# SIMULATION AND ANALYSIS OF WIND POWER PLANT CONNECTED WITH STATCOM FOR FAULT ANALYSIS

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**Abstract**

***Injection of the wind power into an electric grid affects the power quality. The performance of the wind turbine and thereby power quality are determined based on measurements and the norms followed according to the guideline specified in International Electro-Technical Commission standard, IEC-61400. The influence of the wind turbine in the grid system concerning the power quality measurements are-the active power, reactive power, variation of voltage, flicker, harmonics, and electrical behaviour of switching operation and these are measured according to national/international guidelines.***

***The paper study demonstrates the power quality problem due to installation of wind turbine with the grid. In this proposed scheme STATIC Compensator (STATCOM) is connected to mitigate the power quality issues. The battery energy storage is integrated to sustain the real power source under fluctuating wind power. The STATCOM control scheme for the grid connected wind energy generation system for power quality improvement is simulated using MATLAB/SIMULINK in power system block set. The effectiveness of the proposed scheme relives the main supply source from the reactive power demand of the load and the induction generator. The development of the grid co-ordination rule and the scheme for improvement in power quality norms as per IEC-standard on the grid has been presented***

## Introduction

A rapid development of wind power generation has been seen in a global scale. As with increasing the size of wind turbines and wind farms, a large amount of wind power is injected to the power system. Due to random nature of wind energy a huge penetration of power may cause important problems and also affect the characteristics of the wind generators. The consolidation of wind energy into present existing power system creates technical challenges, which require consideration of stability, voltage regulation related power quality problems. The power quality problems can be seen in accordance to wind generation, transmission and distribution system, such as voltage sag, flickers, voltage swells, harmonics etc. Due to change in voltage, flicker and harmonics failure of devices like microprocessor-based controller, programmable logic controller (PLC), variable speed drives, light source flickering and screen occurs [1]. It also may cause to tripping of contactor, failure of protection device, sensitive equipments stoppage like computers, programmable logic control (PLC) system and may halt the process or even may damage of some sensitive equipments.

In transmission and distribution system power quality of supply is very importance measure to be considered. So, considering in wind generation system this power quality issues become so much important measure. As the technology developing in the power generation field the wind power generation developing very quickly. To reduce the disturbances produced by variation in wind flow [2], we use induction generator and connect it directly to the grid system.

**POWER QUALITY**

As per the standard directory of IEEE for electrical and electronics power Quality means "the concept of powering and grounding sensitive electronic equipment in a manner that is suitable to the operation of the equipment". It can also be described as the "the measure, analysis &improvement of bus voltage mostly load bus voltage, to maintain that voltage to be a sinusoidal at rated voltage and frequency"

The definition of perfect power quality can be given as the waveform of voltage is continuous and purely sinusoidal having a constant frequency and fixed amplitude. It can also be expressed in terms of electrical property and physical characteristics. The most often term to describe power quality is voltage, frequency and interruptions. The voltage quality must fulfil all the requirements specified in national and international standards. In such standards, the voltage disturbances are further classified into voltage variations, transients, flicker and harmonic distortion. Fig. 2.1 shows a classification of different power quality phenomena.

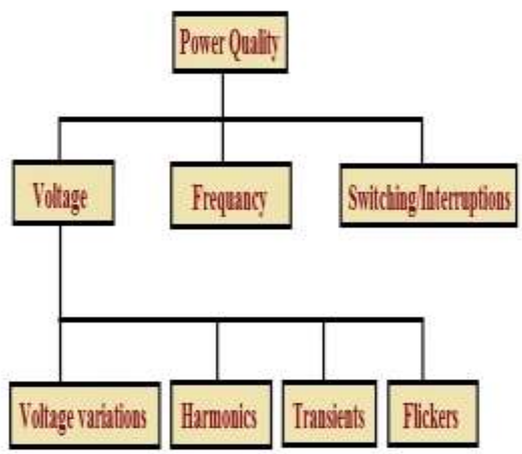


Fig. Power Quality Phenomena

The studies of power quality are important in wind turbine system as an individual unit of certain power level. The advancement in power electronic devices with fast switching makes a trend for reducing the size of power supply. The dark side of such fast switching device is that it produces current distortion. The rapid increase of these electronic controllers in our everyday life increases the distortion level into the line. So as harmonics current increases in the system with increased reactive power demand, this produces adverse effect on some of delectated devices. The increase load demand cannot just fulfil by increasing the power generation due to various adverse effect on environment, the increased fuel cost, etc. So that the rapid growth in power generation is not possible so the existing system burden increases and results in poor power quality.

**DOUBLE FED INDUCTION GENERATOR (DFIG):-**

DFIG is an abbreviation for Double Fed Induction Generator, a generating principle widely used in wind turbines. It is based on an induction generator with a multiphase wound rotor and a multiphase slip ring assembly with brushes for access to the rotor windings. It is possible to avoid the multiphase slip ring assembly (see brushless doubly-fed electric machines), but there are problems with efficiency, cost and size. A better alternative is a brushless wound-rotor doubly-fed electric machine.

**PRINCIPLE OF A DOUBLE FED INDUCTION GENERATOR CONNECTED TO A WIND TURBINE**

The principle of the DFIG is that rotor windings are connected to the grid via slip rings and back-to-back voltage source converter that controls both the rotor and the grid currents. Thus rotor frequency can freely differ from the grid frequency (50 or 60 Hz). By using the converter to control the rotor currents, it is possible to adjust the active and reactive power fed to the grid from the stator independently of the generator's turning speed. The control principle used is either the two-axis current vector control or direct torque control (DTC). DTC has turned out to have better stability than current vector control especially when high reactive currents are required from the generator.

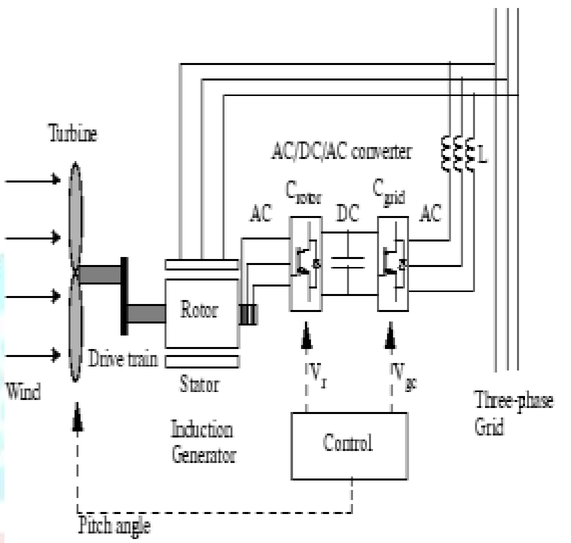


Fig-Operating Principle of the Wind Turbine Doubly-Fed Induction Generator

The doubly-fed generator rotors are typically wound with 2 to 3 times the number of turns of the stator. This means that the rotor voltages will be higher and currents respectively lower. Thus, in the typical ± 30 % operational speed range around the synchronous speed, the rated current of the converter is accordingly lower which leads to a lower cost of the converter. The drawback is that controlled operation outside the operational speed range is impossible because of the higher than rated rotor voltage.

Further, the voltage transients due to the grid disturbances (three- and two-phase voltage dips, especially) will also be magnified. In order to prevent high rotor voltages - and high currents resulting from these voltages - from destroying the IGBTs and diodes of the converter, a protection circuit (called crowbar) is used.

The crowbar will short-circuit the rotor windings through a small resistance when excessive currents or voltages are detected. In order to be able to continue the operation as quickly as possible an active crowbar has to be used. The active crowbar can remove the rotor short in a controlled way and thus the rotor side converter can be started only after 20-60 ms from the start of the grid disturbance. Thus, it is possible to generate reactive current to the grid during the rest of the voltage dip and in this way help the grid to recover from the fault.

## SIMULATION AND RESULTS

### Introduction

The proposed system in this paper work contains a wind generating system combined with the transmission line and the source for proper grid integration. The 3-phase system proposed is integrated with the load and the circuit breaker for protection purpose also. The output voltage, current results shown in the below sections.

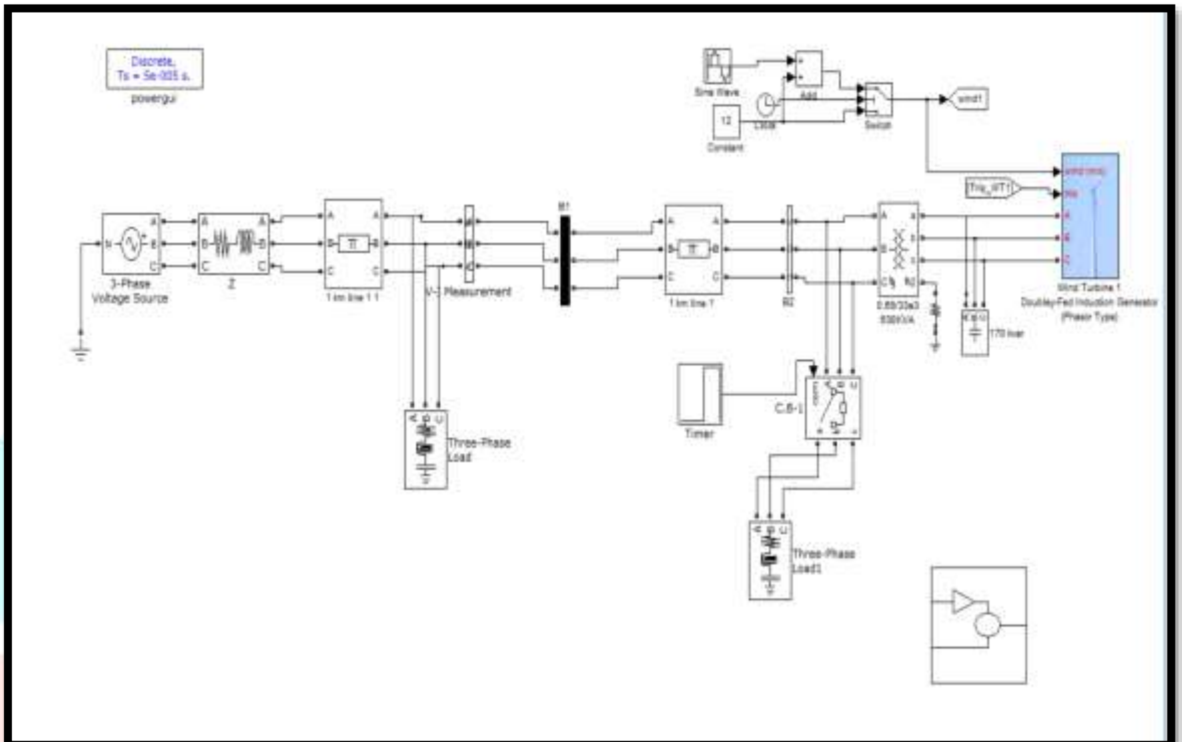

**Figure Single DFIG based Wind Power Plant**

**System Parameters**

DFIG Voltage: - 3-phase, 690 V, 60 Hz
Pitch angle: - 45 degree, Kp = 5, Ki = 25

Wind Based speed: - 9 m/s
1 km Transmission Line Data: - Resistance - 0.1115 Ohm/km (R1)
0.413 Ohm/km (R0)
Inductance- 1.05e-3 H/km (L1)
3.2e-3 H/km (L0)
Capacitance- 11.33e-009 F/km (C1)
5.01e-009 F/km (C0)

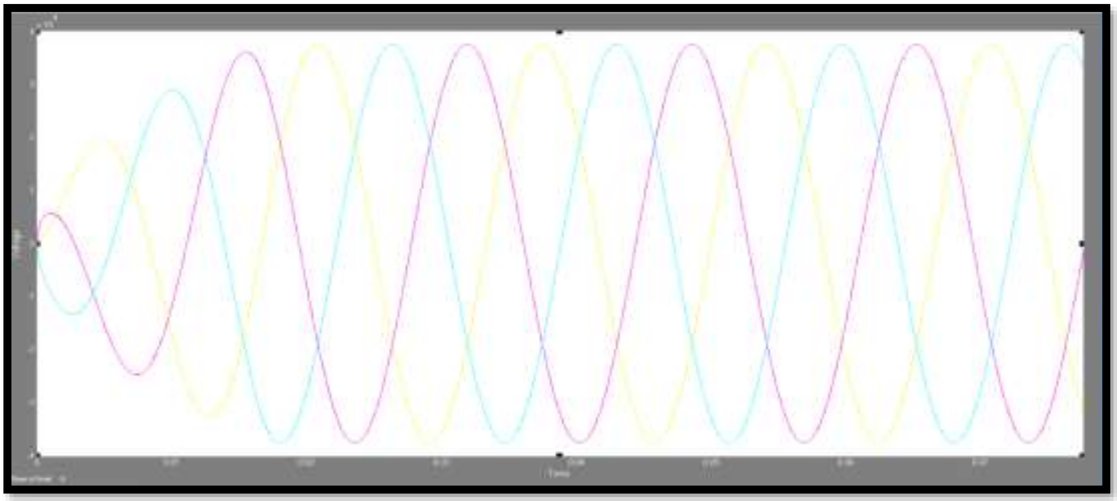

**Figure Voltage at Bus-1 in wind Power Plant**

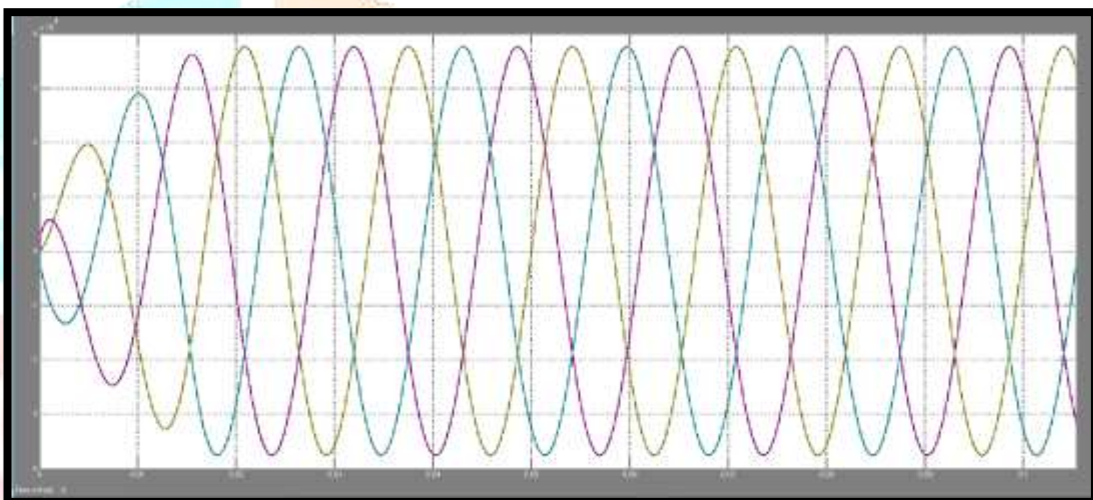

**Figure Voltage fluctuation at Bus-2 in wind Power Plant**

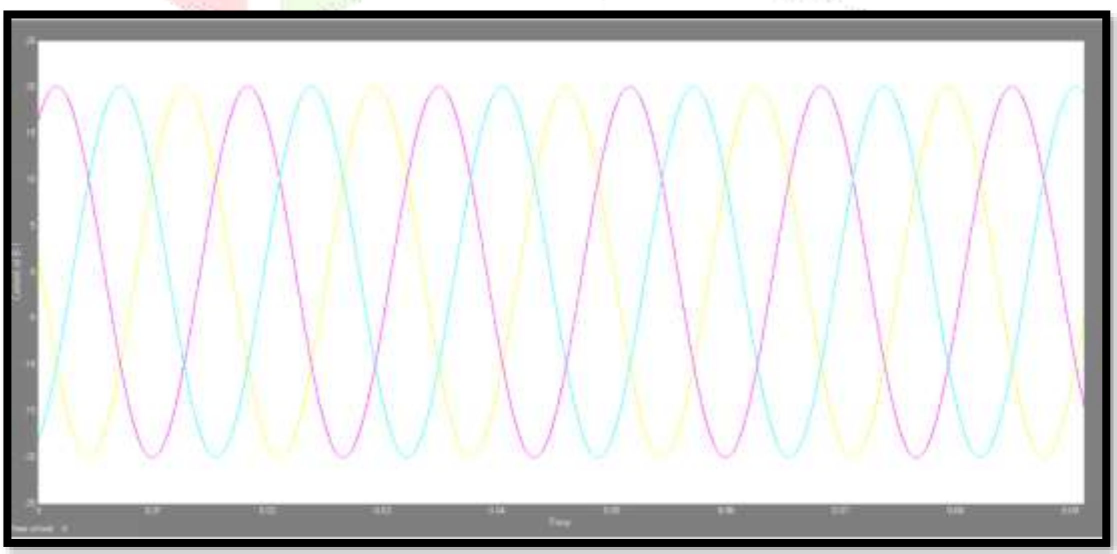

**Figure Current at B-1**

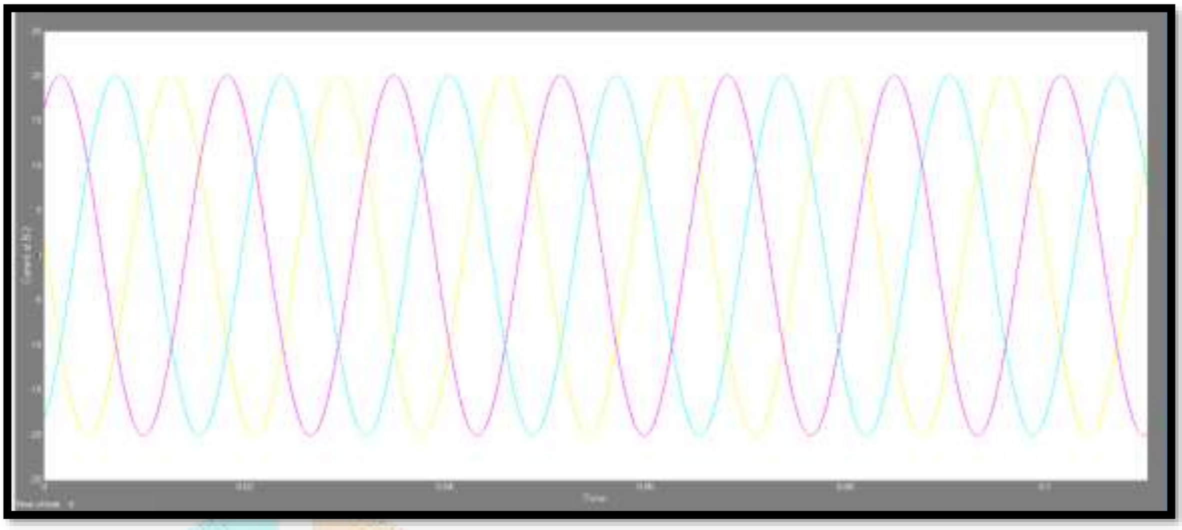

**Figure Current at B-2**

*Proposed System with fault condition*

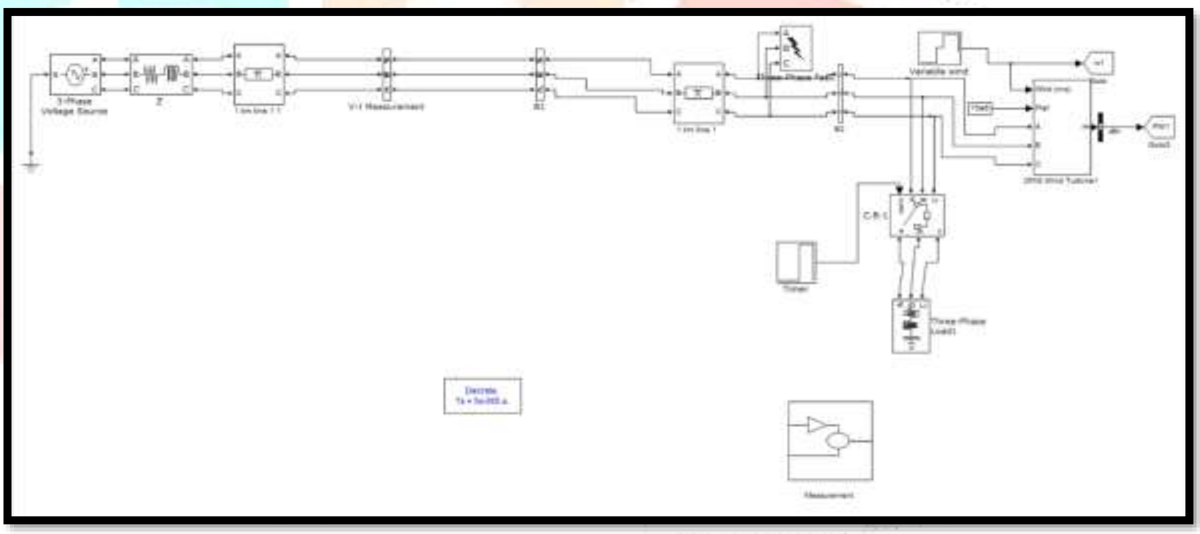

**Figure Proposed Matlab model with fault condition**

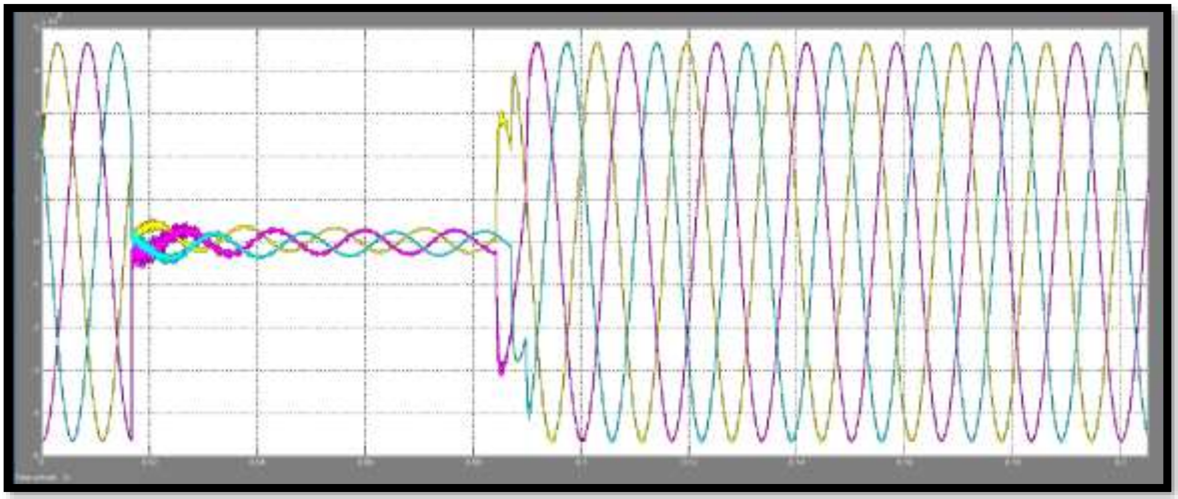

**Figure Voltage at B-1 during fault condition**

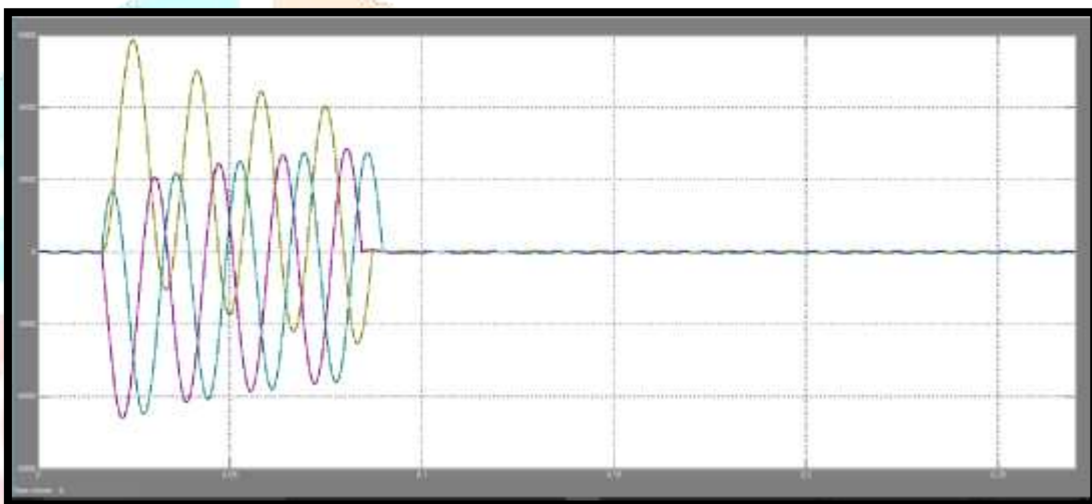

**Figure Current at B-1 during fault condition**

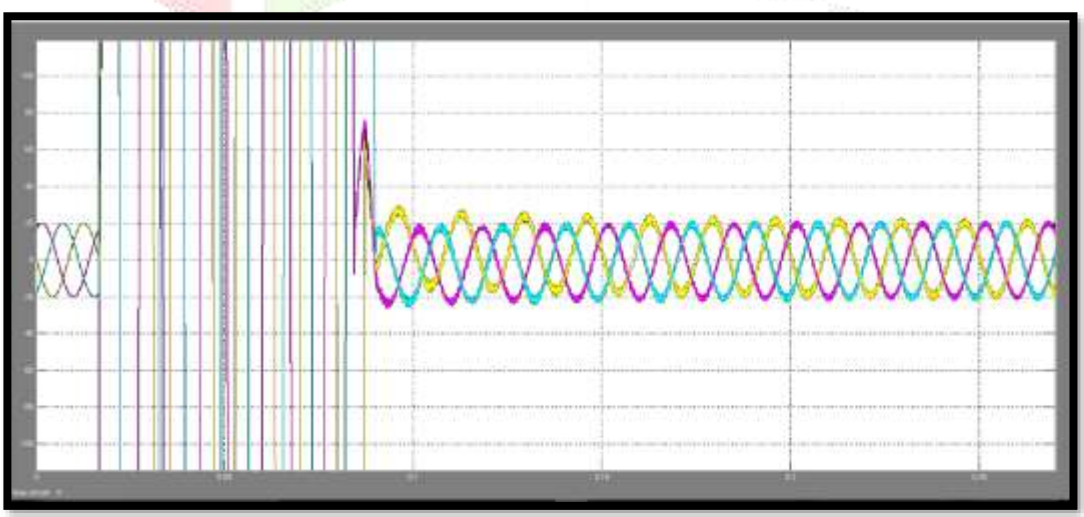

**Figure Current at B-1 during fault condition with Zoom Scale**

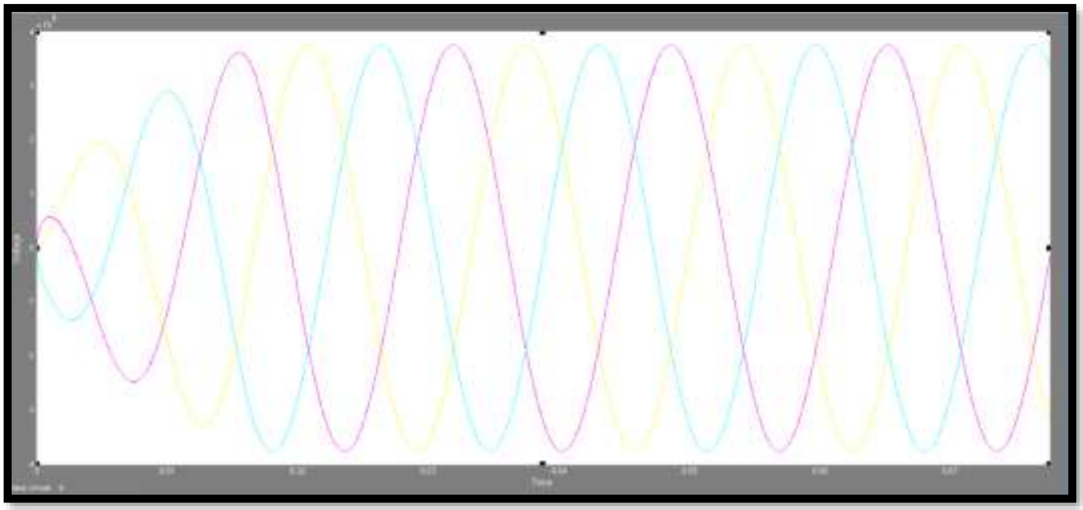

**Figure Voltage at B-2 during fault condition**

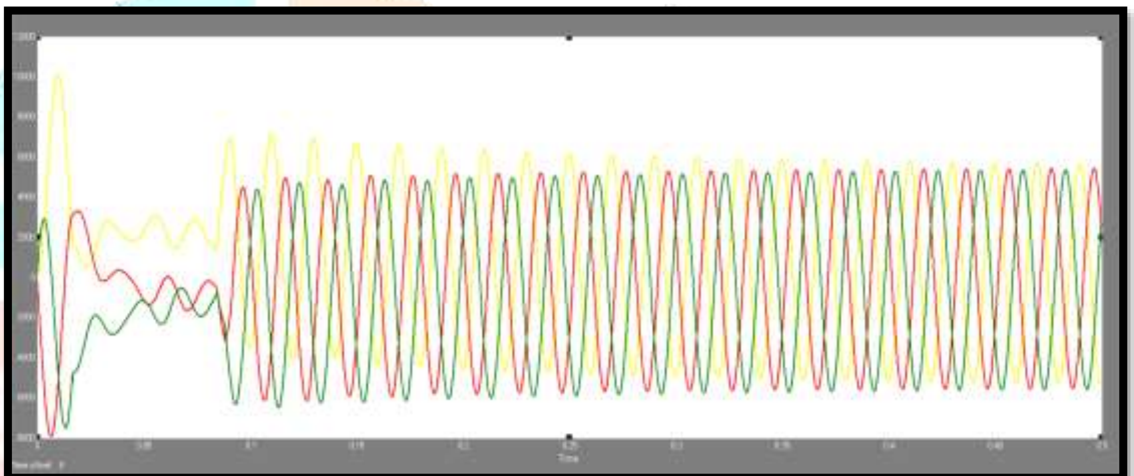

**Figure Current at B-2 during fault condition**

*DFIG Modelling and Control: -*

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.

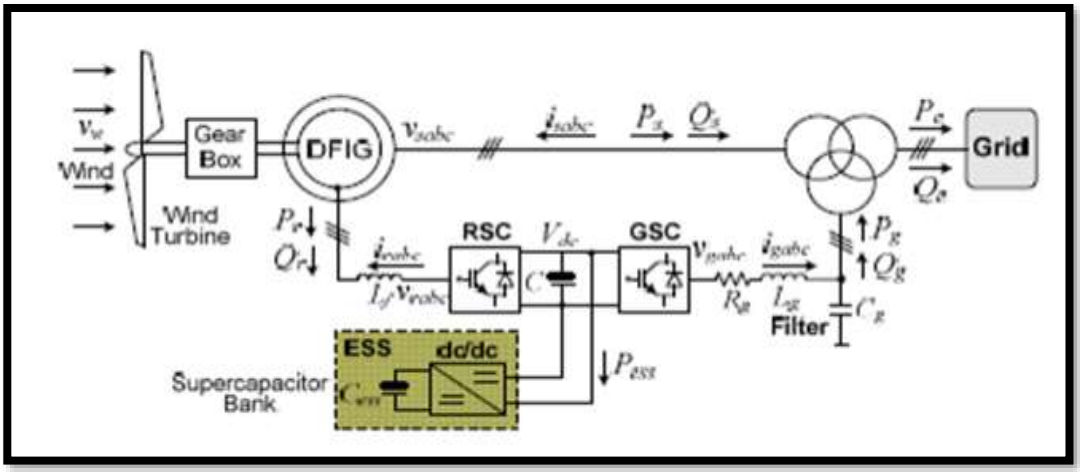


**Figure DFIG wind turbine with ESS**

*SIMULATION WITH DFIG CONTROL STATEGIES*

**TURBINE AND DRIVE TRAIN**

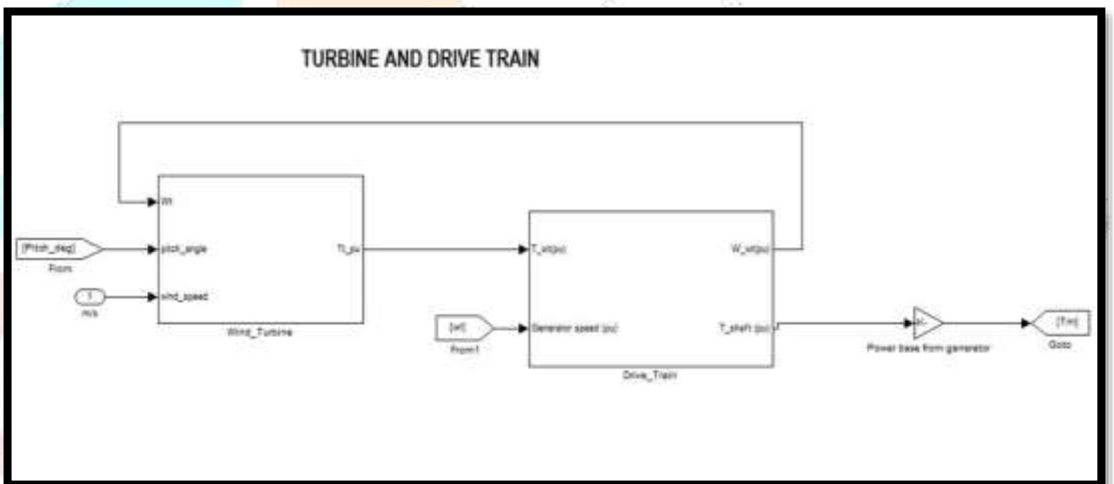


**Figure MATLAB block of turbine and drive train**

**WIND TURBINE**

In turbine and drive train system as input wind speed and pitch degree are taken. Wind speed is rotate turbine. This wind speed is saturated to bound turbine speed. This speed is multiplied with generator feedback speed. Feedback signal is used to check wind speed and to improve wind speed. Ratios of both speeds are taken and multiply with constant K1. If wind speed is not sufficient to rotate, then by adding K1 gain we can improve wind speed. This wind speed is multiplied with pitch angle to produce pitch angle constant Cp.  This pitch angle constant multiplies with wind speed and constant K2. This value is now comparing with nominal mechanical output power $P_{rated}$.

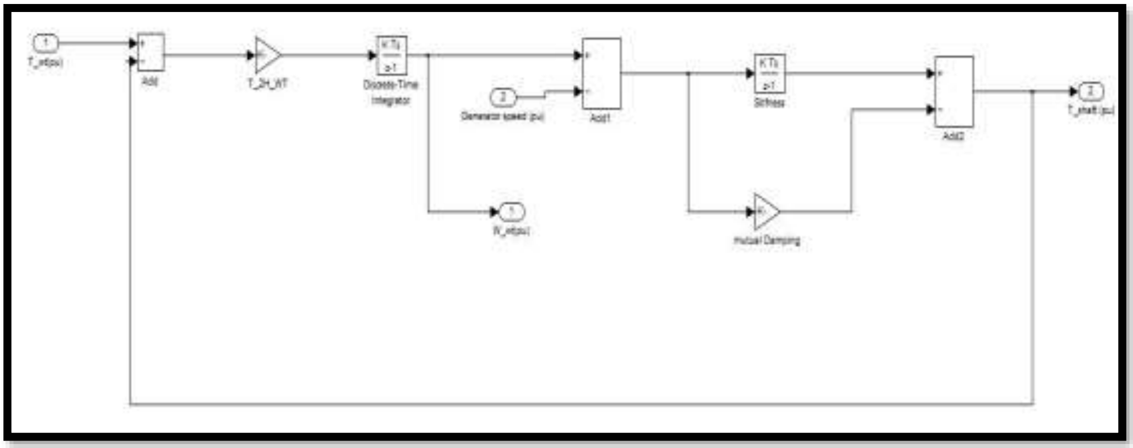


**Figure Block diagram of wind turbine**

If this mechanical power is not sufficient to generate enough torque to rotate turbine then gain is added. This output power is divided by turbine speed and torque is produce.

**DRIVE TRAIN**

This torque which is generated by wind is given to the turbine. This torque is compare with shaft speed to adjust torque. If this torque is not sufficient to rotate turbine then gain is added. Now this torque is given to the turbine to rotate turbine

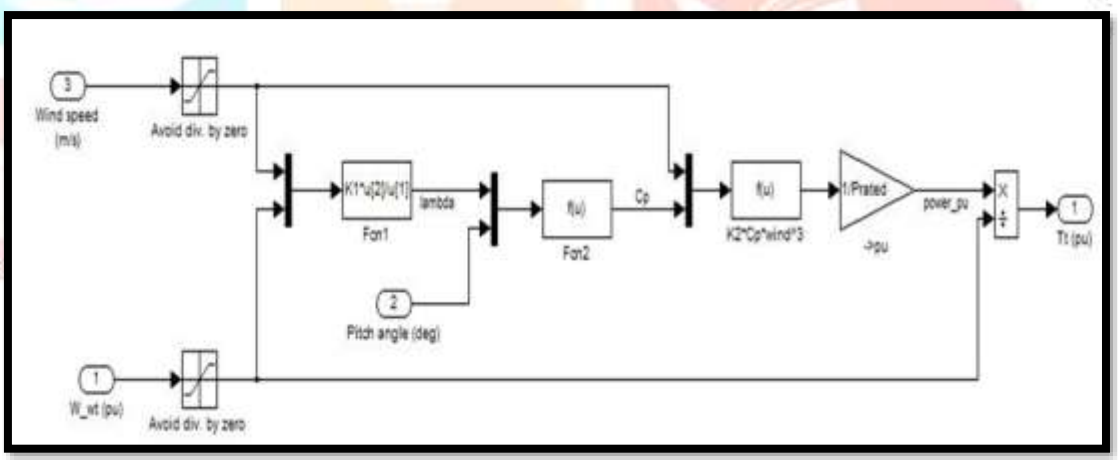


**Figure Block diagram of drive train**

This turbine speed is now comparing with generator rated speed. If turbine speed is not sufficient to rotate generator then generator speed is added. Between turbine and generator shaft is connected. Turbine produces shaft torque. If this torque is not sufficient to rotate shaft, then it is trying to produce own torque by adding gain. If it’s not able to generate own torque, then mutual damping gain is given to the shaft torque. This shaft torque or mechanical power is compare with power nominal if it is not sufficient to produce power to rotate generator then gain is added. This mechanical power output is given to the asynchronous generator. Asynchronous generator is generating power.

*STATCOM Integration with DFIG and Wind Power Plant*

In the below section the STATCOM device has been integrated with proposed wind power plant and DFIG system and the voltage profile improvement and the power control also shown in the simulation results.

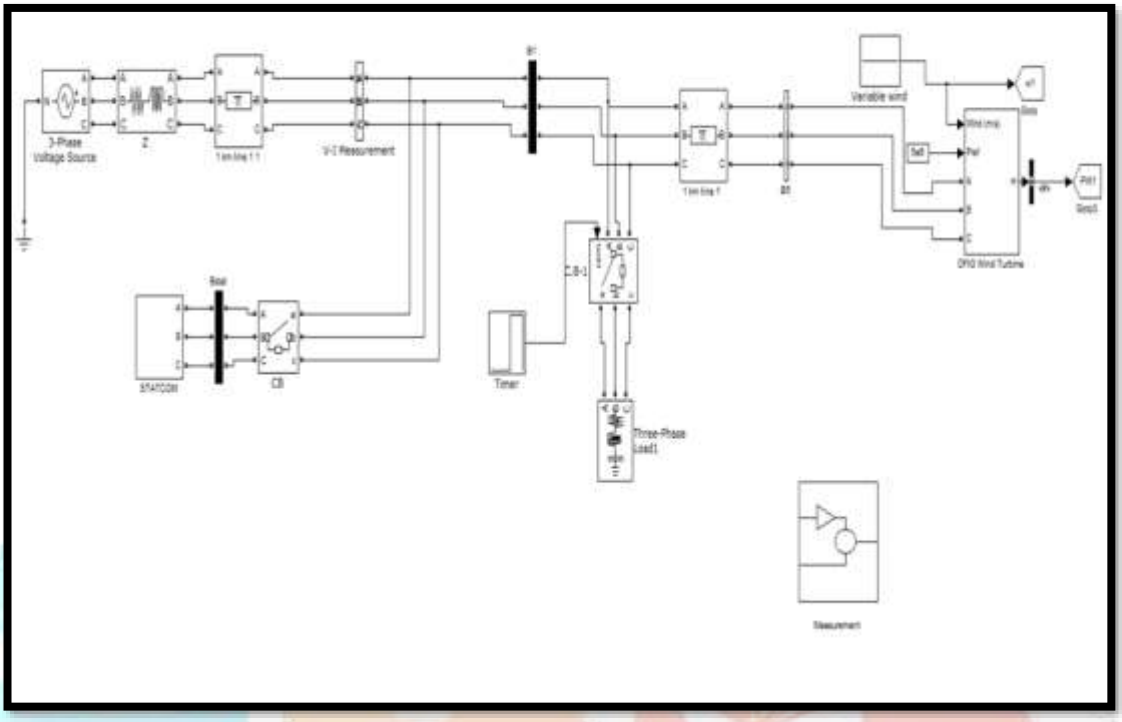


**Figure Proposed system integrated with STATCOM**

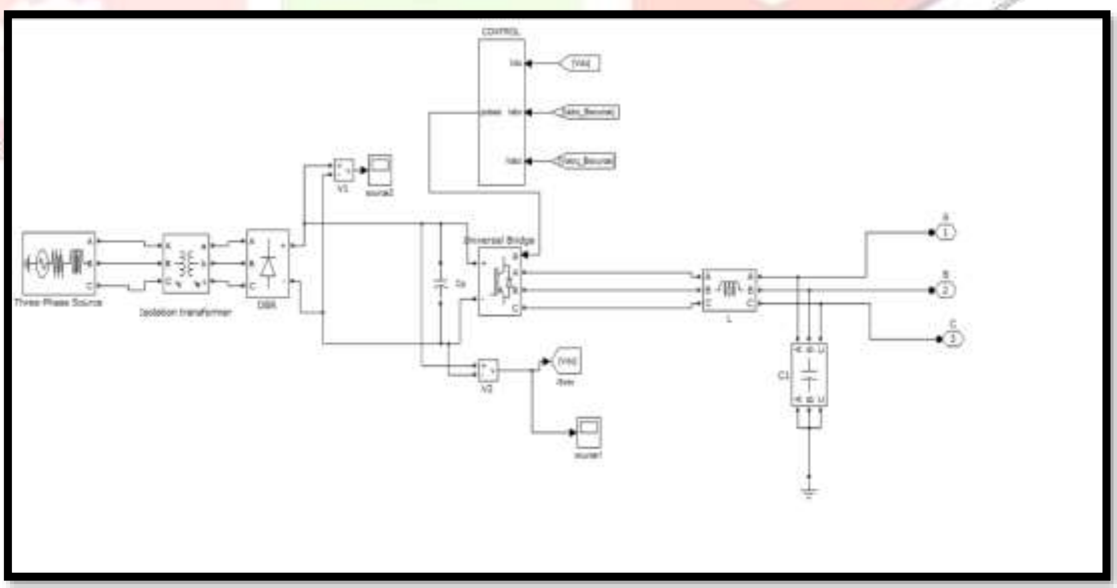

**Figure STATCOM Subsystem**

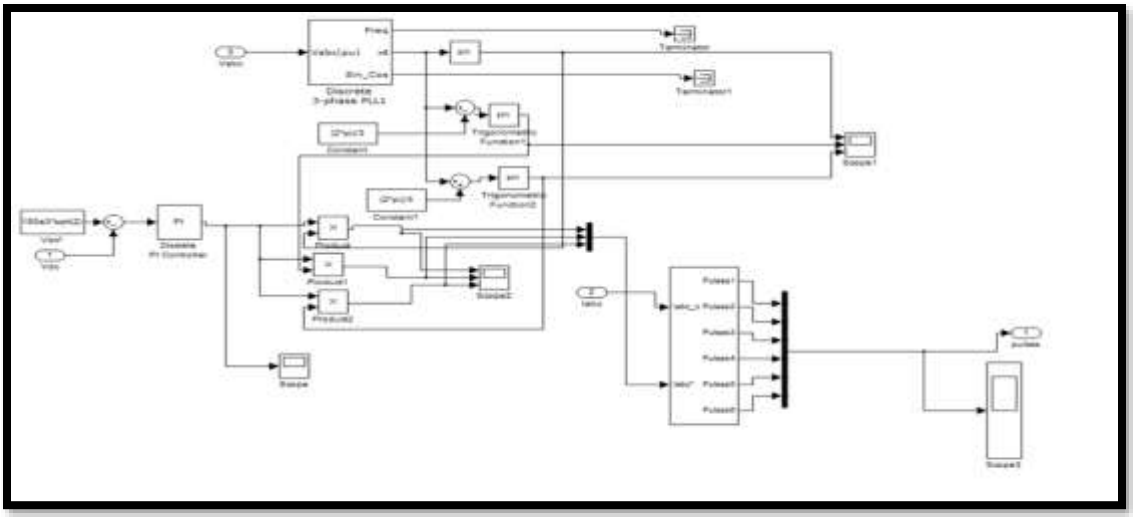

**Figure STATCOM Controlling**

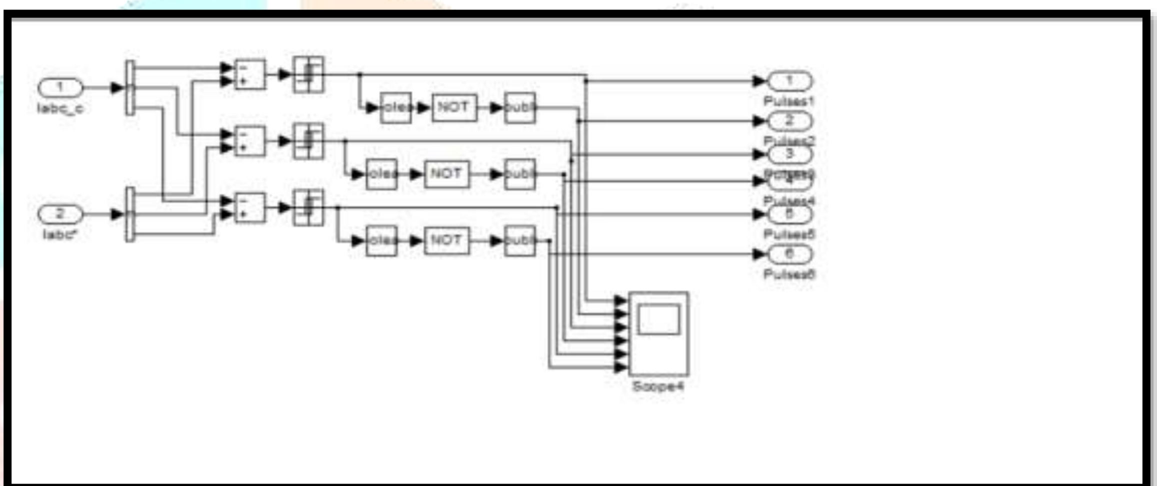


**Figure Hysteresis controller subsystem**

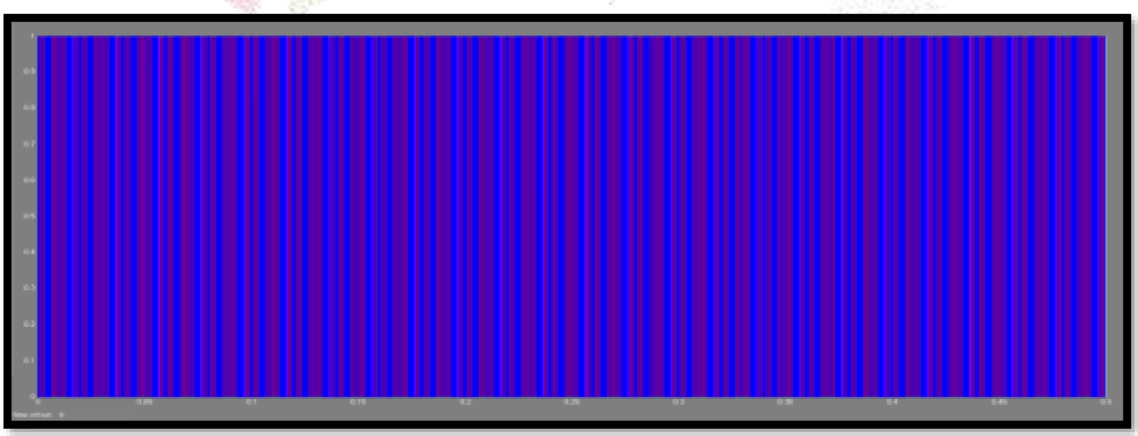

**Figure STATCOM Pulses**

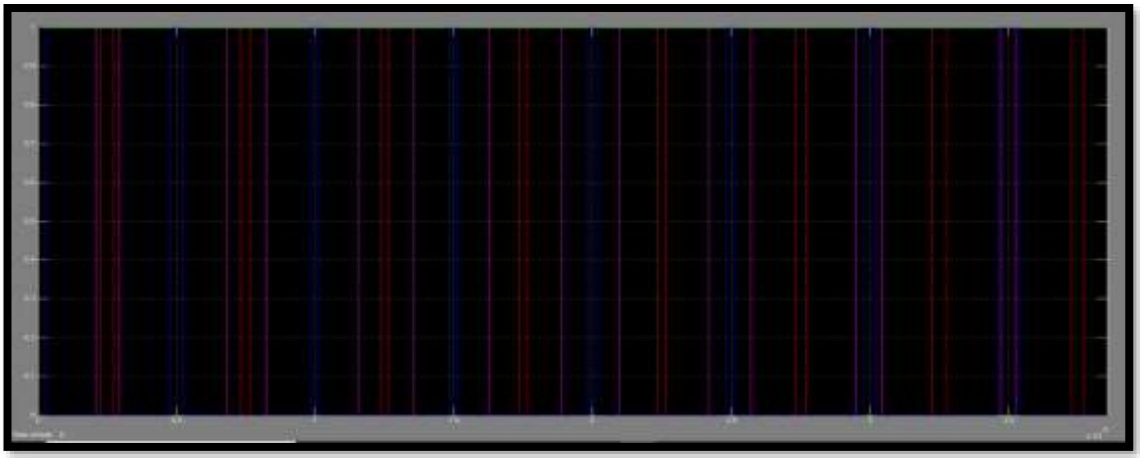

**Figure STATCOM Pulses (Zoom)**

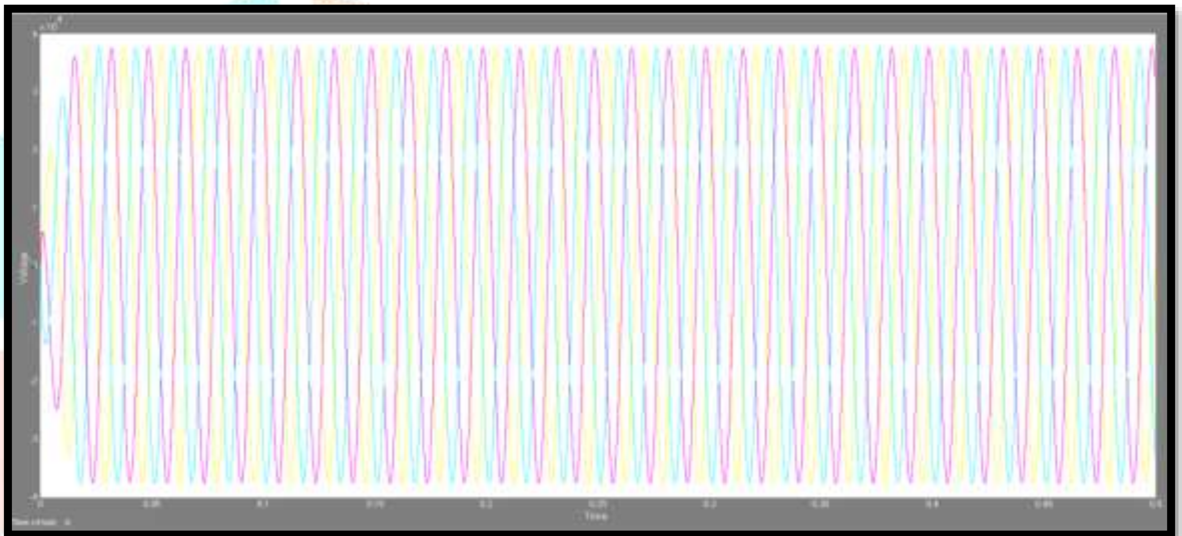

**Figure Voltage improvement after STATCOM integration**

*DFIG and STATCOM integrated during fault conditions*

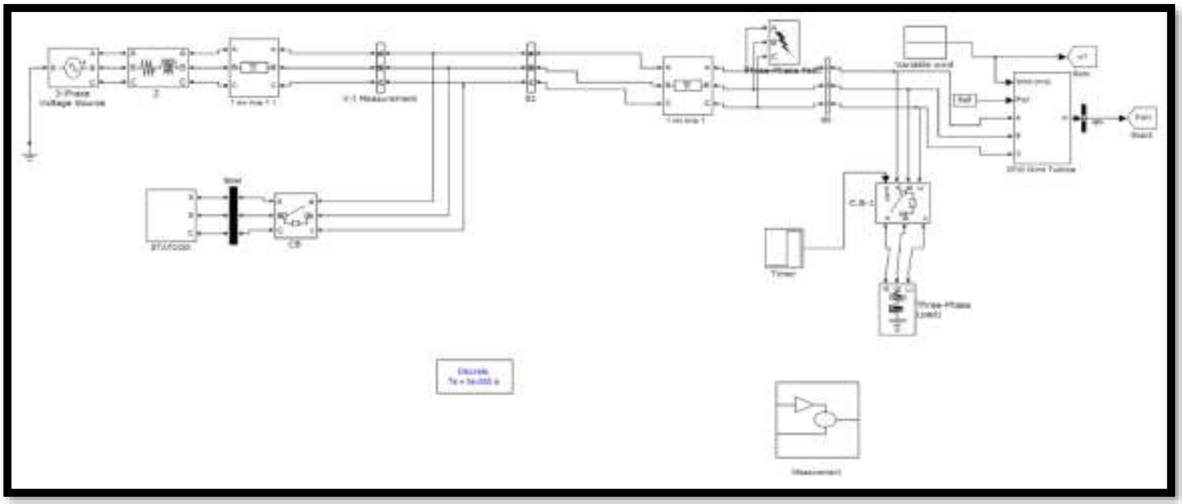

**Fig Fault condition in proposed system in DFIG and STATCOM**

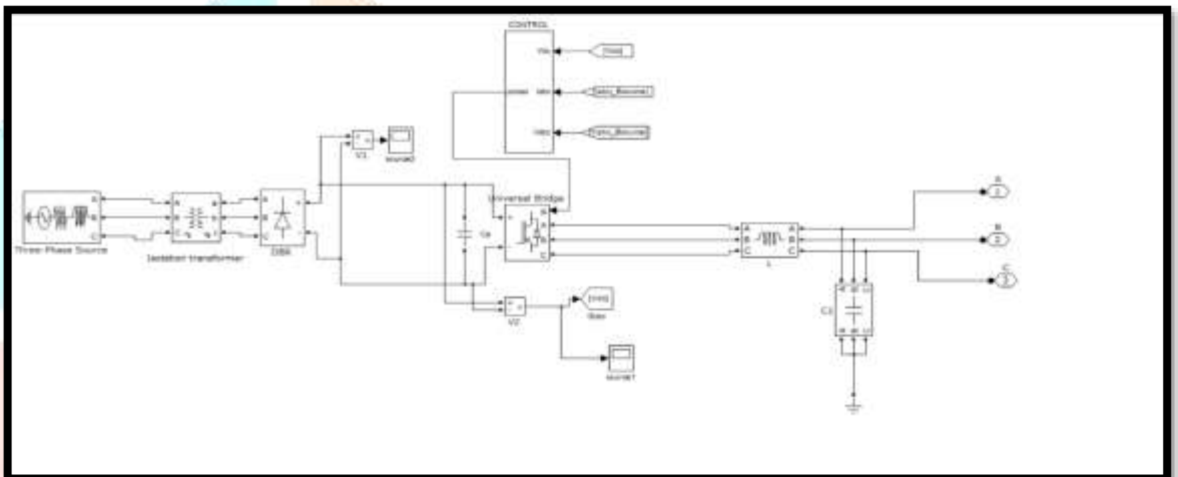

**Fig STATCOM Subsystem**

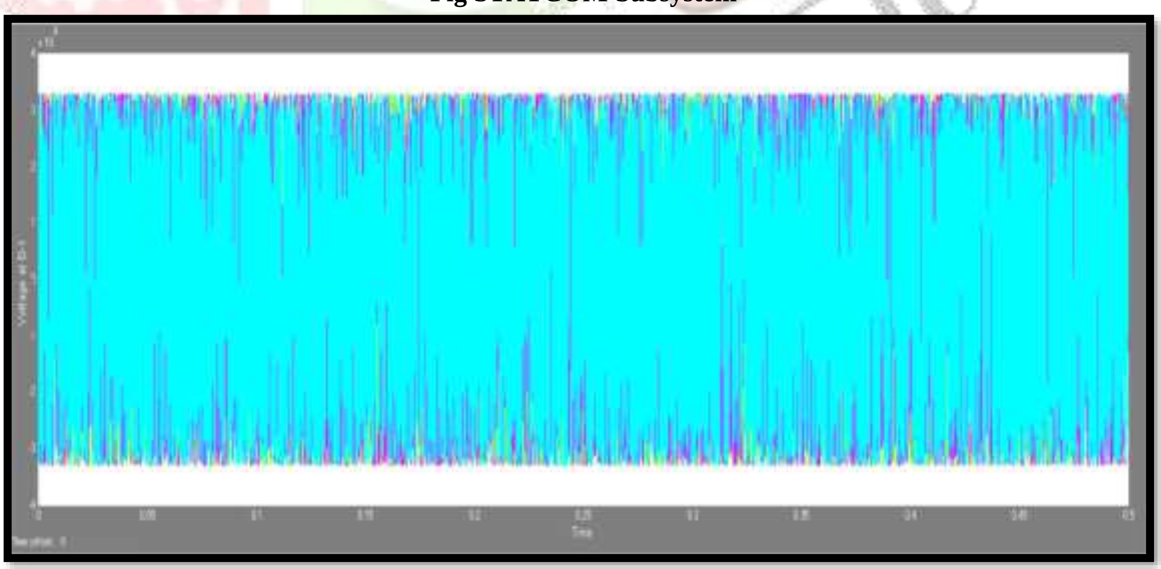

**Fig Voltage at Bus-1**

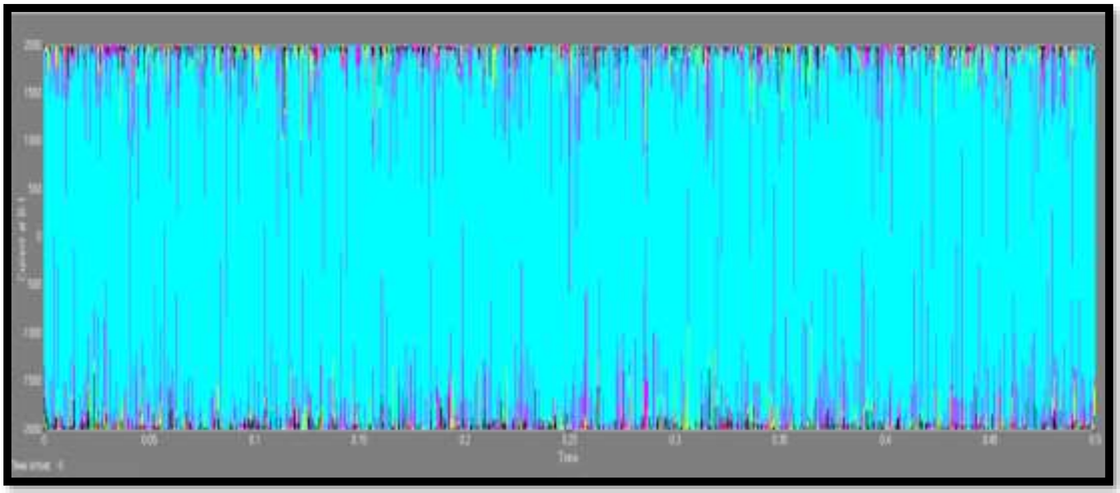

**Fig Current at Bus-1**

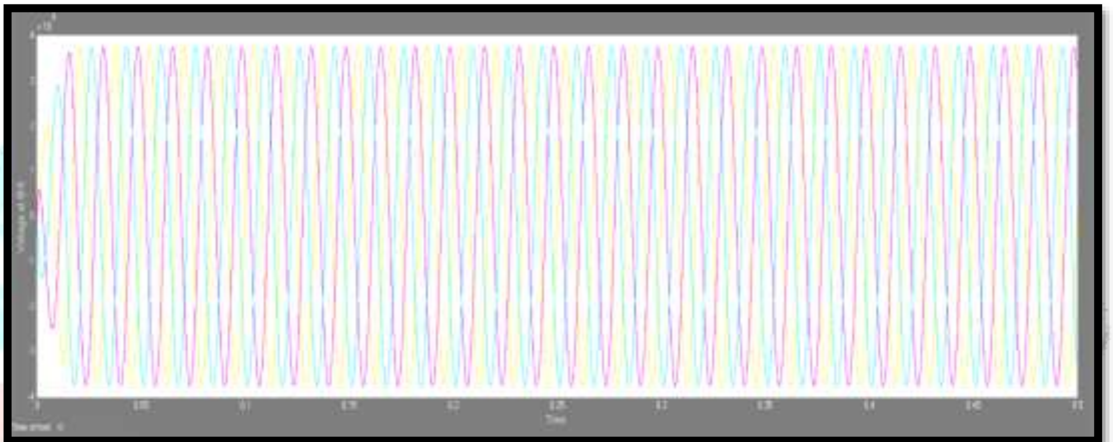

**Fig Voltage at Bus-2**

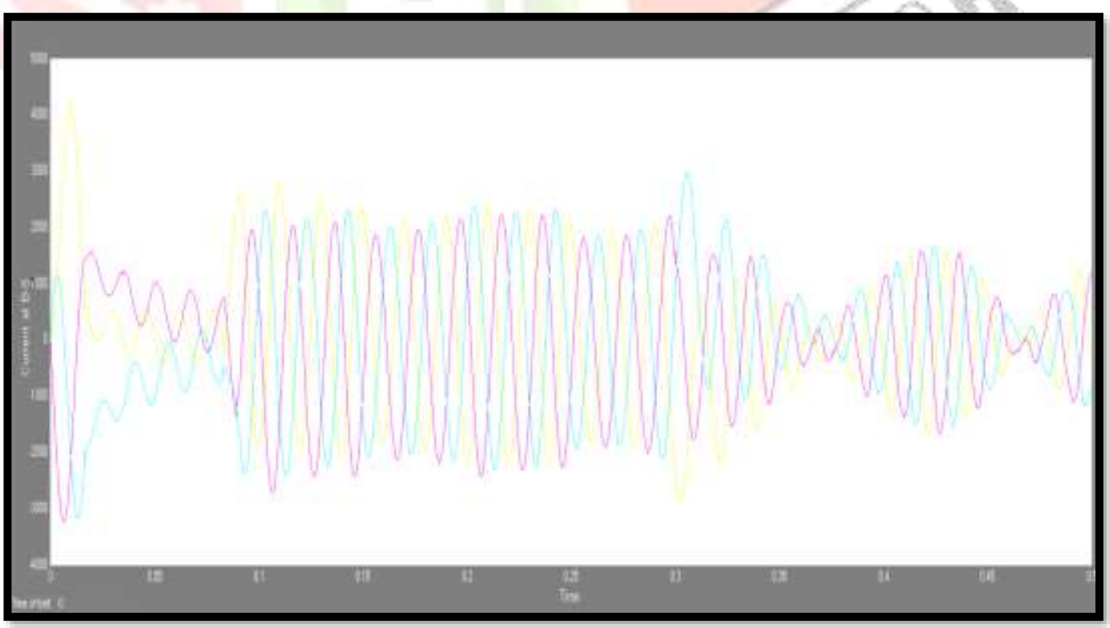

**Fig Current at Bus-2**

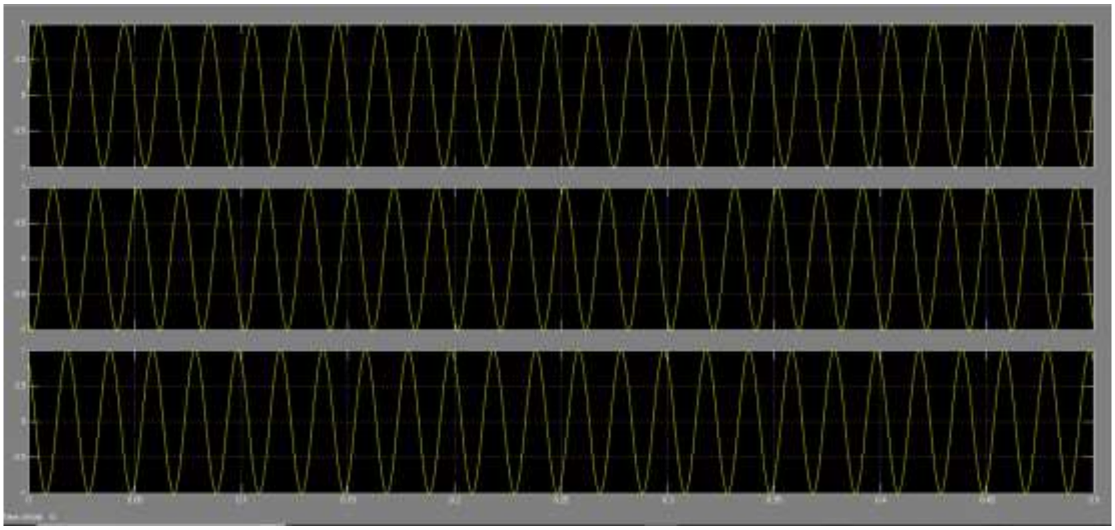

**Fig STATCOM three phase output current**

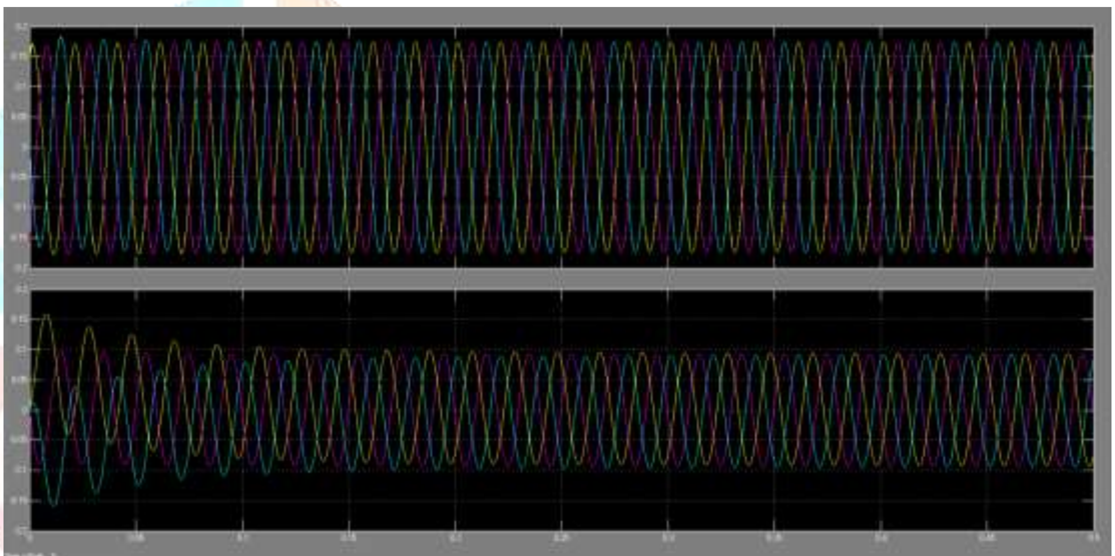

**Fig STATCOM side Voltage and current Improvement**

**Conclusion**

Various parts of this project have been showed and discussed with precision and proper details. Also, it shows that change in load has significant effect on power system voltage and current. Change in load can produce some of power quality problems which are undesirable, but it is due to distribution network and totally depending on power consumers. So, the harmonics production due to load change can't be avoid but it can reduce by using prescribed system. We also create fault and shows the disturbance and power quality problems in the proposed system.

Also, one major part of this paper work is excess power of wind generation can store using high capacity batteries so that the power exchange with grid can be constant and the energy can be utilizing during pike load time. This gives power saving of base load plant and provide a non-polluting power time to time. Thus, the concept is another step in the field of non-polluting energy and reduction in carbon footprint.

**REFERENCES**

(1)Mohammad Ali Tofigh and Nasrudin Abd Rahim, "Voltage Regulation of Grid Connected Wind Farm Using STATCOM", IEEE SYSTEMS JOURNAL, VOL. 4, NO. 3.

(2) Sharad W. Mohod and Mohan V. Aware, "A STATCOM-Control Scheme for Grid Connected Wind Energy System for Power Quality Improvement", IEEE SYSTEMS JOURNAL, VOL. 4, NO. 3, SEPTEMBER 2010.

(3) V. Amarnath Reddy, P. Harshavardhan Reddy, M. Sudheer babu, " Power Quality Improvement in Wind Energy system by using STATCOM on Integration to the Grid", Vol. 2, Issue. 5, Sep.-Oct. 2012 pp-3637-3640 ISSN: 2249-6645 , International Journal of Modern Engineering Research (IJMER).

(4) -Chandulal Tejavoth, M. Trishulapani, V.K.R.Mohan Rao, Y.Rambabu, " Power Quality Improvement for Grid Connected Wind Energy System using STATCOM-Control Scheme", IOSR Journal of Engineering (IOSRJEN) e-ISSN: 2250-3021, Vol. 3, Issue 7 (July. 2013).

(5) Sharad W. Mohod and Mohan V. Aware, "Power quality issues and its improvement in wind energy generation interface to grid system", MIT International Journal of Electrical and Instrumentation Engineering,Vol-1, No-2, August-2011.

(6) Deshveer1, Amit Bhardwaj2 "Simulation and Modeling of STATCOM and WINDFARM in Transmission Line Using MATLAB and Analysis of Bus Voltage", International Journal of All Research Education and Scientific Methods (IJARESM).

(7) Chad Abbey, Kai Strunz, and G´eza Jo´os "A Knowledge Based Approach for Control of Two-Level Energy Storage for Wind Energy Systems", IEEE TRANSACTIONS ON ENERGY CONVERSION, VOL. 24, NO. 2, JUNE 2009.

(8) M.Laouera, A.Mekkaouia, M.Younes, "STATCOM and Capacitor Banks in a fixed-speed wind farm", Science Direct, 1876-6102 , 2014 Elsevier Ltd.

(9)Christian Wessels, Nils Hoffmann, Marta Molinas and Friedrich Wilhelm Fuchs, "STATCOM Control at Wind Farms With Fixed-Speed Induction Generators Under Asymmetrical Grid Faults", IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 60, NO. 7, JULY 2013.

(10) Sarika D. Patil ,"Improvement of Power Quality Considering Voltage Stability in Grid Connected System by FACTS Devices ,"Dept. of Electrical Engineering, Rajiv Gandhi College of Engineering & Research, Nagpur, India.

(11) Mr.Saurabh S. Kulkarni* Mr. Naveen Kumar Mucha," A Matlab/Simulink Model for the control scheme utilized to improve power quality of Wind Generation System connected to Grid" , International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Volume 1 Issue 6 (July 2014).