system in the present era is grid connected doubly fed induction generator. The DFIG brings the advantage of utilizing the turns ratio of the machine, so the converter does not need to be rated for the machine's full rated power. This report deals with the introduction of DFIG, AC/DC/AC converter control and its fault analysis in isolated induction generator with turbine response to a change in wind speed SIMULINK/MATLAB Simulation

KEYWORDS: *Doubly Fed Induction Generator (DFIG), Voltage Source Converters (VSC), Wind turbine. Pulse Width Modulation (PWM).*

I. INTRODUCTION

With increased penetration of wind power into electrical grids, 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. The continuous trend of having high penetration of wind power, in recent years, has made it necessary to introduce new practices. For example, grid codes are being revised to ensure that wind turbines would contribute to the control of voltage and frequency and also to stay connected to the host network following a disturbance. In response to the new grid code requirements, several DFIG models have been suggested recently, including the full-model which is a 5th order model. These models use quadrature and direct components of rotor voltage in an appropriate reference frame to provide fast regulation of voltage. The 3rd order model of DFIG which uses a rotor current, not a rotor voltage as control parameter can also be applied to provide very fast regulation of instantaneous currents with the penalty of losing accuracy. A switch-by-switch representation of the back- to-back PWM converters with their associated modulators for both rotor- and stator-side Converters has been proposed. Power quality is actually an important aspect in integrating wind power plants to grids. This is even more relevant since grids are now dealing with a continuous increase of non-linear loads such as switching power supplies and large AC drives directly connected to the network. By now only very few researchers have addressed the issue of making use of the built-in converters to compensate harmonics from non-linear loads and enhance grid power quality. In, the current of a non-linear load connected to the network is measured, and the rotor-side converter is used to cancel the harmonics injected in the grid. Compensating harmonic currents are injected in the generator by the rotor-side converter as well as extra reactive power to support the grid.

II. SYSTEM UNDER STUDY

2.1 Doubly Fed Induction Generator

Wind turbines use a doubly-fed induction generator (DFIG) consisting of a wound rotor induction generator and an AC/DC/AC IGBT-based PWM converter. The stator winding is connected directly to the 50 Hz grid while the rotor is fed at variable frequency through the AC/DC/AC converter. The DFIG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing 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. Where Vr is the rotor voltage and Vgc is grid side voltage.

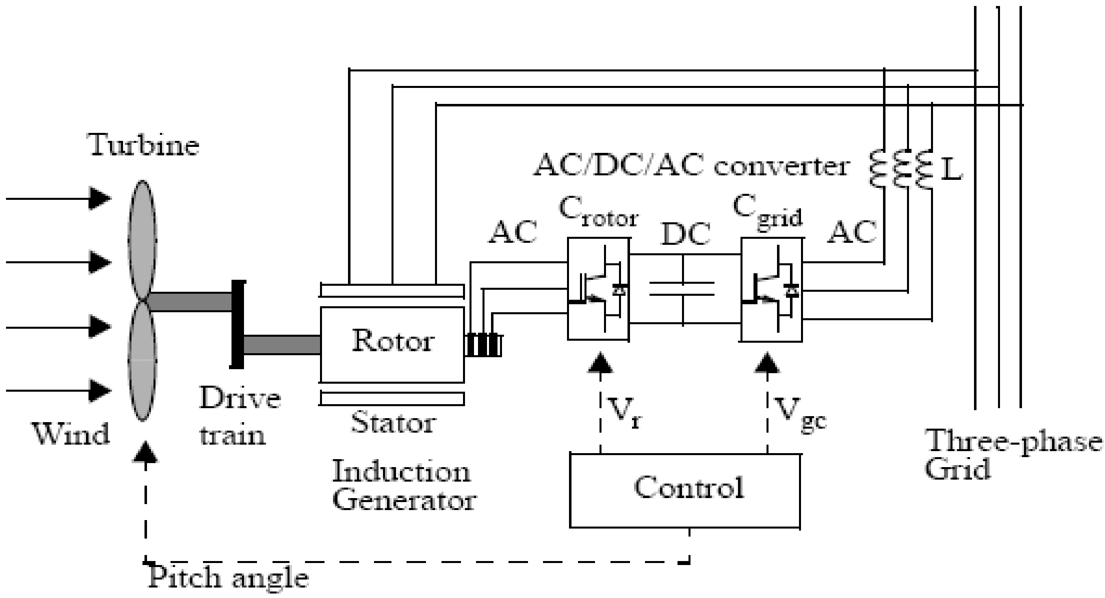


Fig 2.1 Basic diagram of Doubly fed induction generator with converters

PWM technique to reduce the harmonics present in the wind turbine driven DFIG system. Here Crotor is rotor side converter and Cgrid is grid side converter. To control the speed of wind turbine gear boxes or electronic control can be used.

2.2 Operating Principle of DFIG

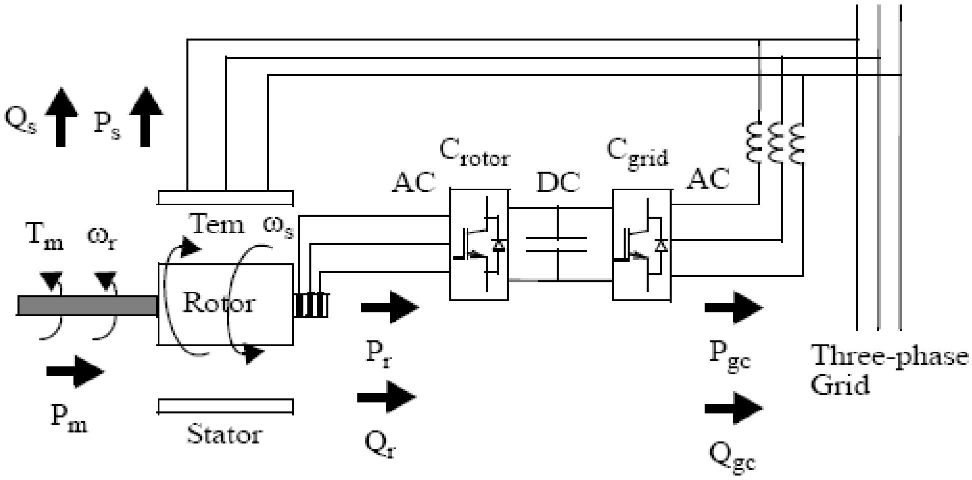


Fig. 2.2 Power flow diagram of DFIG

The stator is directly connected to the AC mains, while the wound rotor is fed from the Power Electronics Converter via slip rings to allow DIFG to operate at a variety of speeds in response to changing wind speed. Indeed, the basic concept is to interpose a frequency converter between the variable frequency induction generator and fixed frequency grid. The DC capacitor linking stator- and rotor-side converters allows the storage of power from induction generator for further generation.. The slip power can flow in both directions, i.e. to the rotor from the supply and from supply to the rotor and hence the speed of the machine can be controlled from either rotor- or stator-side converter in both super and sub-synchronous speed ranges. As a result, the machine can be controlled as a generator or a motor in both super and sub-synchronous operating modes realizing four operating modes. Below the synchronous speed in the motoring mode and above the synchronous speed in the generating mode, rotor-side converter operates as a rectifier and stator-side converter as an inverter, where slip power is returned to the stator. Below the synchronous speed in the generating mode and above the synchronous speed in the motoring mode, rotor-side converter operates as an inverter and stator- side converter as a rectifier, where slip power is supplied to the rotor

The mechanical power and the stator electric power output are computed as follows:

$$P_r = T_m * \omega_r$$

$$P_s = T_{em} * \omega_s$$

For a loss less generator the mechanical equation is:

$$J\frac{d\omega_r}{dt} = T_m - T_{em}$$

In steady-state at fixed speed for a loss less generator

$$T_m = T_{em} \text{ and } P_m = P_s + P_r$$

and It follows that:

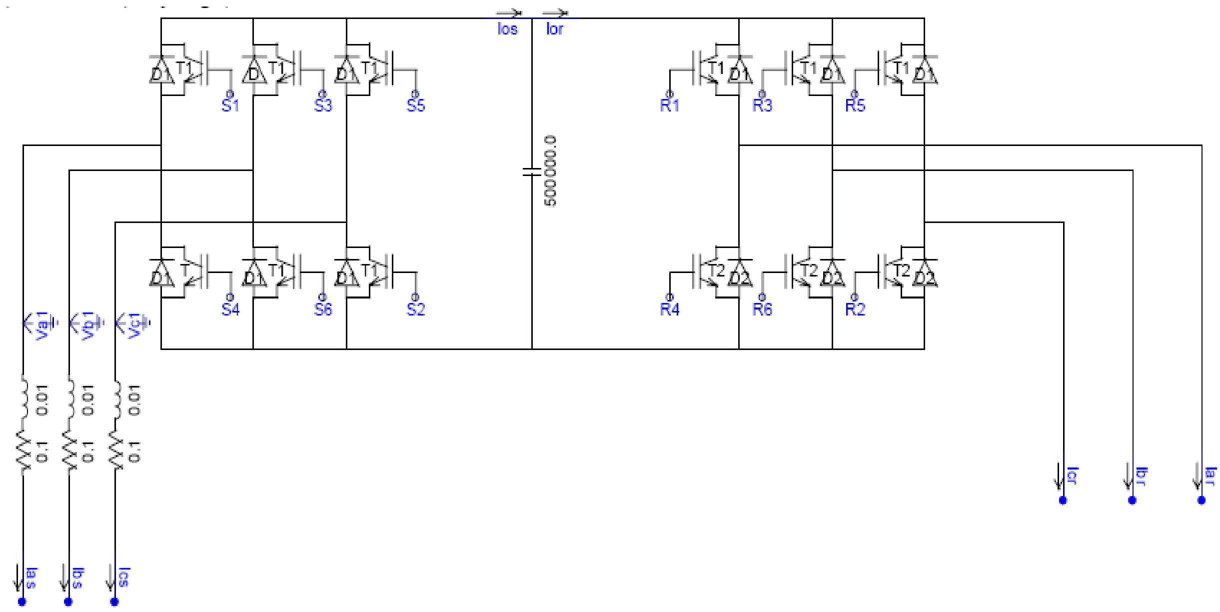
$$P_r = P_m - P_s = T_m \omega_r - T_{em} \omega_s = -sP_S$$

Where

$$S = \frac{(\omega_S - \omega_r)}{\omega_s}$$

Generally the absolute value of slip is much lower than 1 and, consequently, Pr is only a fraction of Ps. Since Tm is positive for power generation and since ω*s* is positive and constant for a constant frequency grid voltage, the sign of Pr is a function of the slip sign. Pr is positive for negative slip (speed greater than synchronous speed) and it is negative for positive slip (speed lower than synchronous speed). For super synchronous speed operation, Pr is transmitted to DC bus capacitor and tends to rise the DC voltage. For sub-synchronous speed operation, Pr is taken out of DC bus capacitor and tends to decrease the DC voltage. Cgrid is used to generate or absorb the power Pgc in order to keep the DC voltage constant. In steady-state for a lossless AC/DC/AC converter Pgc is equal to Pr and the speed of the wind turbine is determined by the power Pr absorbed or generated by Crotor.

2.3 Back-to-Back AC/DC/AC Converter Modeling



This paper proposes a graphic-oriented switch-by-switch representation of the back-to-back PWM converters with their modulators for both rotor- and stator-side converters, where both IGBT and reverse diode devices are represented as a two-state resistive switch. The back to back PWM converter has two converters, one is connected to rotor side and another is connected to grid side. Control by both converters has been discussed here.

2.3.1 Rotor side converter Control System

The rotor-side converter is used to control the wind turbine output power and the voltage measured at the grid terminals. The power is controlled in order to follow a pre-defined power-speed characteristic, named tracking characteristic. This characteristic is illustrated by the ABCD curve superimposed to the mechanical power characteristics of the turbine obtained at different wind speeds. The actual speed of the turbine ωr is measured and the corresponding mechanical power of the tracking characteristic is used as the reference power for the power control loop.

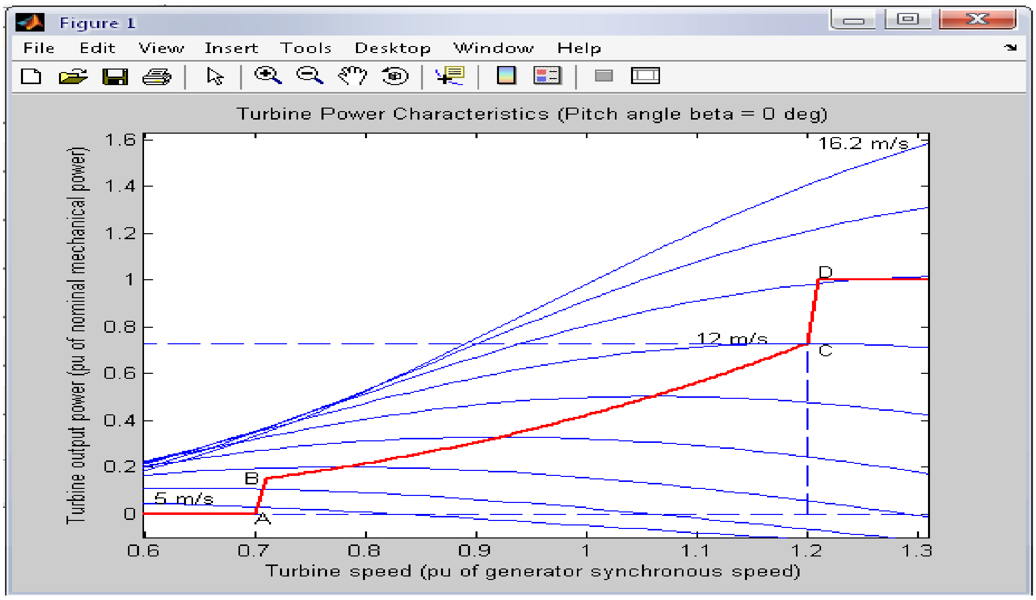


Fig 2.3 Turbine power characteristics

The tracking characteristic is defined by four points: A, B, C and D.From zero speed to speed of point A the reference power is zero. Between point A and point B the tracking characteristic is a straight line. Between point B and point C the tracking characteristic is the locus of the maximum power of the turbine (maxima of the turbine power vs turbine speed curves).

2.3.2 Grid side converter control system

The Grid side converter is used to regulate the voltage of the DC bus capacitor. For the grid-side controller the d-axis of the rotating reference frame used for d-q transformation is aligned with the positive sequence of grid voltage.

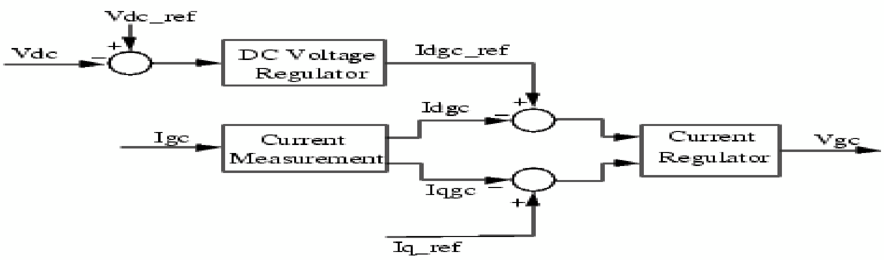


Fig. 2.4 Grid side converter control

III. Power System Fault Analysis

The fault analysis of a power system is required in order to provide information for the selection of switchgear, setting of relays and stability of system operation. A power system is not static but changes during operation (switching on or off of generators and transmission lines) and during planning (addition of generators and transmission lines). Thus fault studies need to be routinely performed by utility engineers (such as in the CEB).Faults usually occur in a power system due to either insulation failure, flashover, physical damage or human error. A challenge associated with the protection of Wind Farms connected to Grid is that the fault current must be detected and extinguished very quickly. lt detection is also important, in order to isolate the fault and restore the system to working order

3.1 Simulink model.

The Software used for simulation is MATLAB/SIMULINK of 2010a (i.e. MATLAB r2010a) version. MATLAB software has been a boon for decades for providing a platform for all Engineers, Students, and Researchers etc. for realising small as well as vast real time models in computers. This has still made us confident in realising various models without the need of practical implementations and observes the results, which is very helpful in the field of Research.

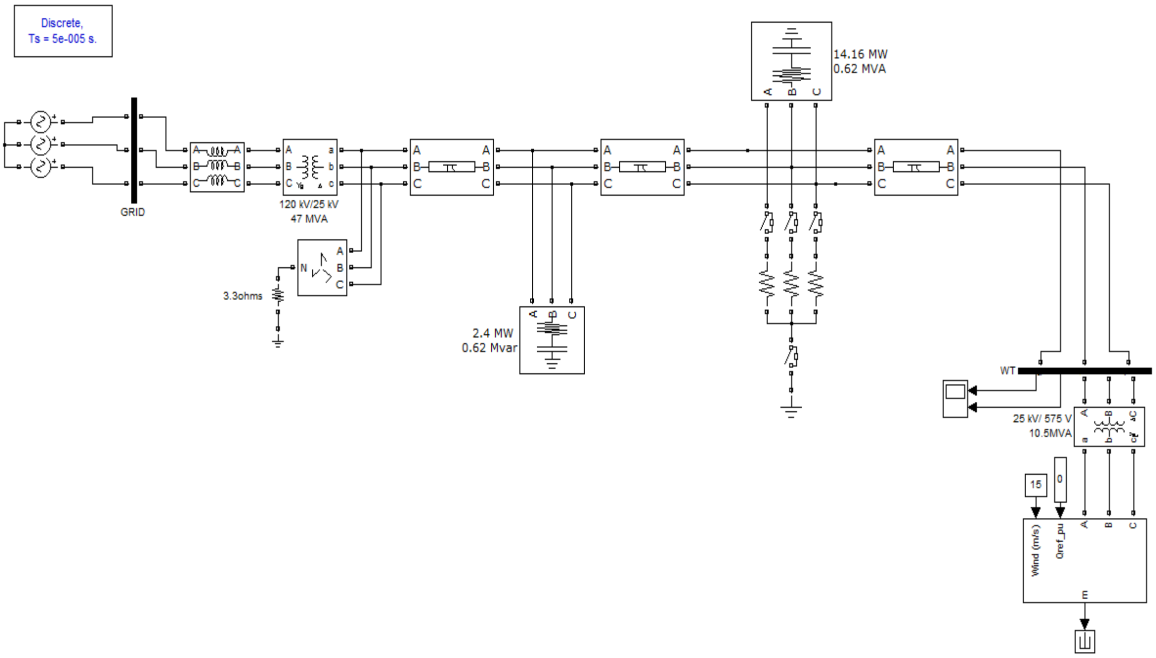


Fig 3.1 simulation Model Of Wind Farm

IV. SIMULATION RESULTS

The performance of the system i.e. the waveforms of Voltage and Current at Wind Turbine under different conditions are observed in this section.

Case1: No Fault Condition

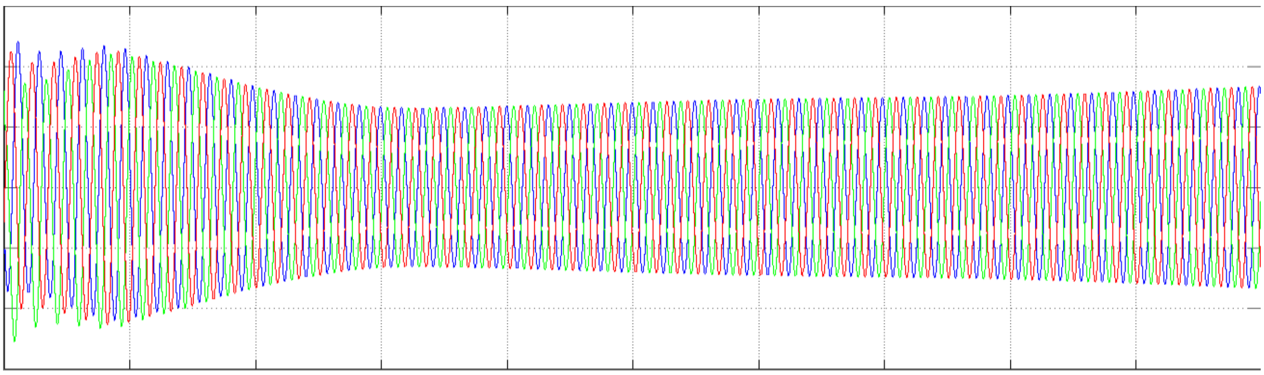


Figure 4.1: Current output at Wind farm for no fault condition

Case 2: Single line to ground fault

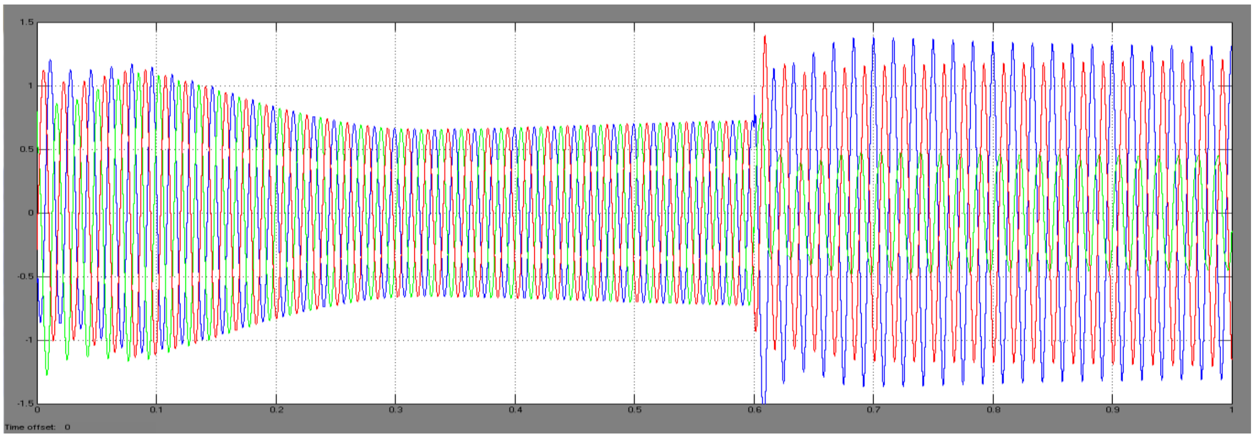


Figure 4.2: Current output at Wind farm for Single Line to Ground Fault

Case 3: Double line fault

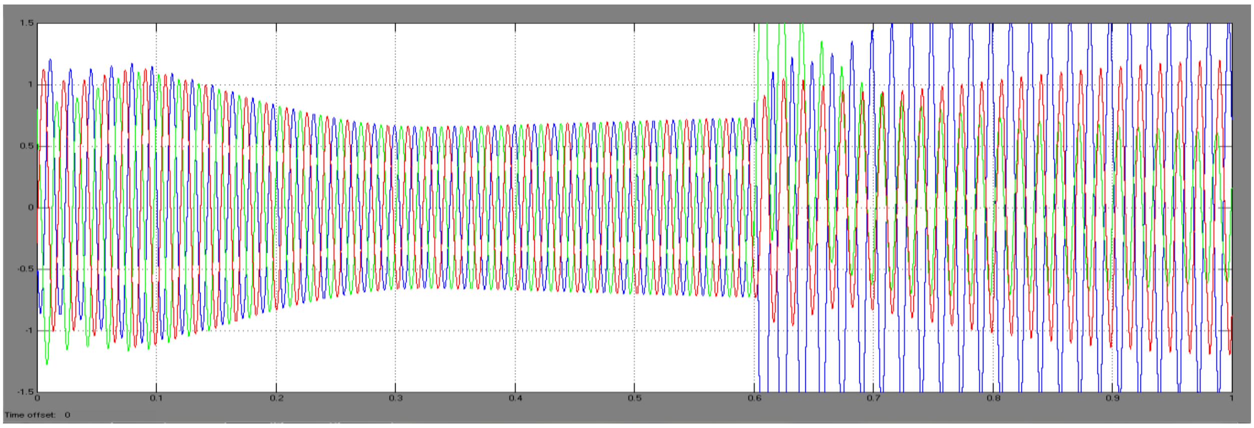


Figure 4.3: Current output at Wind farm for Double Line Fault

Case 4: Triple line fault

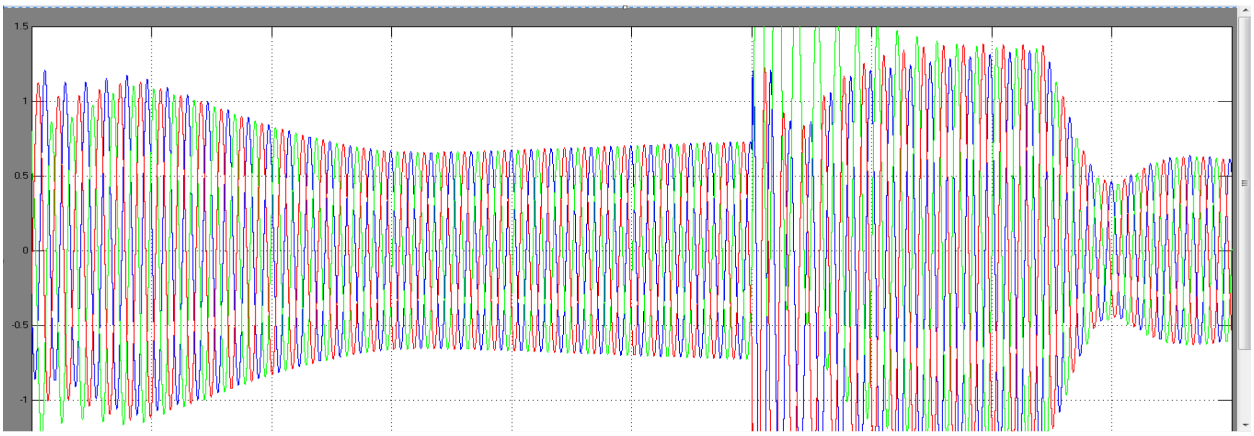
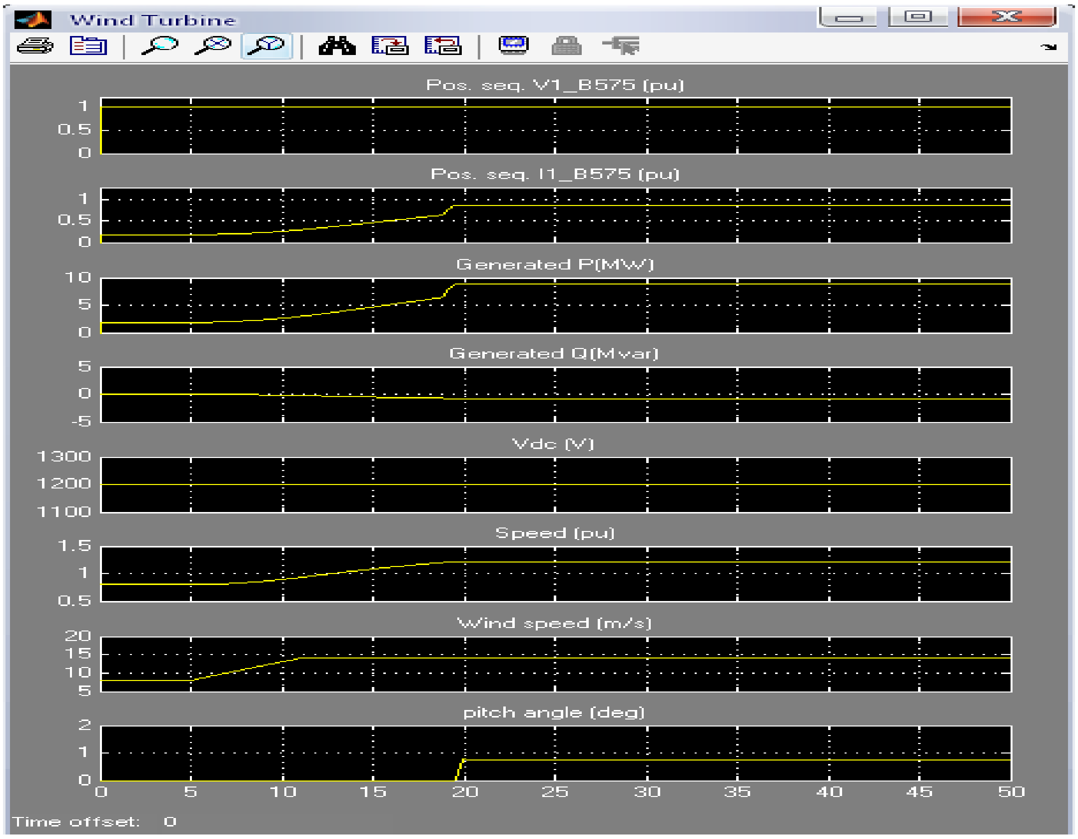


Figure 4.4: Current output at Wind farm for Triple Line Fault

Case 5.Turbine response to a change in wind speed

In the "Wind Speed" step block specifying the wind speed. Initially, wind speed is set at 8 m/s, then at t = 5s, wind speed increases suddenly at 14 m/s. Start simulation and observe the signals on the "Wind Turbine" scope monitoring the wind turbine voltage, current, generated active and Reactive powers, DC bus voltage and turbine speed.



At t = 5 s, the generated active power starts increasing smoothly (together with the turbine speed) to reach its rated value of 9 MW in approximately 20 s. Over that time frame the turbine speed will have increased from 0.8 PU to 1.21 PU. Initially, the pitch angle of the turbine blades is zero degree and the turbine operating point follows the red curve of the turbine power characteristics up to point D. Then the pitch angle is increased from 0 deg to 0.76 deg in order to limit the mechanical power. We also observed the voltage and the generated reactive power. The reactive power is controlled to maintain a 1 PU voltage.

V. CONCLUSION

The basic operation of DFIG and its controls using AC/DC/AC converter is discussed here. A wind turbine driven isolated (not connected to grid) induction generator is also considered. 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. The model is a discrete-time version of the Wind Turbine Doubly-Fed Induction Generator (Phasor) Type) of Matlab/Sim Power Systems. Here I have also discussed the simulation results of a turbine response to a change in wind speed. In future work simulation work will be done of DFIG when connected to grid side with control parameters and also use hybrid (solar) in the above system.

VI. REFERENCES

[1]. Holdsworth L, Wu XG, Ekanayake JB, Jenkins N. Comparison of fixed speed and doubly-fed induction wind turbinesduring power system disturbances. IEE Proceedings: Generation, Transmission, Distribution, 2003, 3: 343-352

[2]. Ekanayake, J.B, Holdsworth, L, Wu, X., Jenkins, N. Dynamic modeling of Doubly Fed Induction generator wind turbines. IEEE Transaction on Power Systems, 2003, 2:803-809

[3]. J. Morren, J.T.G. Pierik, S.W.H. de Haan, J. Bozelie, "Grid interaction of offshore wind farms. Part 1. Models for dynamic simulation", Wind Energy, 8 (3): JUL-SEP 2005.

[4]. R. Pena, J.C. Clare, G.M. Asher, "Doubly-fed induction generator using back-to-back PWM converters and its applications to variable-speed wind-energy generation,"IEEE Proceedings on Electrical Power Applications, Vol. 143, No. 3, May 1996, pp. 231-341.

[5]. The MathWorks, "SimPowerSystems for Use with Simulink", User's Guide Version 4.

[6]. Richard Gagnon, Gilbert Sybille, Serge Bernard, Daniel Paré, Silvano Casoria, Christian Larose "Modeling and Real-Time Simulation of a Doubly-Fed Induction Generator Driven by a Wind Turbine" Presented at the International Conference on Power Systems Transients (IPST'05) in Montreal, Canada on June 19-23, 2005 Paper No. IPST05-162.

[7]. http://www.windpowerindia.com/

[8]. http://www.inwea.org/windenergy

[9]. Hansen, A.D.; Sorensen, P.; Janosi, L.; Bech, J.; , "Wind farm modelling for power quality," Industrial Electronics Society, 2001. IECON '01. The 27th Annual Conference of the IEEE, vol.3, no.9, pp.1959-1964 vol.3, 2001.

[10]. Yuvaraj, V.; Deepa, S.N.; Rozario, A.P.R.; Kumar, M.; , "Improving Grid Power Quality with FACTS Device on Integration of Wind Energy System," Modeling Symposium (AMS), 2011 Fifth Asia, vol.3, no.4, pp.15.