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STATCOM BASED POWER QUALITY IMPROVEMENT OF WIND FARM FED MULTI-MACHINE SYSTEM

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ABSTRACT

Fault Ride-Through (FRT) capability is one of the basic requirements for wind farms. There are two aspects to fault ride-through: to continue power supply without breaking any part of the system and to resume normal operation after clearance of the fault. The doubly-fed induction generator (DFIG) is presently the most popular wind turbine system for large-scale generation. However, a significant disadvantage of the DFIG is its vulnerability to grid disturbances and fluctuations because the stator windings are connected directly to the grid through a transformer and switchgear; the rotor-side is buffered from the grid via a partially-rated converter. In electricity supplyand generation, low voltage ride through (LVRT), or fault ride through (FRT), is a capability of electrical devices, especially wind generators, to be able to operate through periods of lower grid voltage. This thesis investigates the use of a Static Synchronous Compensator (STATCOM) along with wind farms for the purpose of stabilizing the grid voltage after grid-side disturbances such as a three phase short circuit fault, temporary trip of a wind turbine and sudden load changes. The strategy focuses on a fundamental grid operational requirement to maintain proper voltages at the point of common coupling by regulating voltage. The DC voltage at individual wind turbine (WT) inverters is also stabilized to facilitate continuous operation of wind turbines during disturbances. In recent years, with increase in the scale of wind power, the impact of wind power on grid aroused widely. Once large-scale wind power disconnect from the power grid, the stability of power grid will be seriously affected. Therefore, it is crucial to maintain the wind farms remain connected to the grid in the case of grid fault in certain degree. This can be achieved by improving fault ride-through (FRT) capability of wind farm. So the aim of this dissertation is to improve Fault ride through capability can be improved by using FACTS devices.

Keyword: Wind Turbines, Static Synchronous Compensator, Vector Control, Doubly Fed Induction Generator

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I.INTRODUCTION

In recent years, with increasing of the scale of wind power, concern on the impact of wind power the grid aroused widely. Once large-scale wind power disconnect from the power grid, the stability of power grid will be seriously affected. Therefore, it is crucial to maintain the wind farms connect to the grid in the case of grid fault in certain degree. To achieve the aim, the wind farm should have fault ride-through (FRT) capability. When the voltage in the grid is temporarily dropped, the wind farm is required to keep connected with the grid during a certail length of time, even supporting the grid with reactive power. STATCOM, as a kind of popular reactive synchronous compensator, is widely used in improving FRT ability of wind farm. Currently, doubly-fed induction generator of wind turbine (DFIG) and the conventional constant speed wind turbine is the majority of wind farms. The characteristics of these turbines are totally different. The induction generator of wind turbine need more reactive power from grid than DFIG, for there is no converter between generator and grid. The FRT characteristics of IG can be realized with the help of STATCOM also by the FRT characteristics of DFIG can be improved with help of STATCOM. a cascading failure.STATCOM has played a big role in maintaining the transient voltage stability of the power system and improves the fault ride-through capacity of wind farms [1].Fault ride-through performance including the reactive power supply, torque fluctuation and rotor speed with crowbar and series dynamic resistor are compared. The proposed method is an alternative for further protection and requirements of wind farm riding-through grid disturbances [2]. The development of renewable energy sources will increase the amount of generation connected to distribution networks and this raises some technical issues, such as: fault ride-through capabilities; voltage control and power quality; system stability etc [3]. The voltage regulation mode and reactive power capabilities are found to be highly effective for low-voltage ride-through (LVRT) capabilities and transient stability enhancement of the DFIG-based wind generators [6]. This paper identifies and outlines the problem and recommends possible measures to ride through the overvoltage safely. Additionally, active voltage control structures to limit the over voltages are proposed [8]. Different combinations of reactive power control of rotor- and grid-side converters are investigated for voltage-control purposes [9].The power electronics based devices/equipments have become key components in today's modern power distribution system. In spite of the vast advantages offered by utilizing the power electronics based equipment for power processing, the operation of these devices gives rise to some serious drawbacks in terms of power quality. These devices generate harmonics polluting the power distribution system, and demand reactive power. In order to provide technical solutions to the new challenges imposed on the power systems, the concept of flexible AC transmission systems (FACTS) was introduced in the late 1980s. The FACTS devices incorporate power electronics based controllers to enhance the controllability and to increase power transfer capability of the transmission system. There are two approaches for the realization of power electronics based compensators: one employs conventional thyristor-switched capacitors (TSC) and reactors (TSR), and the other uses self-commutated switching converters. Both the schemes help to efficiently control the real and reactive power, but only the second one can be used to compensate current and voltage harmonics. Moreover, self-commutated switching converters present a better response time and more compensation flexibility.

II. PROPOSED SCHEME

In proposed system easy expansion of 3P3W system to 3P4W system. The neutral current, present if any, would flow through this fourth wire toward transformer neutral point. This neutral point current can be compensated by using a split capacitor. This neutral current achievement is used the method P-Q Theory in UPQC. The UPQC consisting of the combination of a series active power filter (APF) and shunt APF. Modern large-scale wind turbines, typically 1 MW and larger, are normally required to include systems that allow them to operate through such an event, and thereby "ride through" the low voltage. Similar requirements are now becoming common on large solar power installations that likewise might cause instability in the event of a disconnecting. Depending on the application the device may, during and after the dip, be required to:The doubly-fed induction generator (DFIG) is presently the most popular wind turbine system for large-scale generation. However, a significant disadvantage of the DFIG is its vulnerability to grid disturbances and fluctuations because the stator windings are connected directly to the grid through a transformer and switchgear; the rotor-side is buffered from the grid via a partially-rated converter.In electricity supplyand generation, low voltage ride through (LVRT), or fault ride through (FRT), is a capability of electrical devices, especially wind generators, to be able to operate through periods of lower grid voltage. Similar requirements for critical loads such as computer systems and industrial processes are often handled through the use of an uninterruptiblepower supply (UPS) to supply make-up power during these events.Many generator designs use electrical current flowing through windings to produce the magnetic field that the motor or generator operates on. This is in contrast to designs that use permanent magnets to generate this field instead. Such devices may have a minimum working voltage, below which the device does not work correctly, or does so at greatly reduced efficiency. Some will cut themselves out of the circuit when these conditions apply. This effect is more severe in doubly-fed Induction generators (DFIG), which have two sets of powered magnetic windings, than in squirrel-cage Induction generatorswhich have only one.

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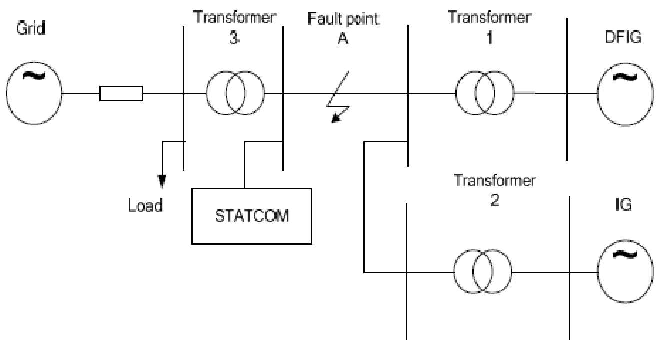

Fig1.Block diagram of System

Hence, the power quality impact caused by the wind turbine can be improved compared to a fixed-speed turbine. The rotational speed of a wind turbine is fairly low and must therefore be adjusted to the electrical frequency.

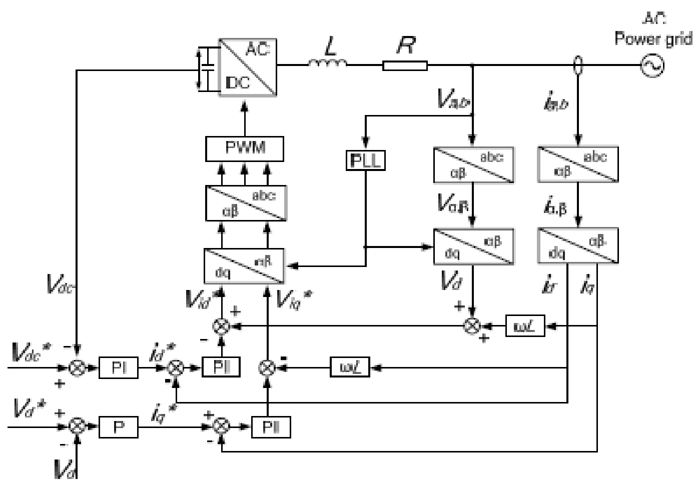

Fig2..Vector System connection

2.1 *Existing Method*

Voltage stability is a key issue to achieve the uninterrupted operation of wind farms equipped with squirrel cage induction generators (SCIG) during grid faults. A Static Synchronous Compensator (STATCOM) is applied to a power network which includes a SCIG driven by a wind turbine, for steady state voltage regulation and transient voltage stability support. The STATCOM is controlled by using PQ controller technique with voltage regulation as basic scenario. The system is implemented using MATLAB/ SIMULINK. Results illustrate that the STATCOM improves the transient voltage stability and therefore helps the wind turbine generator system to remain in service during grid faults. The time to reach steady state torque and speed without using vector control or direct torque control can also be achieved by using this STATCOM control technique

2.2 Static Synchronous Compensator (STATCOM)

A STATCOM is composed of the following components:

A. Voltage-Source Converter (VSC)

The voltage-source converter transforms the DC input voltage to an AC output voltage. Two of the most common VSC types are described below.

1. Square-wave Inverters using Gate Turn-Off Thyristors

Generally, four three-level inverters are utilized to make a 48-step voltage waveform. Subsequently, it controls reactive power flow by changing the DC capacitor input voltage, simply because the fundamental component of the converter output voltage is proportional to the DC voltage.

2.3 Modes of Operation

The STATCOM can be operated in two different modes:

A. Voltage Regulation

The static synchronous compensator regulates voltage at its connection point by controlling the amount of reactive power that is absorbed from or injected into the power system through a voltage-source converter.

In steady-state operation, the voltage V_2 generated by the VSC through the DC capacitor is in phase with the system voltage V_1 (δ=0), so that only reactive power (Q) is flowing (P=0).

When system voltage is high, the STATCOM will absorb reactive power (inductive behavior)

When system voltage is low, the STATCOM will generate and inject reactive power into the system (capacitive).

Subsequently, the amount of reactive power flow is given by the equation:

$Q = [V_1(V_1-V_2)] / X$

B. Var Control

In this mode, the STATCOM reactive power output is kept constant independent of other system parameter

In addition, special interconnection transformers are employed to neutralize harmonics contained in the square waves produced by individual inverters.

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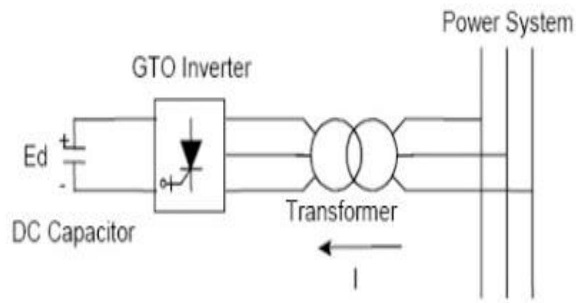

Fig3. GTO-based STATCOM Simple Diagram

2. PWM Inverters using Insulated Gate Bipolar Transistors (IGBT)

It uses Pulse-Width Modulation (PWM) technique to create a sinusoidal waveform from a DC voltage source with a typical chopping frequency of a few kHz. In contrast to the GTO-based type, the IGBT-based VSC utilizes a fixed DC voltage and varies its output AC voltage by changing the modulation index of the PWM modulator.
Moreover, harmonic voltages are mitigated by installing shunt filters at the AC side of the VSC.

B. DC Capacitor

This component provides the DC voltage for the inverter.

C. Inductive Reactance (X)

It connects the inverter output to the power system. This is usually the leakage inductance of a coupling transformer.

D. Harmonic Filters

Mitigate harmonics and other high frequency components due to the inverters.
In the case of two AC sources, which have the same frequency and are connected through a series reactance, the power flows will be:
Active or Real Power flows from the leading source to the lagging source.
Reactive Power flows from the higher to the lower voltage magnitude source.

Consequently, the phase angle difference between the sources decides the active power flow, while the voltage magnitude difference between the sources determines the reactive power flow. Based on this principle, a STATCOM can be used to regulate the reactive power flow by changing the output voltage of the voltage-source converter with respect to the system voltage.

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2.4 Control Stratergy

A static synchronous compensator (STATCOM) is a power electronic device based on the principle of voltage source converter, which possesses the characteristics of quick response and smooth regulation and can quickly adjust the reactive power of the power grid. Fig.4.1 is the schematic diagram of STATCOM.

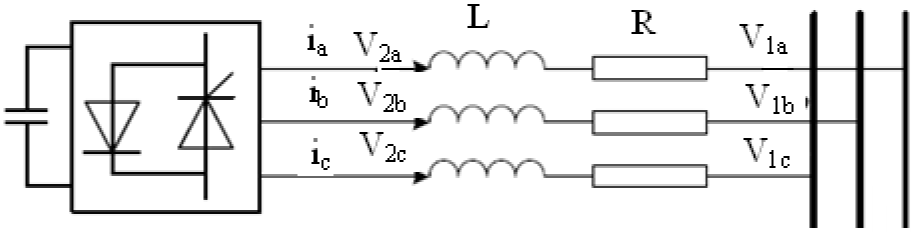


Fig. 4.1 Diagram of STATCOM

The voltage equation of STATCOM in the system is:

$$\begin{bmatrix} V_{1a} \\ V_{2b} \\ V_{3c} \end{bmatrix} = R\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + L\begin{bmatrix} di_b/dt \\ di_c/dt \\ di_a/dt \end{bmatrix} + \begin{bmatrix} V_{2a} \\ V_{2b} \\ V_{2c} \end{bmatrix}$$

Where, V_{1a}, V_{1b}, V_{1c} are the voltage of grid, V_{2a}, V_{2b}, V_{2c} and i_a, i_b, i_c are STATCOM voltage and current, R is the resistance and L is the inductance between grid and STATCOM. When the coordinate system is converted to *d-q* Coordinates, then, the voltage equation can be described as follow:

$$\begin{bmatrix} V_{1d} \\ V_{1q} \end{bmatrix} = R\begin{bmatrix} i_d \\ i_q \end{bmatrix} + L\begin{bmatrix} d_{id}/dt \\ d_{iq}/dt \end{bmatrix} + L\begin{bmatrix} 0 & -\omega \\ \omega & 0 \end{bmatrix}\begin{bmatrix} i_d \\ i_q \end{bmatrix} + \begin{bmatrix} V_{2d} \\ V_{2c} \end{bmatrix}$$

If make the d-axis direction the same with voltage direction, Then, *V*1q=0 and the decoupled control of active and reactive power can be achieved.

$$P = \frac{3}{2} V_{1d}\, i_d = V_{dc}\, i_{dc}$$

$$Q = -\frac{3}{2} V_{1d}\, i_q$$

There exists a variant of the DFIG method that uses controllable external rotor resistances (compare to slip power recovery). Some of the drawbacks of this method are that energy is unnecessary dissipated in the external rotor resistances and that it is not possible to control the reactive power. Manufacturers, that produce wind turbines with the doubly-fed induction machine as generator are, for example, De Wind, GE Wind Energy, Nordex, and Vestas

2.5 Simulink Software

Simulink (Simulation and Link) is an extension of MATLAB by Math works Inc. It works with MATLAB to offer modeling, simulating, and analyzing of dynamical systems under a graphical user interface (GUI) environment. The construction of a model is simplified with click-and-drag mouse operations. Simulink includes a comprehensive block library of toolboxes for both linear and nonlinear analyses. Models are hierarchical, which allow using both top-down and bottom-up approaches. As Simulink is an integral part of MATLAB, it is easy to switch back and forth during the analysis process and thus, the user may take full advantage of features offered in both environments. This tutorial presents the basic features of Simulink and is focused on control systems as it has been written for students in my control system

III APPLICATIONS

STATCOMs are typically applied in long distance transmission systems, power substations and heavy industries where voltage stability is the primary concern, doubly (DFIG), which have two sets of powered magnetic windings, than in squirrel-cage Induction generatorswhich have only one is more efficient for FRT.Wind turbines can operate with either fixed speed (actually within a speed range about 1%) or variable speed. For fixed-speed wind turbines, the generator (induction generator) is directly connected to the grid. Since the speed is almost fixed to the grid frequency, and most certainly not controllable, it is not possible to store the turbulence of the wind in form of rotational energy. Therefore, for a fixed-speed system the turbulence of the wind will result in power variations, and thus affect the power quality of the grid. For a variable-speed wind turbine the generator is controlled by power electronic equipment, which makes it possible to control the rotor speed. In this way the power fluctuations caused by wind variation scan be more or less absorbed by changing the rotor speed and thus power variations originating from the wind conversion and the drive train can be reduced. Hence, the power quality impact caused by the wind turbine can be improved compared to a fixed-speed turbine. The rotational speed of a wind turbine is fairly low and must therefore be adjusted to the electrical frequency.

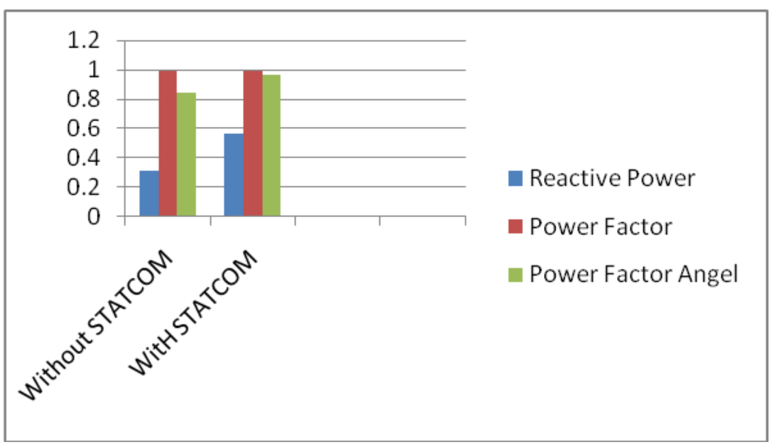
IV RESULTS

The simulation of the proposed system has been done using MATLAB/SIMULINK

.Simulation studies have shown that the additional voltage/var support provided by an external device such as a STATCOM can significantly improve the wind turbine's fault recovery by more quickly restoring voltage characteristics. The extent to which a STATCOM can provide support depends on its rating. The higher the rating, the more support provided. The interconnection of wind farms to weak grids also influences.

Sr No	Model Design	Reactive Power	Power Factor	Power Factor Angel
1	WIND DFIG IG Without STATCOM	0.3117	0.99	0.841
2	WIND DFIG IG With STATCOM	0.5659	0.99	0.9693

Table 1. Readings for reactive power and pf for DFIG-IG circuit



Graph 1. Readings for reactive power and pf for DFIG-IG circuit

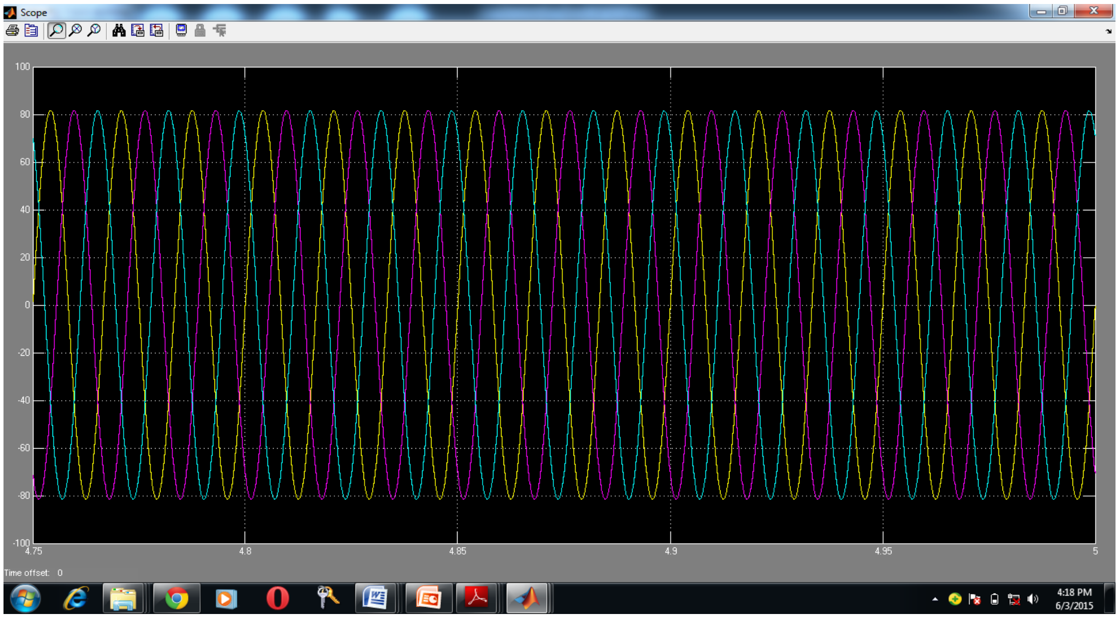


Fig 5.1. Input 3 phase voltage

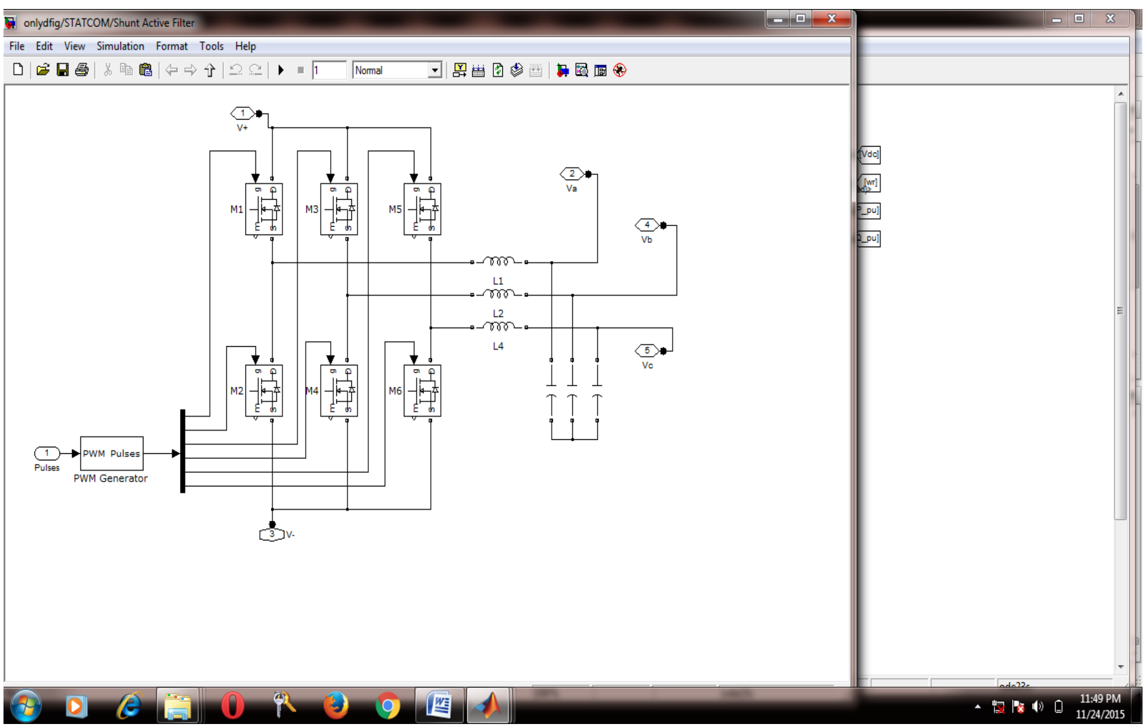


Fig.5.2 Statcom Design

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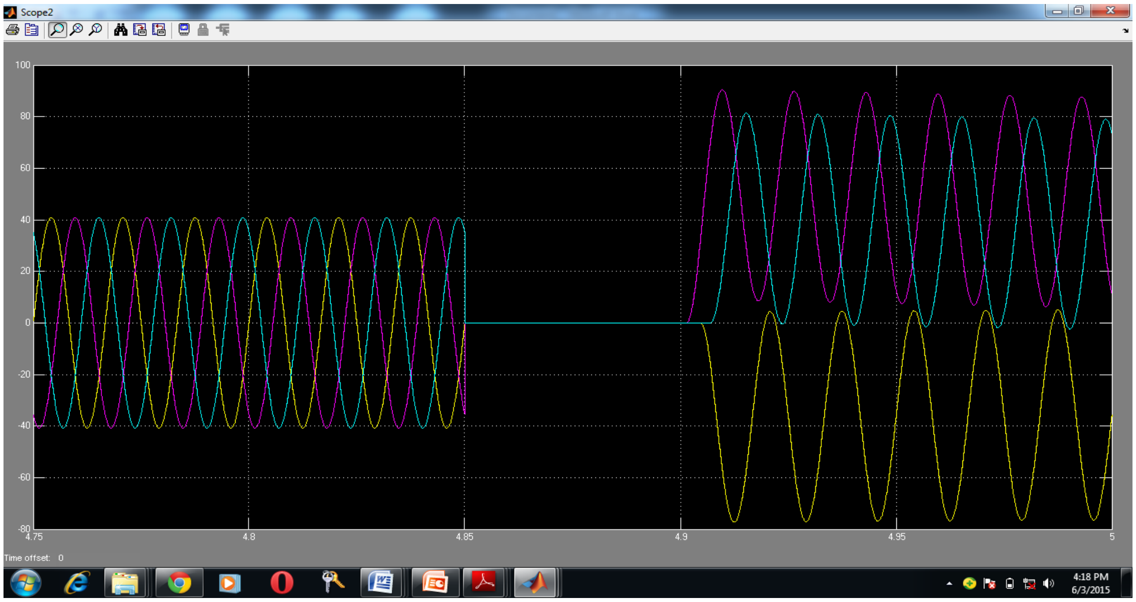

Fig5.3.Distorted Output voltage due to nonlinear load.

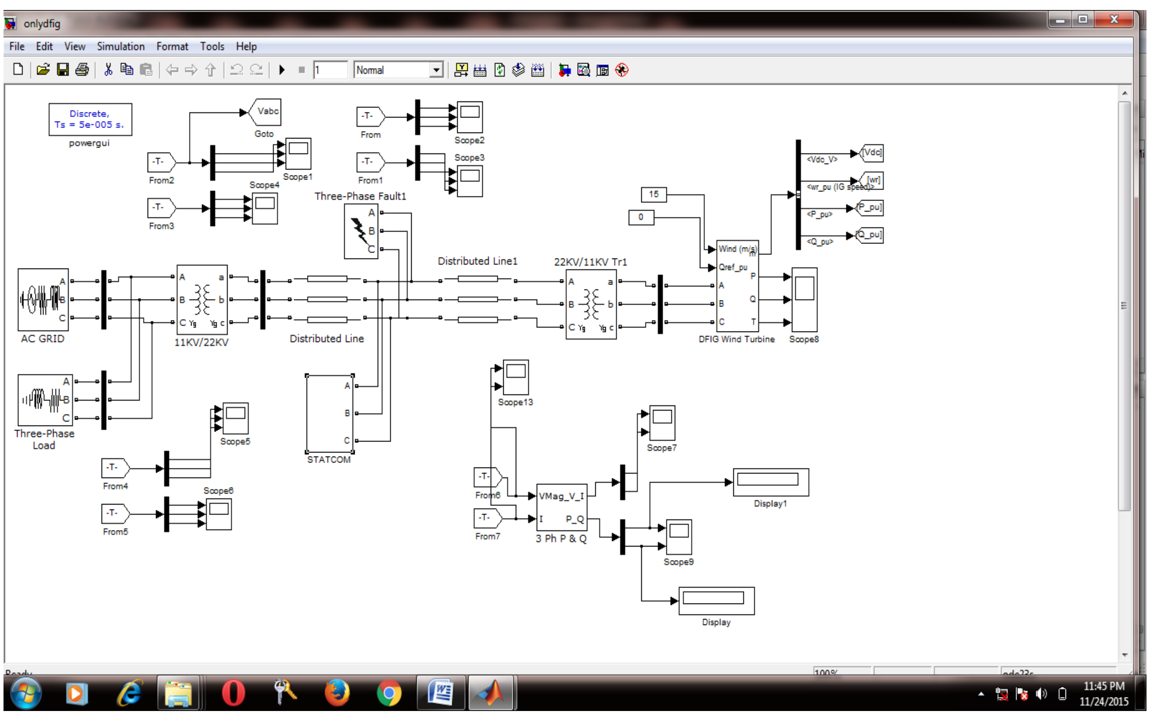

Fig5.4.Statcom Based system.

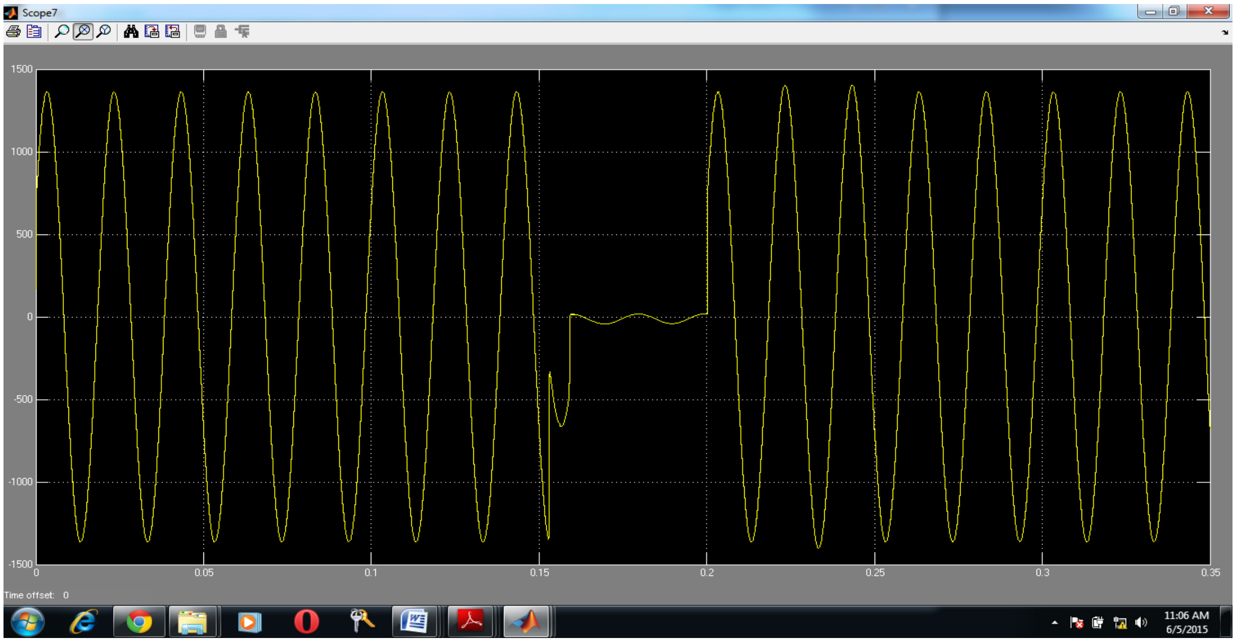

Fig 5.Output voltage with 3 phase fault

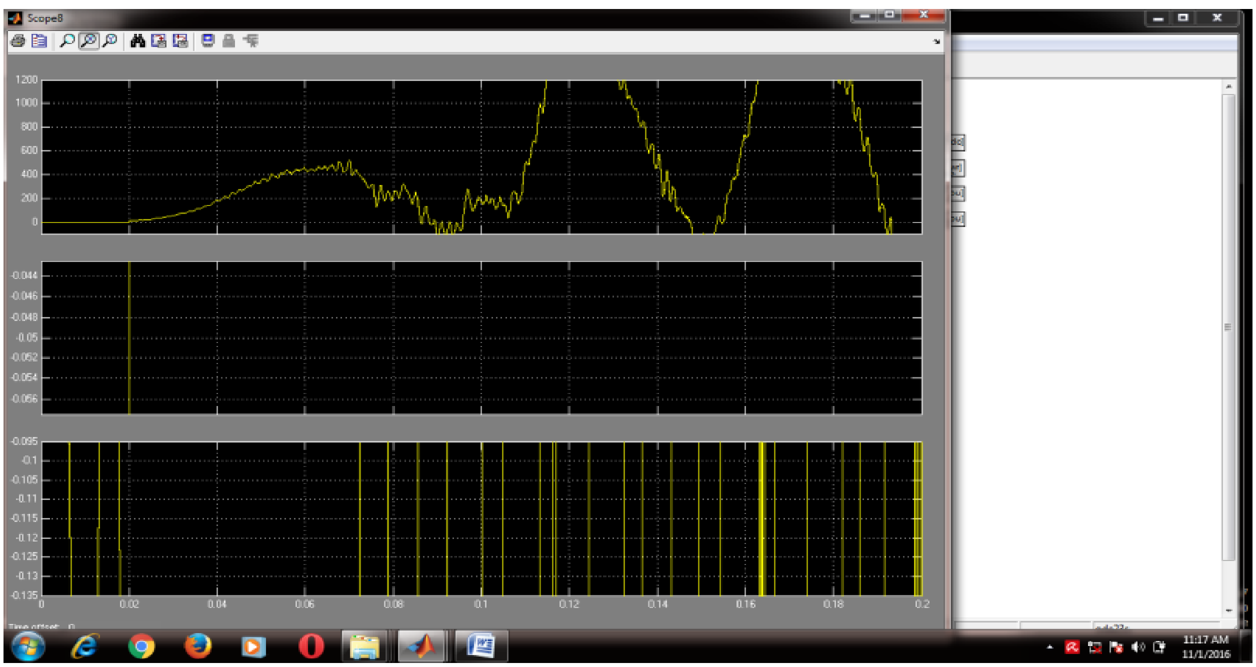

Fig 5.6 DFIG Generator response

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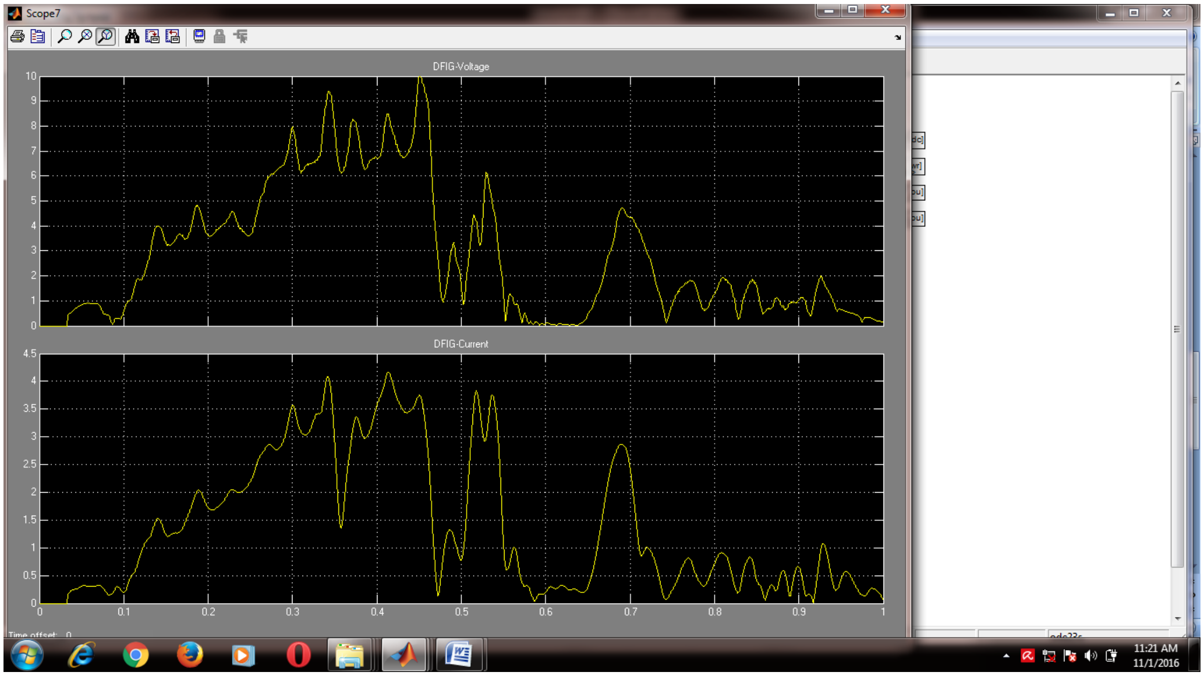

Fig 5.7 DFIG Active & Reactive power response.

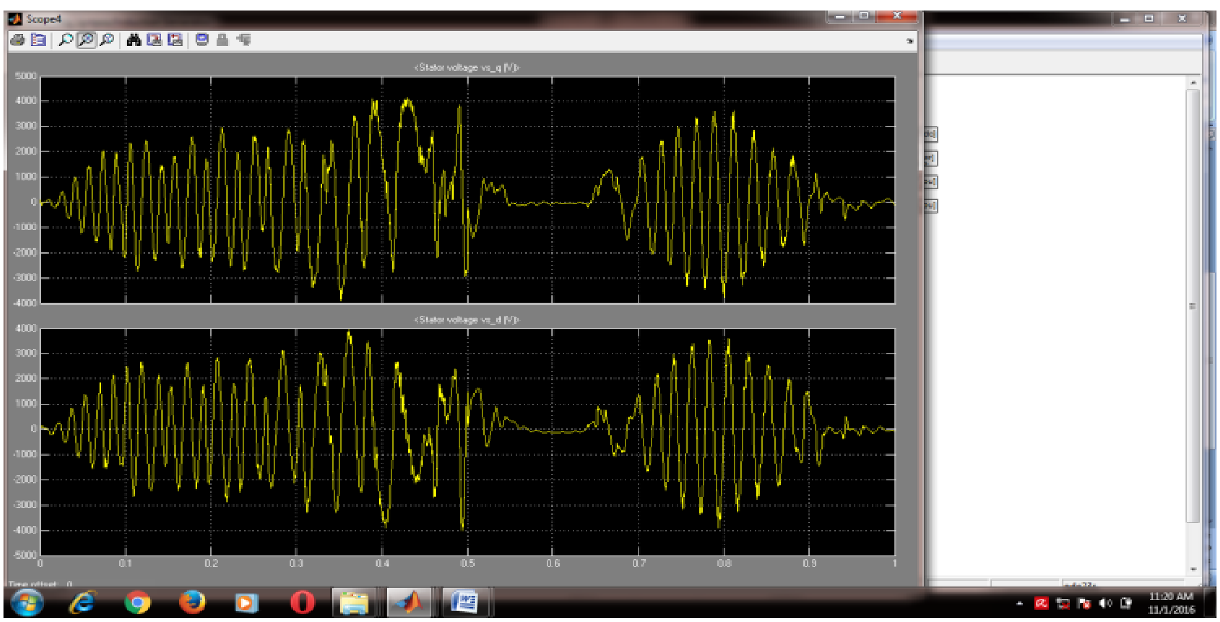

Fig 5.8 . IG Generator response

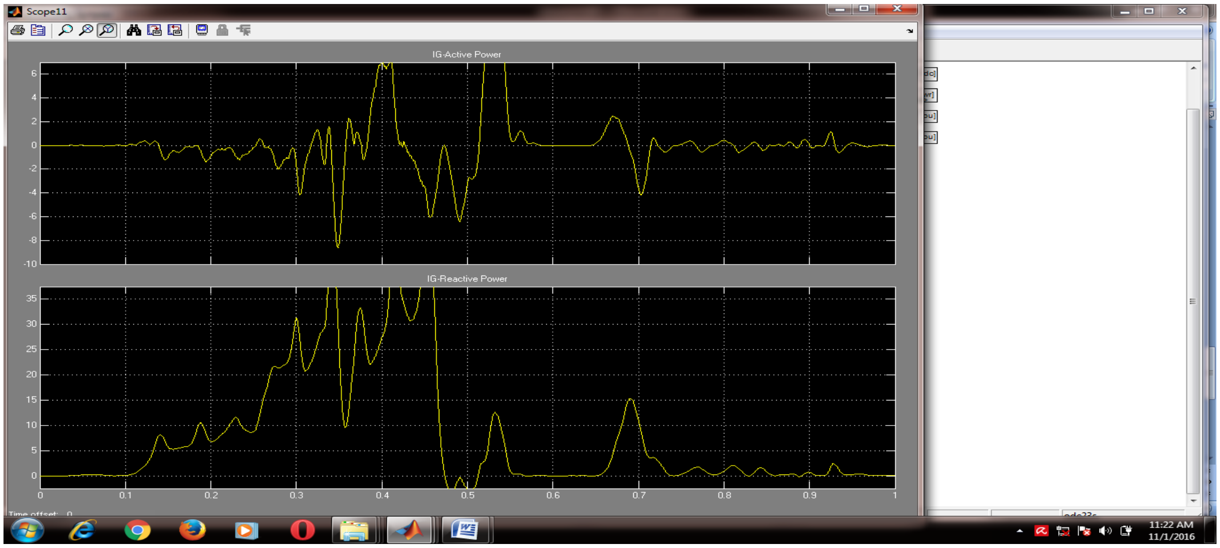

Fig 5.9 IG Active & Reactive power response

VIII CONCLUSIONS

In this project we are investigating the use of a Static Synchronous Compensator (STATCOM) along with wind farms for the purpose of stabilizing the grid voltage after grid-side disturbances such as a three phase short circuit fault, temporary trip of a wind turbine and sudden load changes. The strategy focuses on a fundamental grid operational requirement to maintain proper voltages at the point of common coupling by regulating voltage. The DC voltage at individual wind turbine (WT) inverters is also stabilized to facilitate continuous operation of wind turbines during disturbances. Many generator designs use electrical current flowing through windings to produce the magnetic field that the motor or generator operates on. This is in contrast to designs that use permanent magnets to generate this field instead. Such devices may have a minimum working voltage, below which the device does not work correctly, or does so at greatly reduced efficiency. Some will cut themselves out of the circuit when these conditions apply. This effect is more severe in doubly-fed Induction generators (DFIG), which have two sets of powered magnetic windings, than in squirrel-cage Induction generators which have only one.In a grid containing many distributed generators subject to low-voltage disconnect, it is possible to create a chain reaction that takes other generators offline as well. This can occur in the event of a voltage dip that causes one of the generators to disconnect from the grid. As voltage dips are often caused by too little generation for the load, removing generation can cause the voltage to drop further. This may bring the voltage low enough to cause another generator to trip out, lower it further, and causing a cascading failure. Simulation studies have shown that the additional voltage/var support provided by an external device such as a STATCOM can significantly improve the wind turbine's fault recovery by more quickly restoring voltage characteristics. The extent to which a STATCOM can provide support depends on its rating. The higher the rating, the more support provided. The interconnection of wind farms to weak grids also influences.

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