MODELLING AND SIMULATION OF DFIG BASED WIND-FARM FOR CONSTANT POWER CONTROL AND FAULT-RIDE THROUGH

Jay Dhruv[1], Prof. Mihir Rathod[2]
[1]PG Scholar, [2]Assistant Professor,
[1,2]Electrical Department, LDRP-ITR, Gandhinagar, Gujarat, India

ABSTRACT

Wind turbine generators (WTGs) are usually controlled to generate maximum electrical power from wind under normal wind conditions. With the increasing penetration of wind power into electric power grids, energy storage devices will be required to dynamically match the intermittency of wind energy. To meet the requirements of frequency and active power regulation, energy storage devices will be required to dynamically match the intermittency of wind energy. A novel two-layer constant-power control scheme for a wind farm equipped with doubly-fed induction generator (DFIG) wind turbines. It is connected to the power grid at both stator and rotor terminals. The stator is directly connected to the grid while the rotor is fed through a variable-frequency dc-link-voltage converter, which consists of a rotor-side converter (RSC) and a grid-side .converter .Each DFIG wind turbine is equipped with a super capacitor energy storage system (ESS) and is controlled by the low-layer WTG controllers and coordinated by a high-layer wind-farm supervisory controller (WFSC). The proposed system and control scheme provides a promising solution to help achieve high levels of penetration of wind power into electric power grids

INTRODUCTION

In the modern times the wind power plant / energy has been one of the most popular renewable energy source. It is also a very useful and sustainable energy source for power generation. So, it is very popular and important renewable energy source after the solar energy. As we discuss about the advantage of wind power plants, it has also some drawbacks like the variation in wind speed according to time. Due to some advancement in technology in latest time these more efficient; lights in weight, strong bladder is design for wind power plant. These are also very useful power electronics converter has been established for different variable speed wind turbines. This type of variable speed wind turbines is used for different machines like wound rotor I.M., squirrel cage type I.M., PMMC type synchronous machine etc. Use of double feed induction generation (DFIG) allows us to utilize maximum energy from the wind. It is use for low wind speed with the help of turbine speed. With the help of DFIG we can minimize the mechanical stress on the wind turbine.

All these studies only consider on control and operation of individual WTG and they did not research on the grid regulation of WTG. Here, in this thesis we proposed the constant power control mechanism for a wind

power plant operated on DFIG with super capacitor storage system. Here for constant power control mechanism these are two controllers used:

1. Wind farm supervisory controller
2. Multiple low layer WTG controller

In this system high layer WFSC controller generates active power reference for low layer WTG controllers. The DFIG is very popular and most frequently applicable for large grid connected wind turbines. Compare to other system DFIG provides following advantages of reducing inverter and output filter cost due to the use of low ratings at rotor and grid side power conversion. DFIG based control turbine is very useful against voltage dips in the system.

The lower layer WTG controller is easily regulating the DFIG operation to generate required value of active power. In this proposed system the difference between input and output is mitigated by energy storage system. In this system the proposed mechanism is verified in MATLAB / SIMULINK software using 15 DFIG wind turbine in a wind farm

WIND POWER

Wind is available in all over world and it is available or its existence is due to the unrequired heating on the earth surface and due to the earth's rotation. The normally methods which is used for electricity generation is using oil, gas, coal etc. But, the main drawback of this system is this system is this type of conventional system of power plant produce pollution in environment. Due to these effects like pollution, temperature increase, greenhouse effect etc. The use and application of renewable energy sources are increased and mainly solar, wind, hydro power. Another best advantage of renewable energy source is that the overall cost of renewable energy sources is decreased day by day due to advancement in the new technologies.

FEATURES OF WIND POWER SYSTEMS: -

These are so many advantages feature of use of wind power system. In most of the wind power plant site location is in rural area, island area and marine areas. The energy equipment in these kinds of places are simple and does not require high electrical power.

1. The power system supplies cheap variable voltage for heating purpose and expensive higher voltage for motor and lights.
2. The rural grid system is very weak up to 33 KV system. The grid integration of wind energy conversion system is very difficult, and problem occur for worker of the plant.
3. These are some time duration is coming where wind energy is not available. That's storage system is necessary for continuous power supply.

POWER FROM THE WIND: -

The mechanical energy as kinetic energy is provided from the wind to rotate generator and produce electricity. These are so many factors are important for better efficiency and maximum power generation from the wind. The first and very important factor is wind speed to determine the capacity of wind to obtain maximum amount of power. So, the power produced from the wind turbine is equal to the cube of wind speed. So, it will double the value of wind speed than power produce is 8 times to original power.

The relation between power generated and velocity of wind and diameter of rotor blades are given as below:

$$P_{wind} = \frac{\pi}{8} dD^2 v_{wind}^3$$

For selection of wind turbine available in market the best and efficient wind turbine is that which is capable of use of kinetic energy of wind.

Wind power plant has the following advantages over the other conventional power plants:

- Improve the price complexity
- Easy installation of plant
- Fast and reliable construction
- Easy power generation
- Improve the system reliability
- Pollution free

DOUBLE FED INDUCTION GENERATOR (DFIG)

DFIG which is also known as Double feed induction generator which is mostly used in wind turbines. The DFIG is based on the working principle of an induction generator which is provided with multiphase wound rotor and slip ring design configurations. The alternative of DFIG is brushless wound rotor doubly fees induction machine.

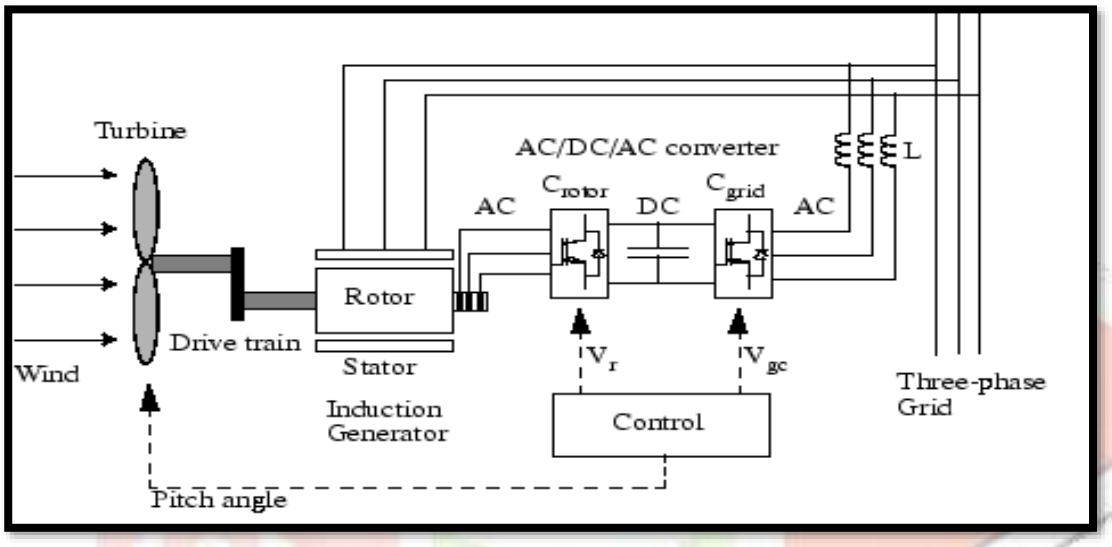
PRINCIPLE OF GRID CONNECTED DOUBLE FEED INDUCTION GENERATOR SYSTEM

The principle operation of DFIG is that the rotor windings are connected to the grid via slip rings and back to back VSC (voltage source converter) which provides the control of rotor side and grid side currents. The voltage source converter provides the control at rotor side current and provides the active and reactive power control feeding to the grid. The principle of control is provided using direct axis control or two axis control system. In the DFIG system the rotors are typically wound with number of turns of 2 to 3 multiple of stator turns. Due to this the rotor voltage value is higher and rotor current value is lower. So, in this configuration the operation speed of rotor is ±30% of the synchronous speed. The current rating of converter is lower due to that

the cost of converter is low. The rotor voltage value is high due to that the controlled operation in operation speed range is not possible. Provide the protection against higher rotor voltage there are IGBT and diode configuration is used. Use of crowbar protection there are small currents and voltages are detected. For the continuous operation as fast as, possible there is an active crowbar protection is provided.

In short circuit condition the active crowbar is remove and so the rotor side converter can be started after 20-60ms from the starting of grid disturbance. So, it is possible to generate the reactive current in the grid during the voltage dip and due to that grid is recover from the fault.

Fig: Operating Principle of the Wind Turbine Doubly-Fed Induction Generator



The double feed induction machine has several advantages over conventional induction machine for wind power application. The induction machine use power electronics converter the induction machine can import and export of reactive power in the system. Due to these kind of features the induction machine can provide power system stability and provide the support to grid during voltage disturbances. Another important feature is that induction machine is capable to synchronize with grid while wind turbine speed is variable. The variable speed wind turbine efficiently used during light wind conditions. Due to these kinds of several feature and advantages the efficiently of DFIG is very good.

SYSTEM MODEL:

The model of the system electrically is developed using phase of complex vectors in synchronous rotating reference frame theory. The calculation assumes + ve axis as real axis and – ve axis as imaginary axis. In different conditions the real and imaginary axis are align with vectors at different position and at different angles. The different assumption which are consider during development of electrical model of the system are:

1. The losses like iron losses converter losses are neglected.
2. The magnetic circuit of the machines can be represented by linear model in the system.
3. The whole mechanical model of the system of the system can be modelled using lumped parameters of inertia like electrical angle and speed of induction generator.

4. The power converter using in the system are represented by state space representation for their low frequency values.
5. It is assumed that the wind farm networks are electrically stiff with respect to point of common coupling (PCC) and the conventional DFIG circuit is transformed into an equivalent circuit.

DFIG CONTROL:

The DFIG is connected to the network is represented by three steps which has been represented as following steps. First step is regulating the stator voltage with respect to reference voltage. Second step is the power control and regulation between stator and network.

Fig 4.2: First step of DFIG control

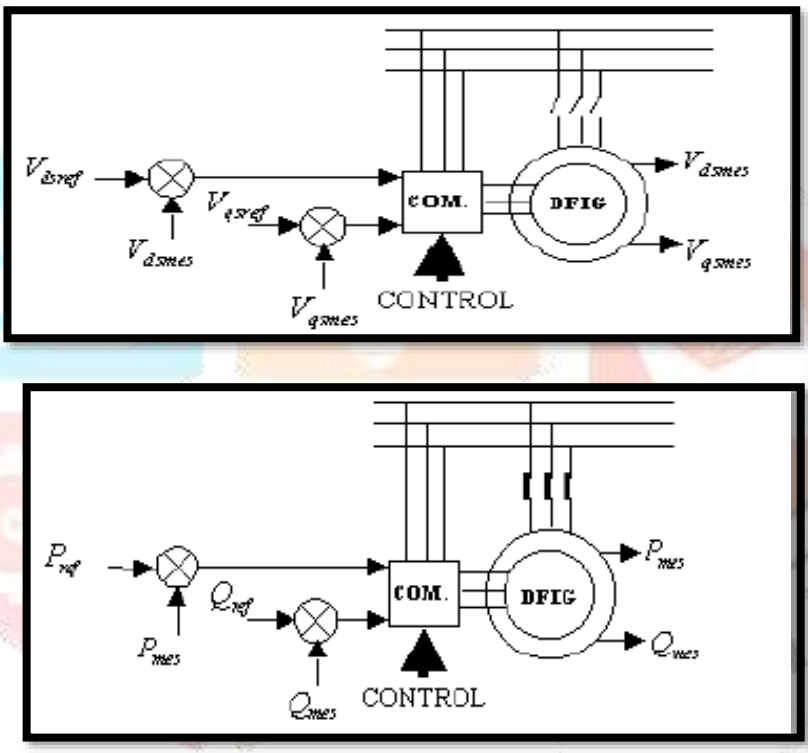


Fig 4.3: Second step of DFIG control

MODELLING AND SIMULATION

The design configuration of DFIG based wind turbine connected with super capacitor bank-based energy storage system is shown in fig below. In the given system the low speed wind turbine drives the high speed DFIG using gearbox system. The DFIG is wound rotor type induction machine which is connected to the power grid at stator and rotor terminals. The stator is directly connected to the system while the rotor is connected through grid side converter and rotor side converter to the grid in the system. The DFIG based wind turbine generator rotates at the operational speed of 20-30% to the synchronous speed in the system and the active and reactive power is controlled independently in the system. In this design configuration the energy storage system

is provided using super capacitor bank and two quadrant dc-dc converter. The ESS works as a source or sink to control the active power to the wind turbine generator system.

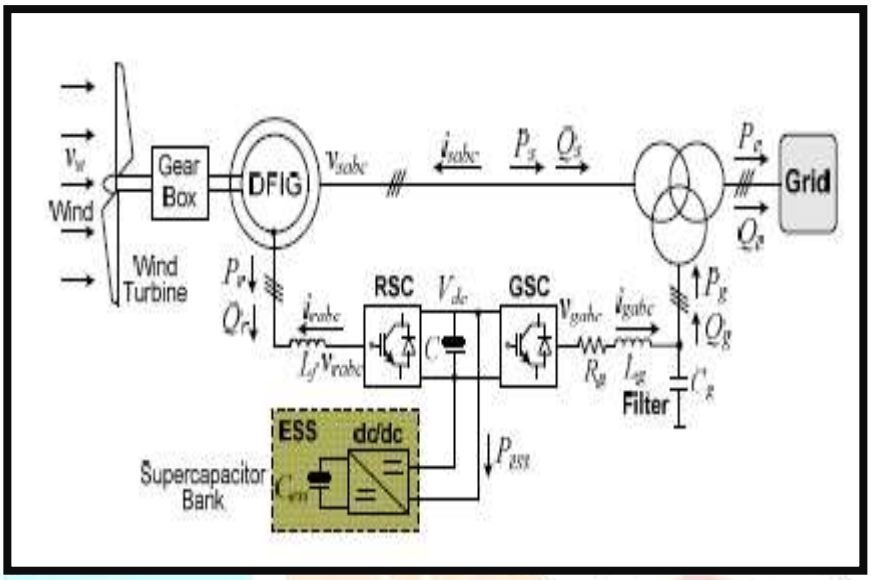


Fig DFIG wind turbine with ESS

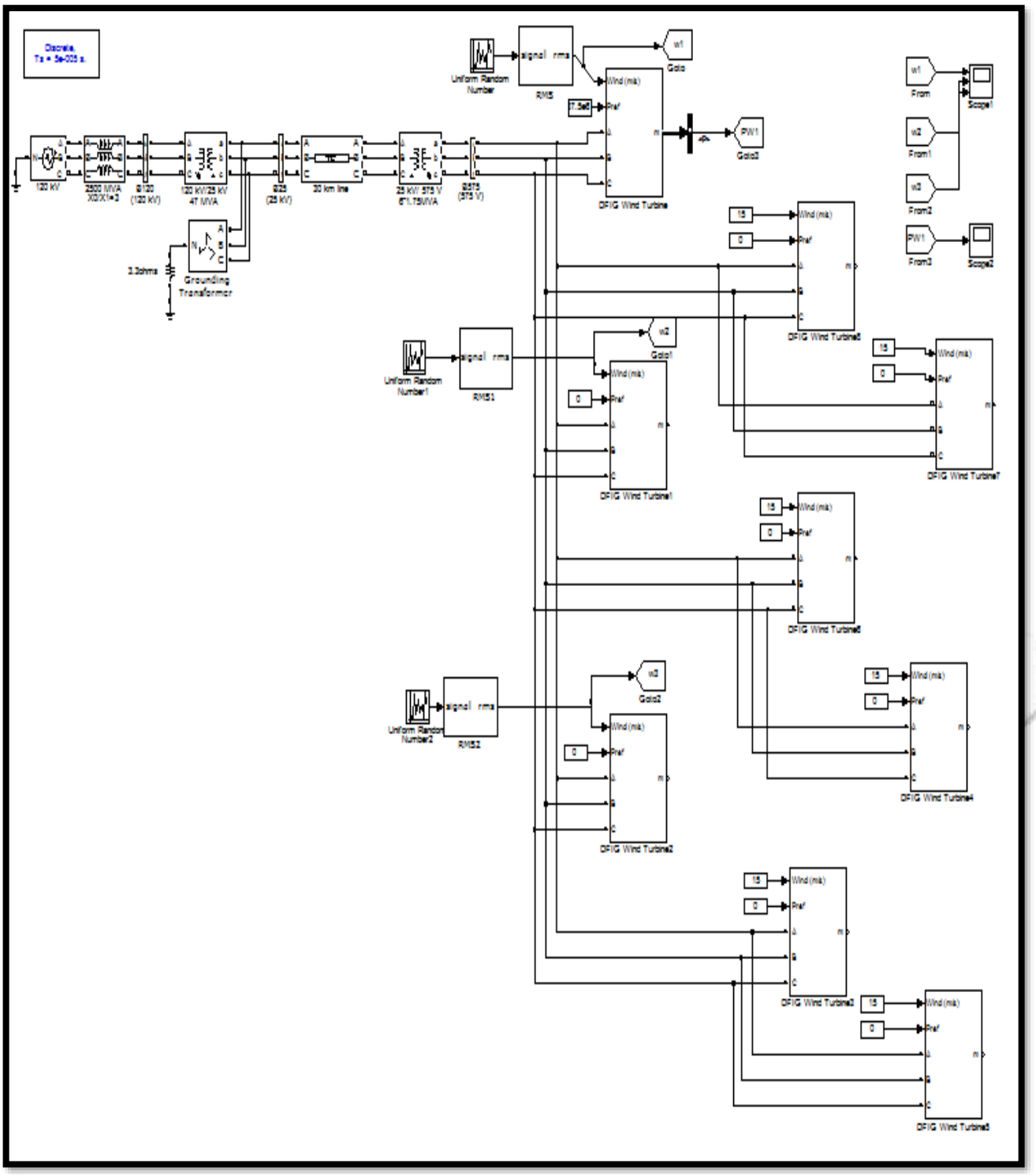


Fig Simulink model of DFIG wind turbine without any control strategies and energy storage system

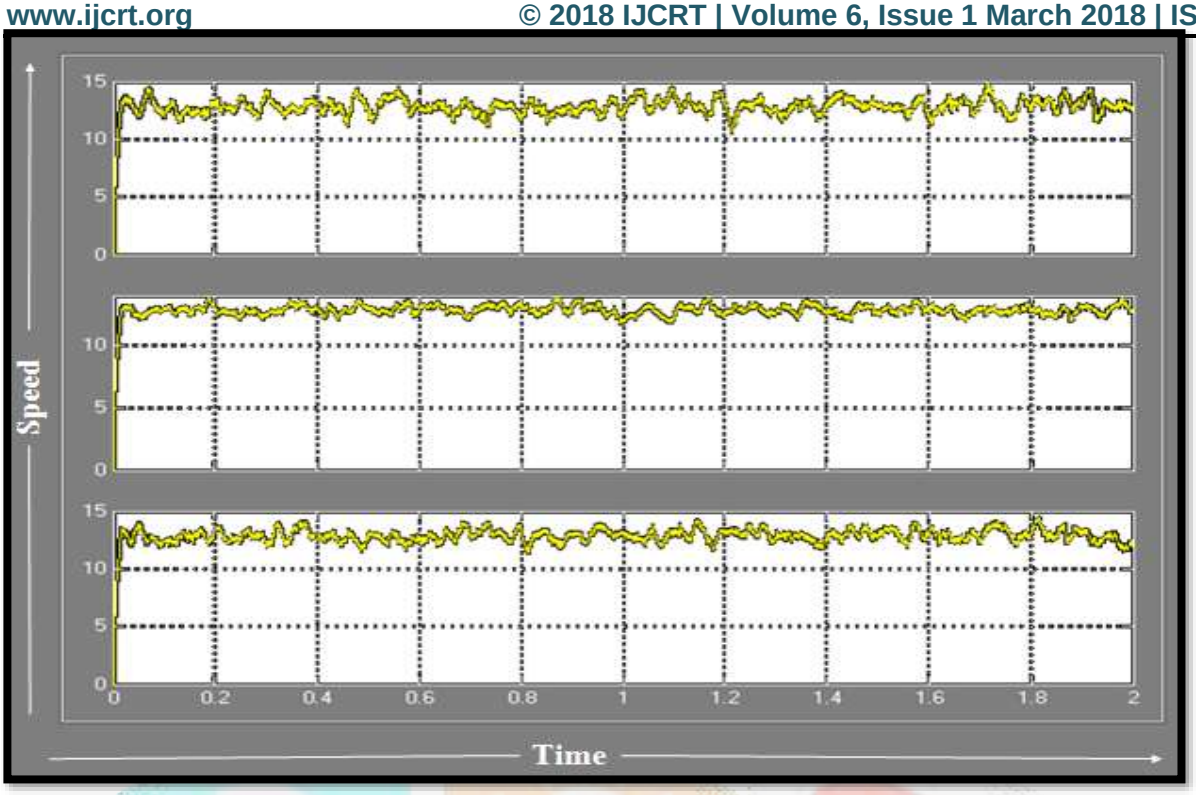


Fig wind speeds of turbines

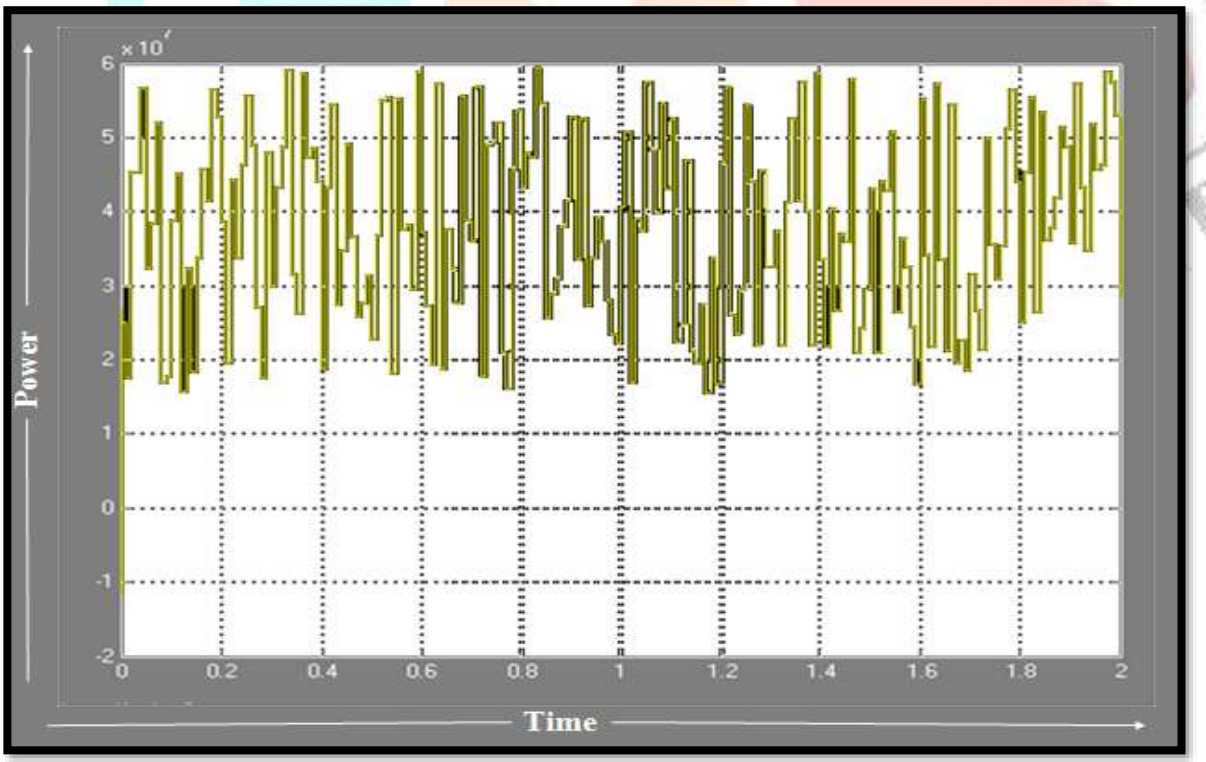


Fig DFIG wind turbine power

SIMULATION RESULTS

Simulation studies carried out to verify performance of control strategies under various condition. There are some results of simulation shown.

WIND SPEED

Fig Wind speed of wind turbine 1,2 & 3

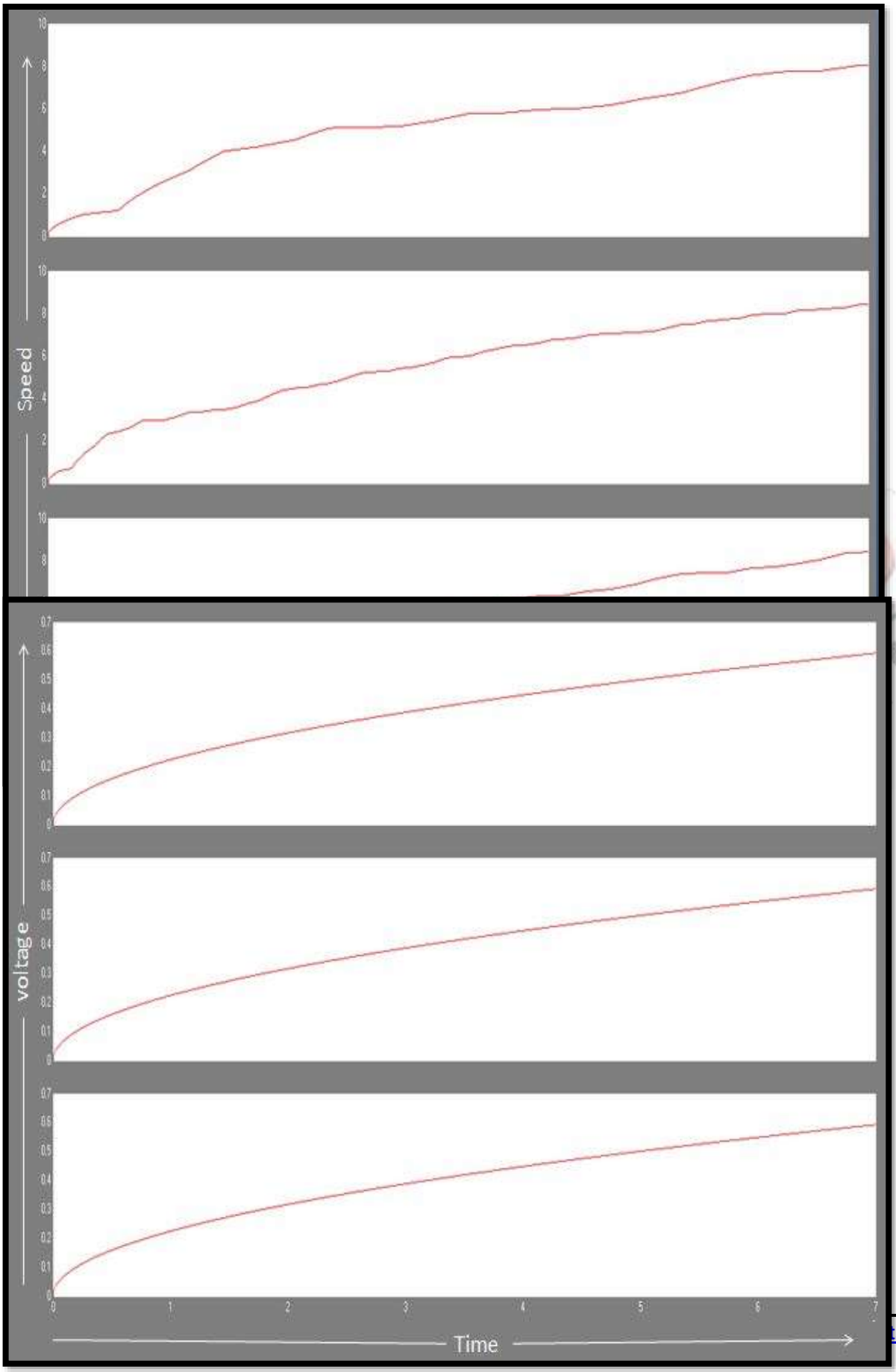


Fig shows the wind speed profile applied to wind turbine 1, wind turbine 2 and wind turbine 3. The wind speed across wind turbine generator in a range of 4 m/s to 12 m/s. mean value of wind speed across wind generator is 12m/s.

VOLTAGE AT ENERGY STORAGE SYSTEM

Voltage across energy storage system is shown in fig which indicate voltage between rotor side converter and grid side converter.

Fig Voltage at energy storage system

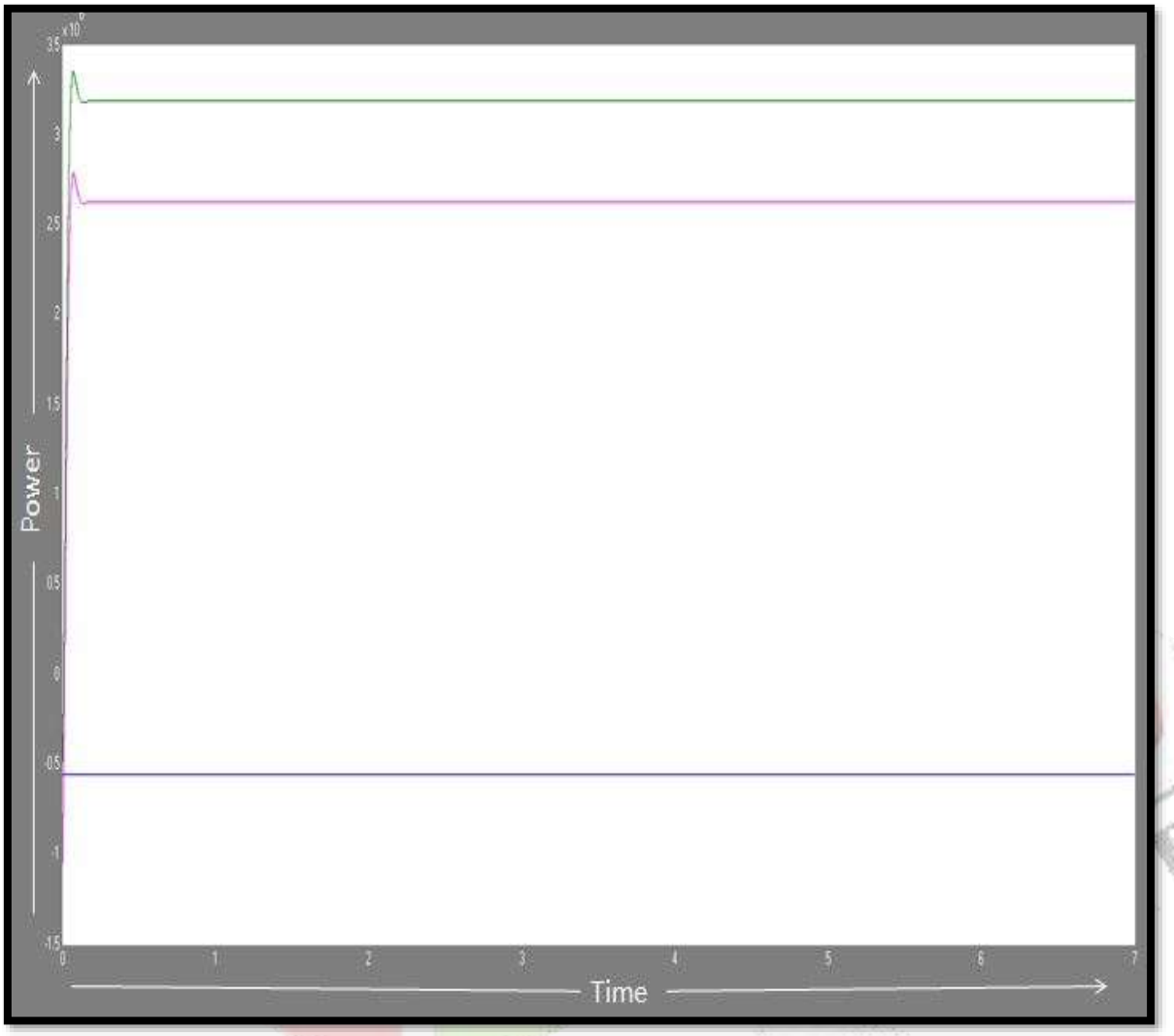


Fig 5.14: Wind Turbine 1 - active & reactive power, power at wind turbine, GSC power

DFIG for Controlling the Grid Parameters

In this section the proposed DFIG system has been integrated with crowbar protection-based control for fault ride through enhancement and controlling the output parameters of the Grid.

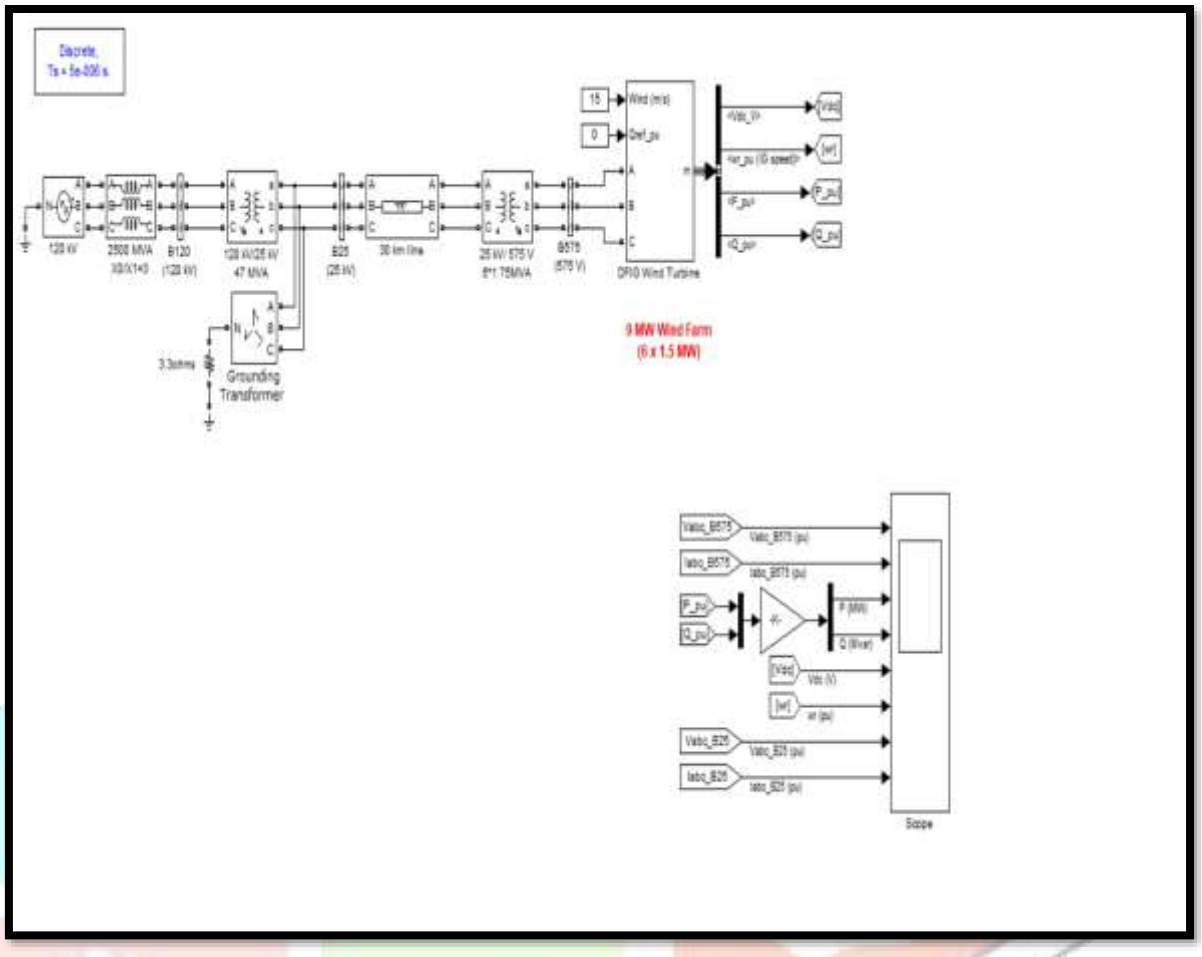


Fig DFIG Controlled System

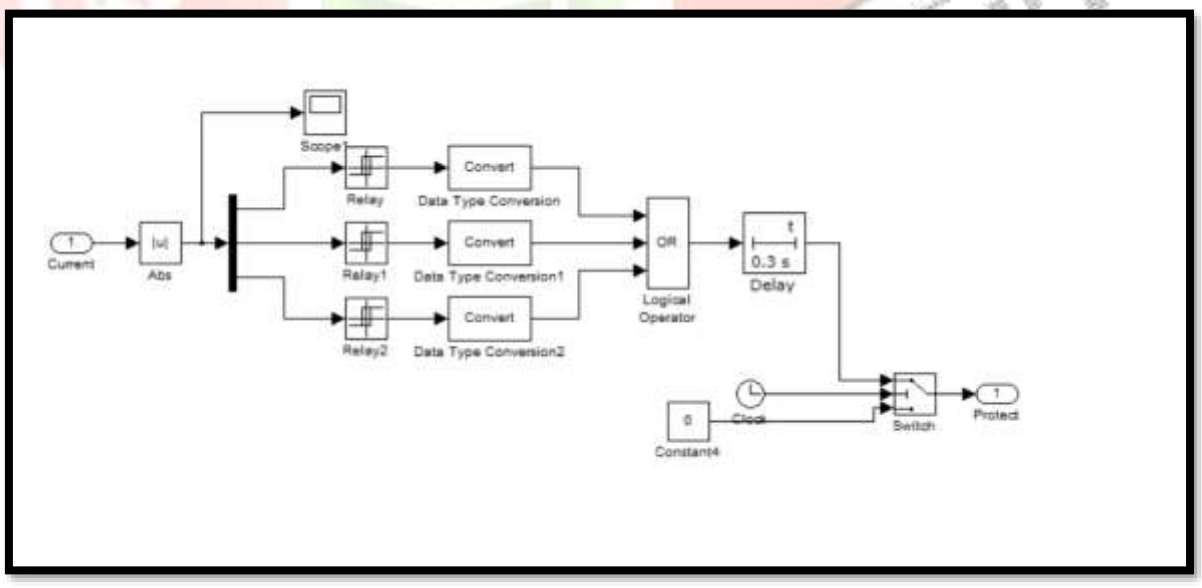


Fig Crowbar Protection subsystem for fault ride through

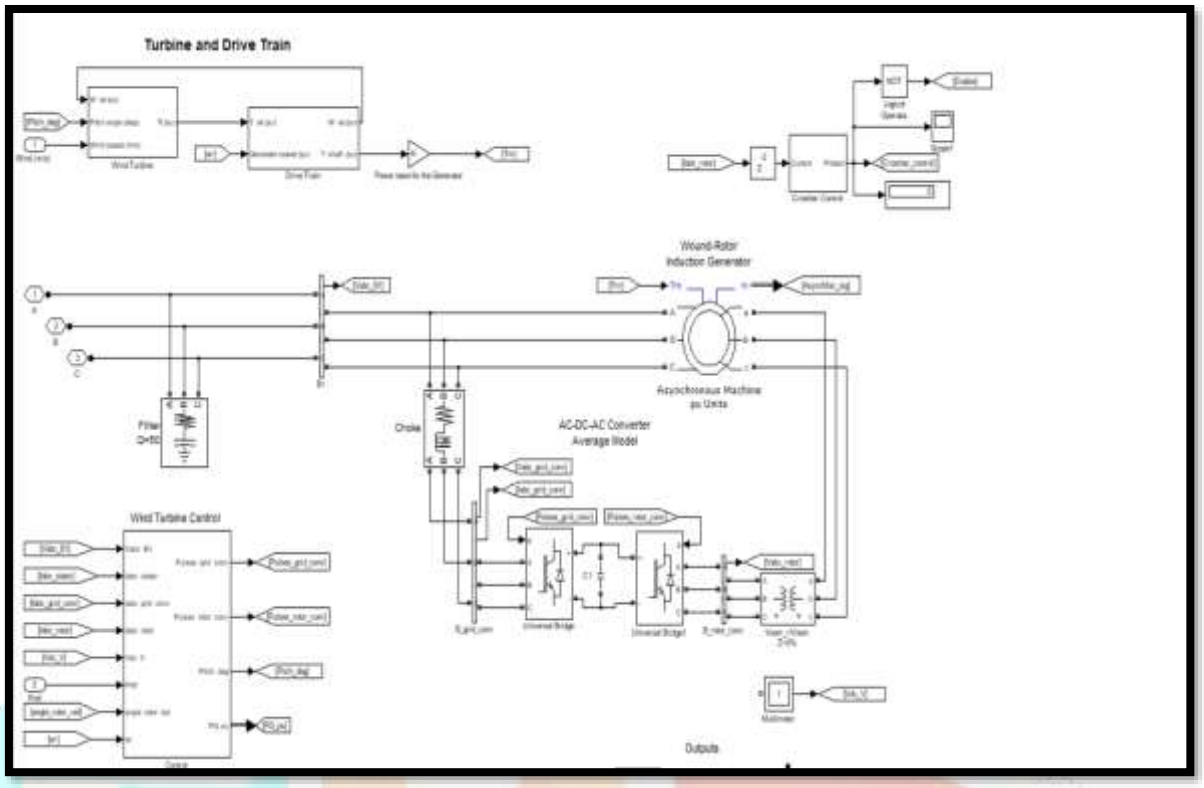


Fig DFIG integrated with Crowbar Protection

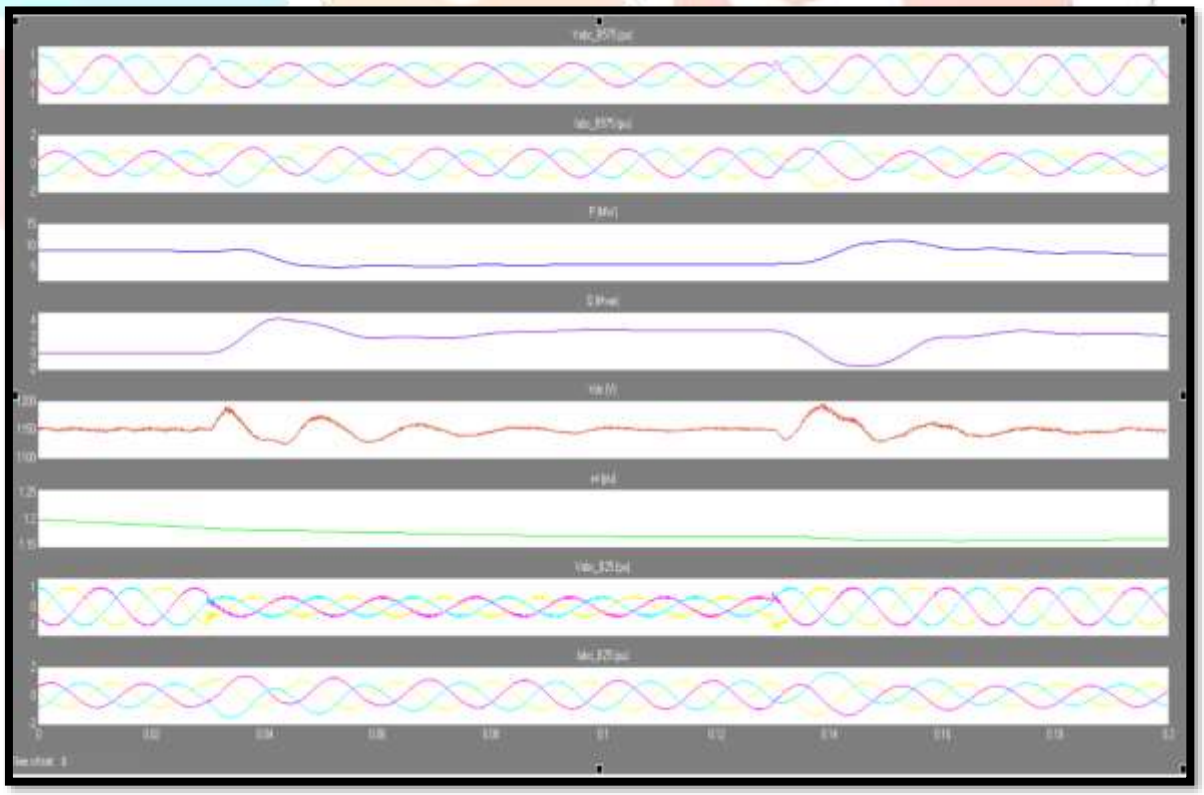


Fig Controlled output parameters (Voltage, Current, Active & Reactive Power)

Single machine Circuit of DFIG

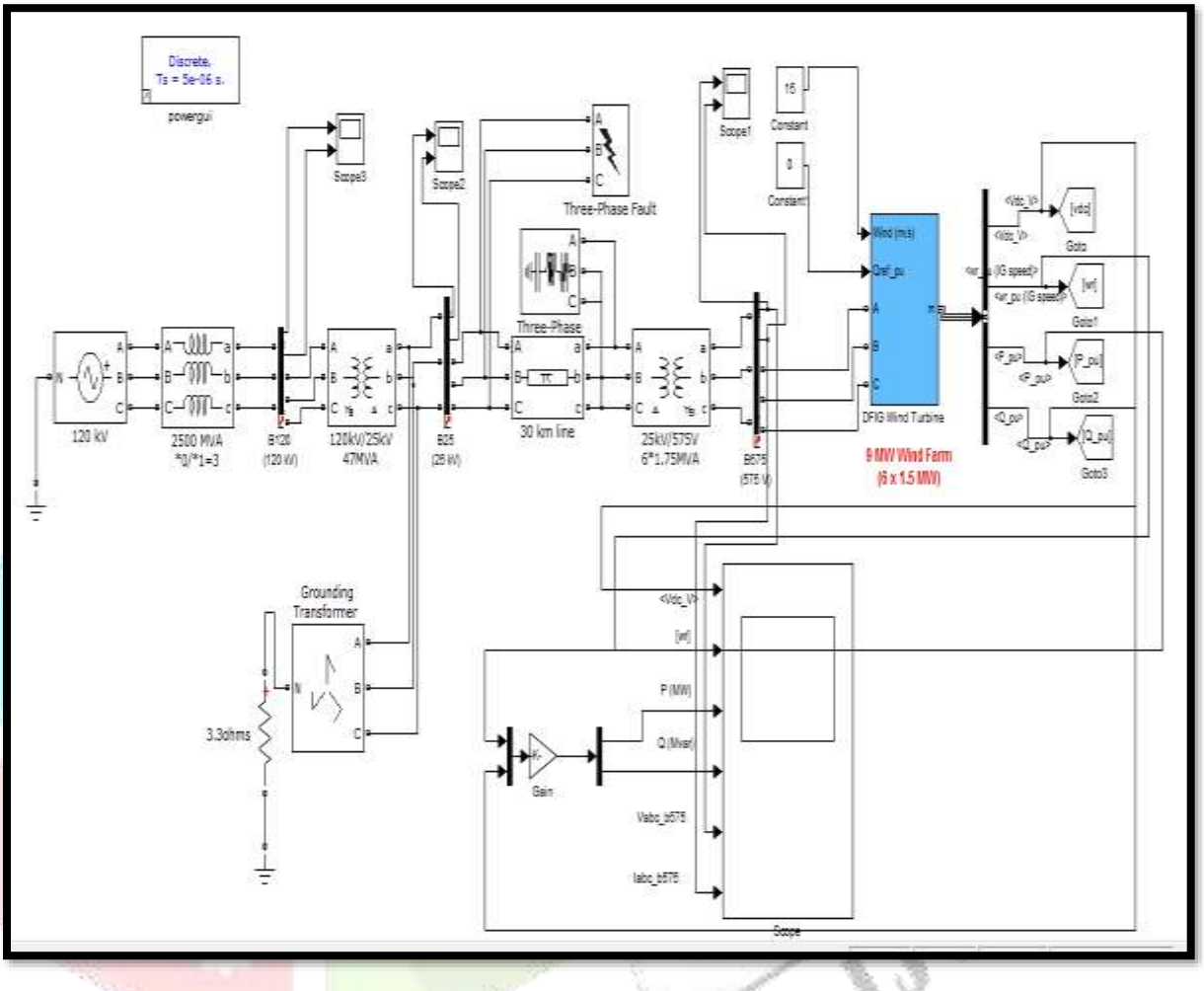


Fig Single Machine Circuit of DFIG

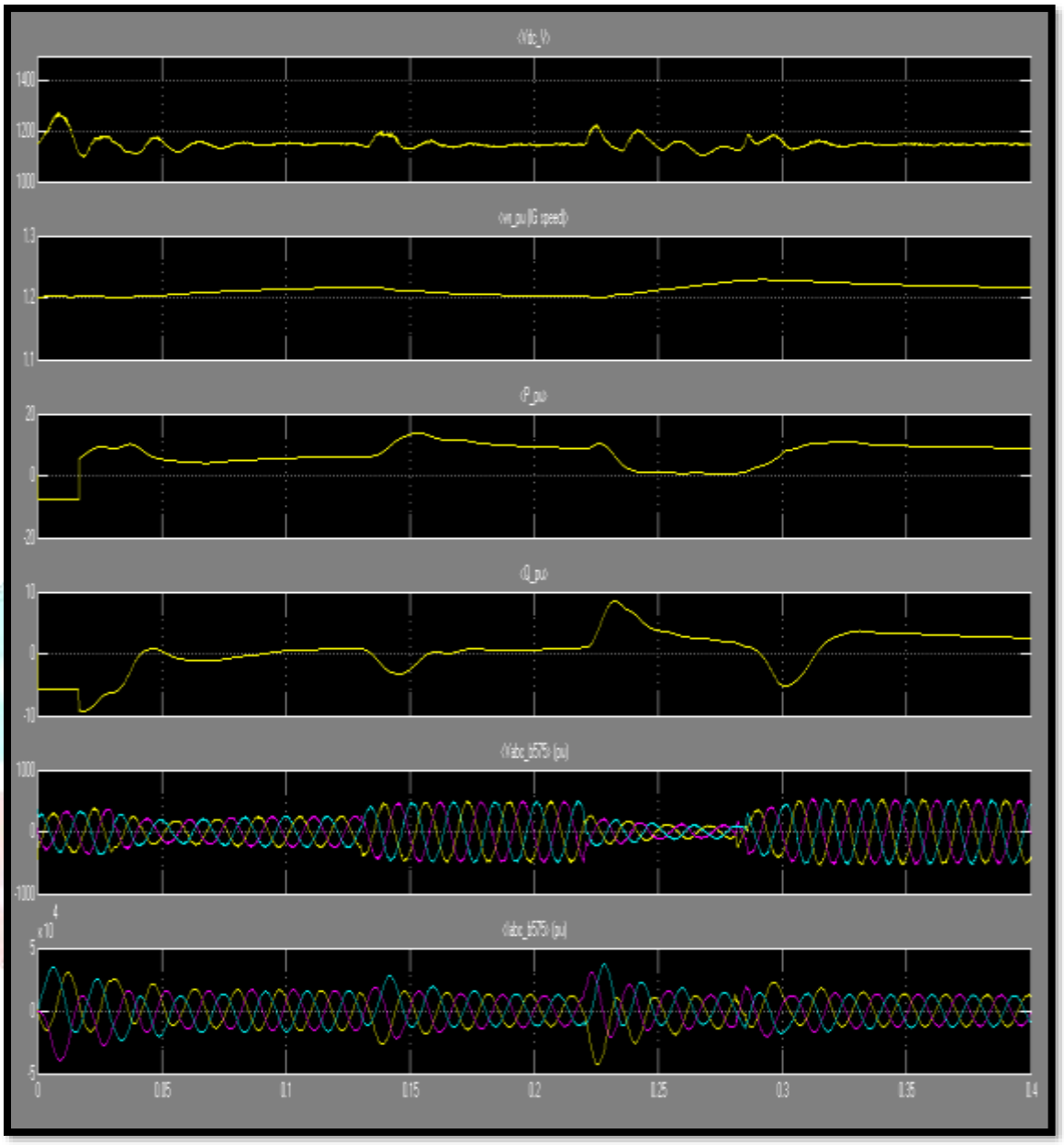


Fig Single Machine Circuit based DFIG output waveforms

3-machine 9-bus system

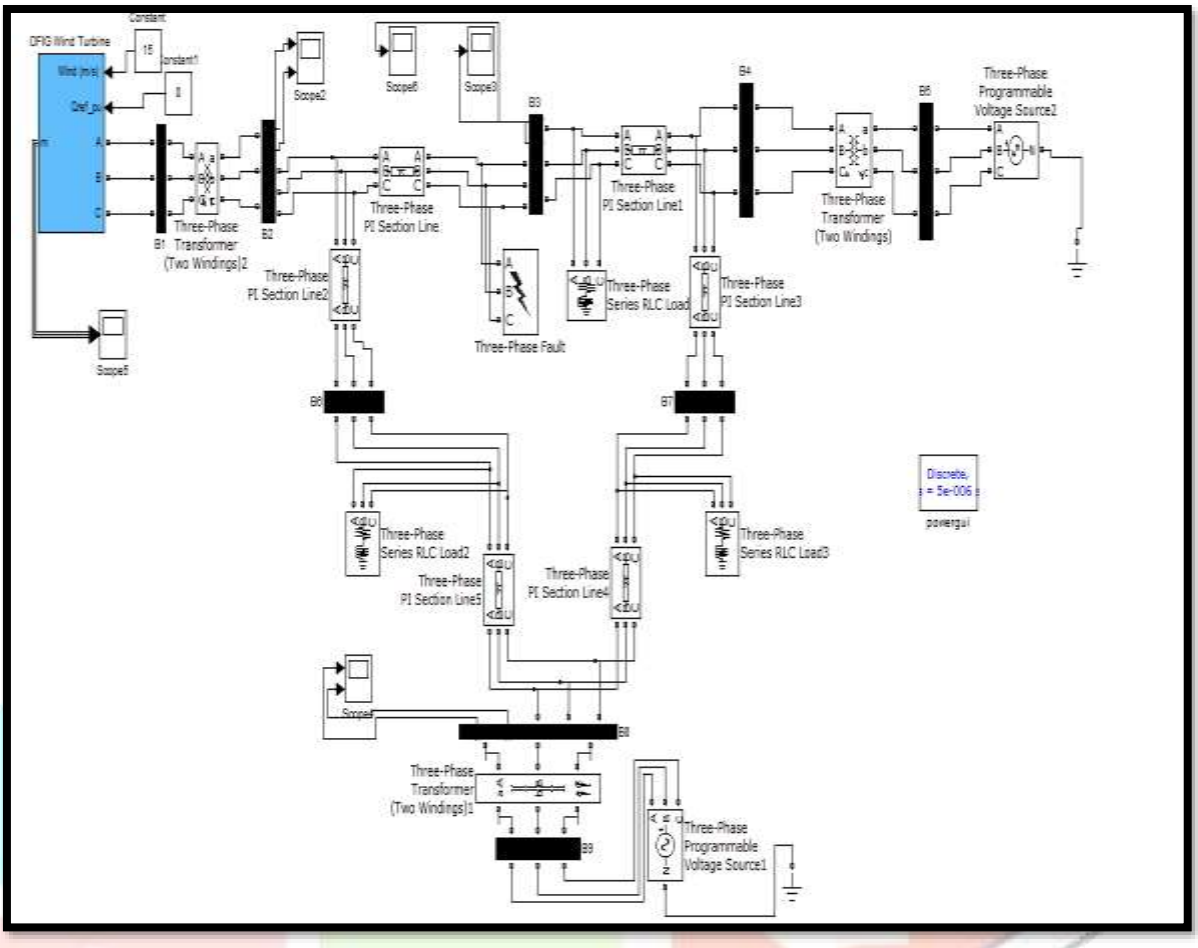


Fig 3-machine 9-bus system

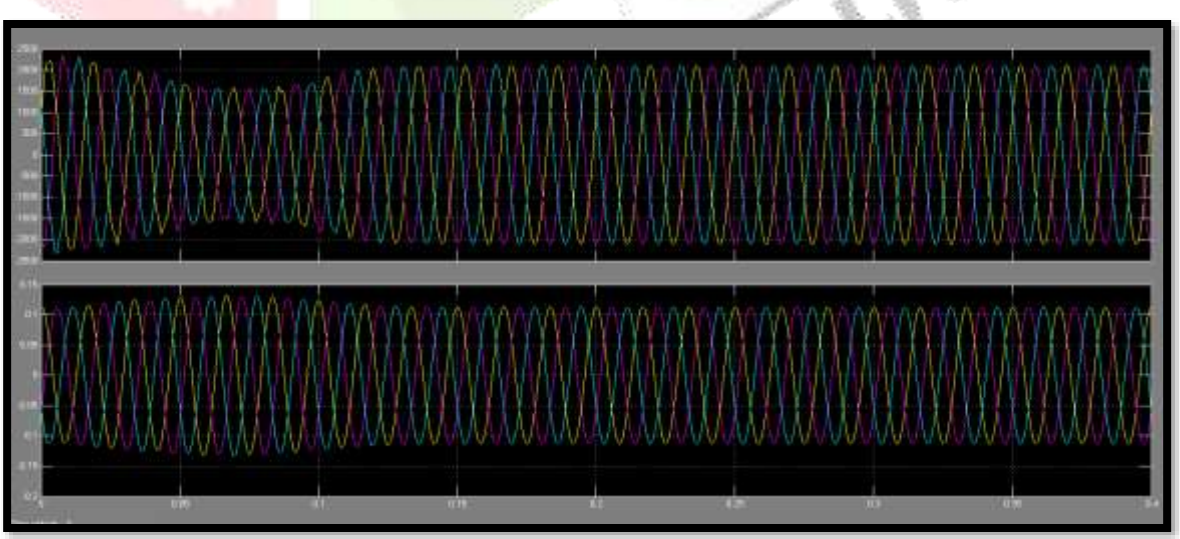


Fig Without fault condition waveform

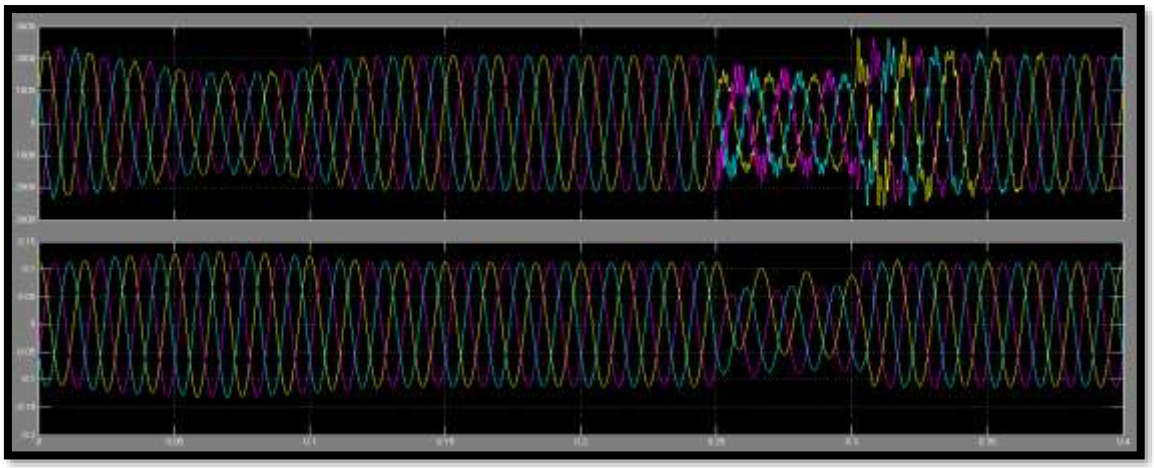


Fig With fault condition waveform

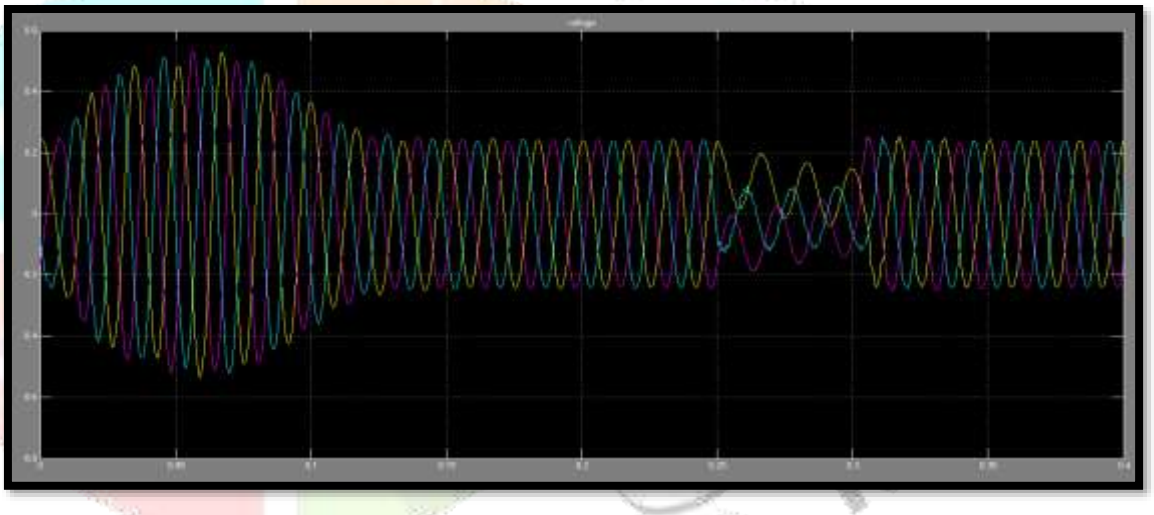


Fig Low voltage ride through waveform improvement in DFIG using Crowbar system

- If grid fault occurs at that time large voltage and current flow in the rotor circuit, which may damage the power electronic converters.
- The voltage recovery or voltage sag recover used many techniques.

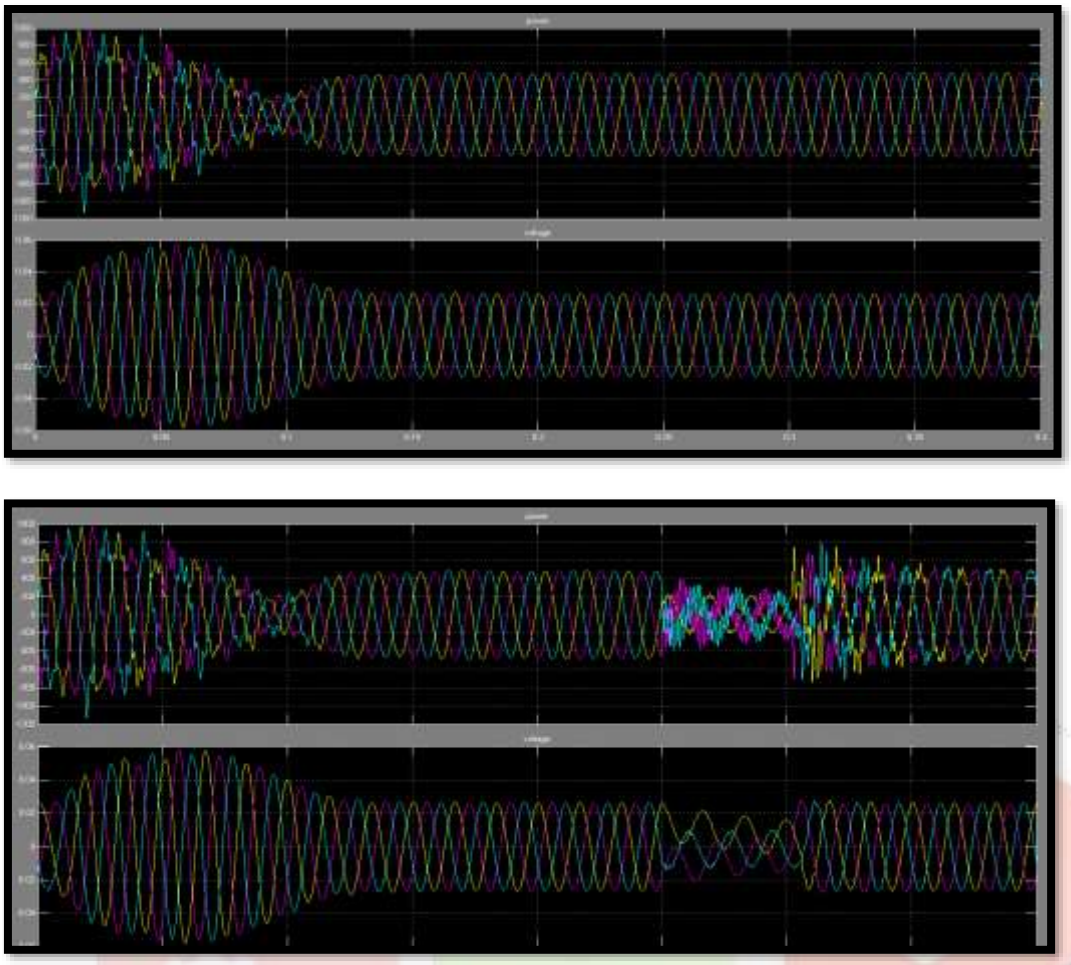


Fig Low voltage ride through waveform improvement in DFIG using Crowbar system

CONCLUSION

With the increasing penetration of wind power, it is necessary to participate of WTG in the grid power supply as well as supply active power for control power flow. We can see from some output of WTG without any control strategies, there are fluctuations in speed of rotor and output power. After applying the PLL control Strategy and rotor and grid side converter control, we can generate the constant output power at the DFIG generation side. The value of active and reactive power will become constant using DFIG control and the value of D.C voltage at converter control side also become constant.

REFERENCES

[1] Liyan Qu, Wei Qiao,“ Constant Power Control of DFIG Wind Turbines With Supercapacitor Energy Storage”, IEEE TRANSACTIONS ON INDUSTRY APPLICATION, volume:47 Issue:1 ©2011 IEEE.

[2] Marwa Ezzat, Mohamed Benbouzid, S.M. Muyeen and Lennart Harnefors, "Low-Voltage Ride-Through Techniques for DFIG-Based Wind Turbines:State-of-the-Art Review and Future

Trends'',IEEE Harnefors is with ABB, Corporate Research Västerås, Sweden.

[3] Zaijun Wu , Chanxia Zhu and Minqiang Hu

"Improved Control Strategy for DFIG Wind Turbines for Low Voltage Ride Through'', Energies 2013, 6,1181-1197; doi: 10.3390/en6031181, 25 February 2013.

[4] Mr. Subir Datta, Mr. Ksh. Robert Singh, Mr.

Subhasish Deb, "Enhancement of Fault Ride through Capability of Doubly Fed Induction Generator Based Wind Energy Conversion System",

International Journal of Advanced Information Science and Technology (IJAIST) ISSN: 2319:2682 Vol.28, No.28, August 2014.

[5] R. A. Ibrahim, M.S. Hamad, Y.G. Dessouky, B.W. Williams, "A Review on Recent Low Voltage Ride-Through Solutions of Wind Farm for Permanent

Magnet Synchronous Generator", International Journal of Electrical And Electronics Research ISSN 2348-6988 (online) Vol. 3, Issue 2, pp: (256-263), Month: April - June 2015.

[6] Himanshu Verma, Jaimala Gambhir, Sachin Goyal

"Energy Storage: A Review", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-3, Issue-1, and June 2013.

[7] Guohong Wu, Yutaka Yoshida, Tamotsu Minakawa, "Mitigation of Wind Power Fluctuation by Combined Use of Energy Storages with Different Response Characteristics", Science Direct ICSGCE 2011: 27–30 September 2011, Chengdu, China.

[8] A.H.M.A.Rahim, S.A. Al-Baiyat, "An Adaptive Neural Network Based Energy Storage Control for Operation Enhancement of a Multi-Generator AC and Wind Power System" Australian Journal of Basic and Applied Sciences, 7(6): 211-222, 2013 ISSN 1991-8178.