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APPLICATIONS OF STATCOM IN THE IMPROVEMENT OF DYNAMIC PERFORMANCE OF WIND POWER GENERATION

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ABSTRACT :

To meet the strict criteria of grid codes for the integrated wind farm with the grid has become a major point of concern for engineers and researchers today. More overvoltage stability is a key factor for the stable operation of grid connected wind farm during fault ride through and grid disturbances. This paper investigates the implementation and comparison of FACTS devices like STATCOM and SVC for the voltage stability issue for DFIG-based wind farm connected to a grid and load. The study includes the implementation of FACTS devices as a dynamic voltage restorer at the point of common coupling to maintain stable voltage and thereby protecting DFIG-based wind farm interconnected powers system from isolating during and after the disturbances. The power system model is simulated in MATLAB / SIMULINK and the results show that the STATCOM is better than SVC for the stable operation of wind turbine generator system to remain in service during grid fault.

Key words : Wind farms, STATCOM, MATLAB / SIMULINK, Grid codes , Doubly Fed Induction Generators (DFIGs)

1.0 Introduction and Literature review:

The wind power penetration has increased dramatically in the past few years, hence it has become necessary to address problems associated with maintaining a stable electric power system that contains different sources of energy including hydro, thermal, coal, nuclear, wind, and solar. In the past, the total installed wind power capacity was a small fraction of the power system and continuous connection of the wind farm to the grid was not a major concern. With an increasing share derived from wind power sources, continuous connection of wind farms to the system has played an increasing role in enabling uninterrupted power supply to the load, even in the case of minor disturbances.

The wind farm capacity is being continuously increased through the installation of more and larger wind turbines. Voltage stability and an efficient fault ride through capability are the basic requirements for higher penetration. Wind turbines have to be able to continue uninterrupted operation under transient voltage conditions to be in accordance with the grid codes [2]. Grid codes are certain standards set by regulating agencies. Wind power systems should meet these requirements for interconnection to the grid. Different grid code standards are established by different regulating bodies, but Nordic grid codes are becoming increasingly popular [3]. One of the major issues concerning a wind farm interconnection to a power grid concerns its dynamic stability on the power system [4]. Voltage instability problems occur in a power system that is not able to meet the reactive power demand during faults and heavy loading conditions. Stand alone systems are easier to model, analyze, and control than large power systems in simulation studies. A wind farm is usually spread over a wide area and has many wind generators, which produce different amounts of power as they are exposed to different wind patterns. Flexible AC Transmission Systems (FACTS) such as the Static Synchronous Compensator (STATCOM) and the Unified Power Flow Controller (UPFC) are being used extensively in power systems because of their ability to provide flexible power flow control [5]. The main motivation for choosing STATCOM in wind farms is its ability to provide busbar system voltage support either by supplying and/or absorbing reactive power into the system.

The applicability of a STATCOM in wind farms has been investigated and the results from early studies indicate that it is able to supply reactive power requirements of the wind farm under various operating conditions, thereby improving the steady-state stability limit of the network [6].

Transient and short-term generator stability conditions can also be improved when a STATCOM has been introduced into the system as an active voltage/var supporter [5, 7]. The methods used to develop an equivalence of a collector system in a large wind power plant are described in [8]. The requirements, assumptions and structure of an aggregate model of a wind park with constant speed turbine and variable speed turbines are discussed in [9].

This thesis explores the possibility of enabling wind farms to provide voltage support during normal conditions, as well as under conditions when system voltages are not within desired limits. The transient behavior of wind farms can be improved by injecting large amounts of reactive power during fault recovery [10].

This thesis examines the use of STATCOMs in wind farms to stabilize the grid voltage after grid disturbances such as line outages or severe system faults. The wind turbines (WTs) considered in this thesis are Doubly Fed Induction Generators (DFIGs) that are capable of variable speed operation. A DFIG has a power electronic converter by which both real power and reactive power can be controlled. A STATCOM was employed to regulate the voltage at the bus, to help maintain constant DC link voltages at individual wind turbine inverters during disturbances. This feature will facilitate the continuous operation of each individual wind turbine during disturbances, thus enabling the wind farm to participate in the grid side voltage and power control. The dynamic DFIG model available in Dig SILENT PowerFactory Version 13.2 [11] was used for the simulations. The STATCOM with a higher rating capacity was developed based on the study of an available low capacity STATCOM model. The complete power grid studied in this thesis is a combined case study of interconnected two wind turbines, a synchronous generator, a STATCOM and a typical load all forming a four bus system. Power control is vital for transient and voltage stability during faults and is required to meet the connection requirements of the wind turbines to the grid which vary mostly with the short circuit capacity of the system considered. Reactive power is required to compensate for the additional reactive power demand of the generator and the matching transformers so that the wind power installation does not burden the system.

Low Voltage Ride Through (LVRT) is a recently introduced requirement that transmission operators demand from wind farms. A STATCOM is being evaluated for its performance to effectively provide LVRT for wind turbines in a wind farm.

2.0 SCOPE OF WORK:

The European electrical power system contains larger amounts of wind power and the share of embedded wind generation is increasing in other power systems as well. The significant size of new wind power installations requires realistic modeling capabilities of wind generators for assessing the power system planning and to perform stability studies with increased wind power share. Matlab version r2010a was used for the simulation studies on the modeled test system. Matlab is an acronym for is one the most powerful power system software with an integrated graphical one-line interface. Matlab has faster simulation time when compared to PSCAD, SimPower systems in MATLAB. In terms of accuracy of the results and implementation of the models, all the softwares are similar in nature. This is becoming popular in DFIG model was used to model the turbines in a wind farm and the STATCOM model was developed specific to this application.

This thesis is presented in five sections. Section 2 is about the wind power statistics, types of wind turbines, wind farm modeling requirements, stability and reliability considerations, and fault studies on the WTs, and the performance of WTs with faults on the system. Section 3 deals with the need for voltage control in the presence of wind energy. Also, the reactive power capability of wind turbines, the need for reactive power support along with the applicability of FACTS devices, and the reasons for choosing STATCOM are presented. The dynamic performance of the test system is analyzed for three cases, viz. three phase impedance faults, tripping of a WT in the wind farm and sudden temporary load changes.

In this work, the STATCOM/ESS will be treated. The main focus will be on the converter topology for the STATCOM and its control system. This will both be treated theoretically, in simulations. In addition, the energy storage system will be treated theoretically and simulated.

3.0 Modelling and Simulation

SimPowerSystems and other products of the Physical Modeling product family work together with Simulink to model electrical, mechanical, and control systems is used in this study. SimPowerSystems operates in the Simulink environment. Power systems are combinations of electrical circuits and electromechanical devices like motors and generators. Engineers working in this discipline are constantly improving the performance of the systems. Requirements for drastically increased efficiency have forced power system designers to use power electronic devices and sophisticated control system concepts that tax traditional analysis tools and techniques. Further complicating the analyst's role is the fact that the system is often so nonlinear that the only way to understand it is through simulation. Land-based power generation from hydroelectric, steam, or other devices is not the only use of power systems. A common attribute of these systems is their use of power electronics and control systems to achieve their performance objectives. SimPowerSystems is a modern design tool that allows scientists and engineers to rapidly and easily build models that simulate power systems. SimPowerSystems uses the Simulink environment, allowing to build a model using simple click and drag procedures. Not only the circuit topology can be drawn rapidly, but analysis of the interactions with mechanical, thermal, control, and other disciplines can be done. This is possible because all the electrical parts of the simulation interact with the extensive Simulink modeling library. SimPowerSystems and SimMechanics share a special Physical Modeling block and connection line interface. The simulation of STATCOM for improvement of dynamic performance of wind farms are shown below in figure 1 and 2.

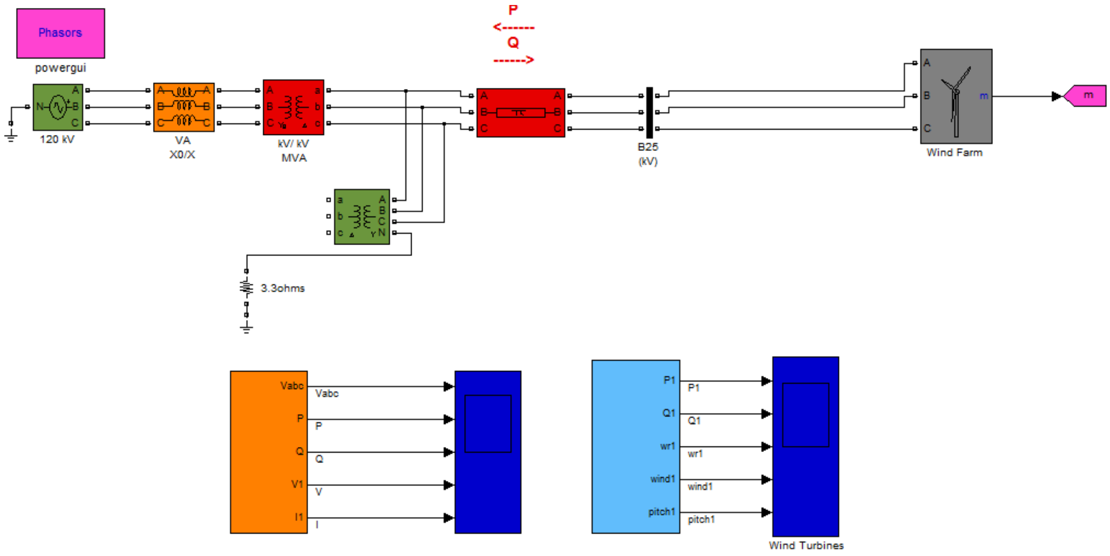

Fig1 wind system without use STATCOM

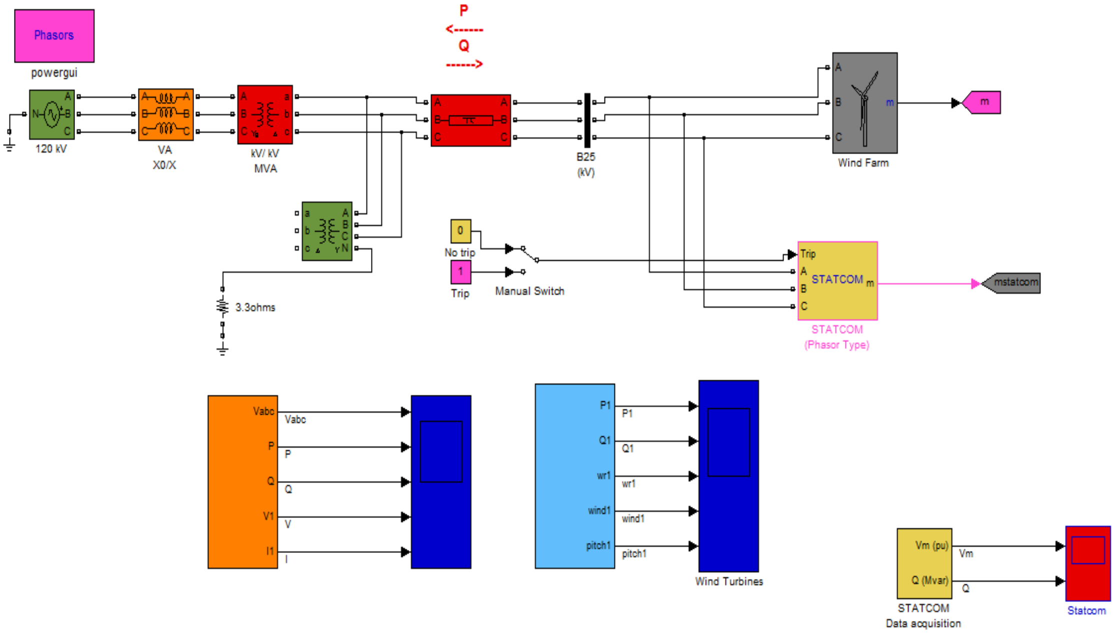

Fig2 wind system whit use STATCOM without Wind

The system parameters selected are :

i. System nominal voltage and frequency Vrms L-L, f(Hz)[25e3, 50]

ii. Converter rating (VA): 3e6

iii. Nominal wind turbine mechanical output power **W+ 2*1.5e6**

iv. Base wind speed (m/s): 3

v. Maximum power at base wind speed (pu of nominal mechanical power) =1

vi. Base rotational speed (pu of base generator speed)=1

vii. Maximum pitch angle (deg)=45

viii. Maximum rate of change of pitch angle (deg/s):=2

ix. nom. power, L-L volt. and freq.: [Pn (VA), Vn (Vrms), fn (Hz)]

x. [2*1.5e6/0.9 575 .50]

xi. Stator [Rs,Lls] (pu):

xii. [0.004843 0.1248]

xiii. Rotor [Rr',Llr'] (p.u.):

xiv. [0.004377 0.1791]

xv. nertia constant, friction factor, and pairs of poles: [H(s) F(pu) p]

xvi. [5.04 0.01 3]

xvii. Line section length (km) :50

4.0 SIMULATIONS RESULTS

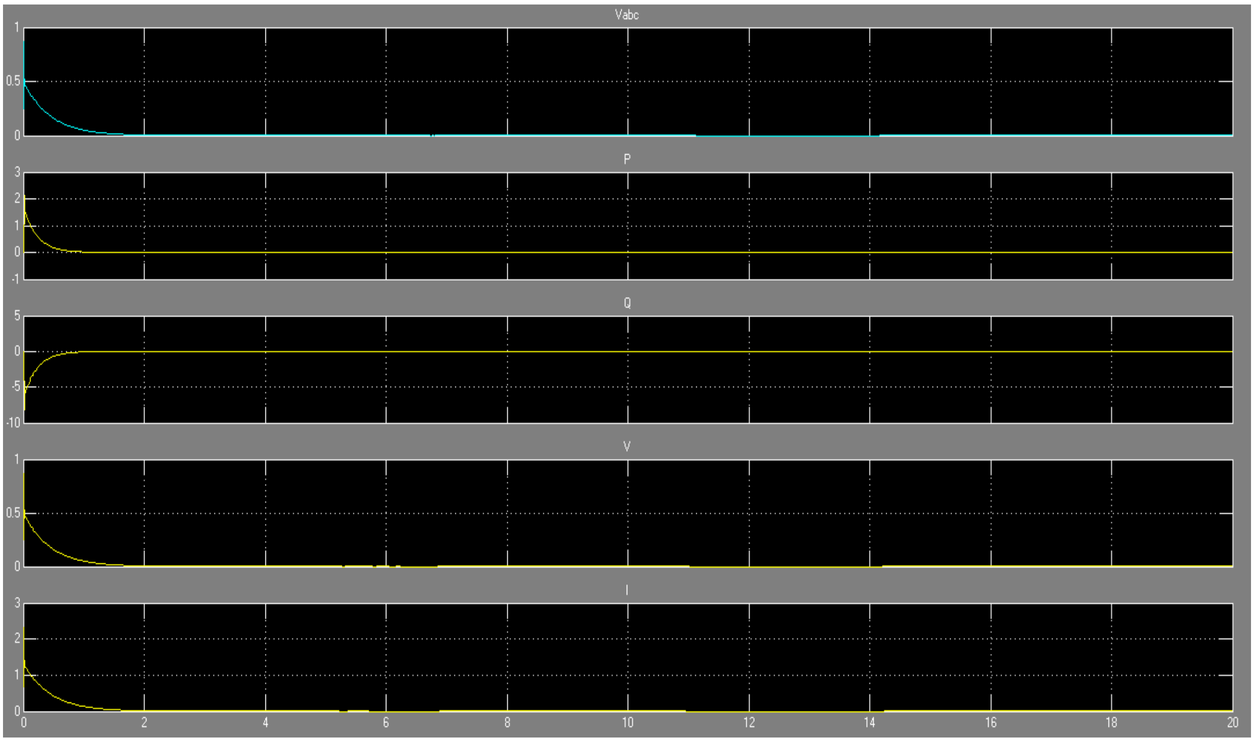

Fig 3 output power without STATCOM in wind system

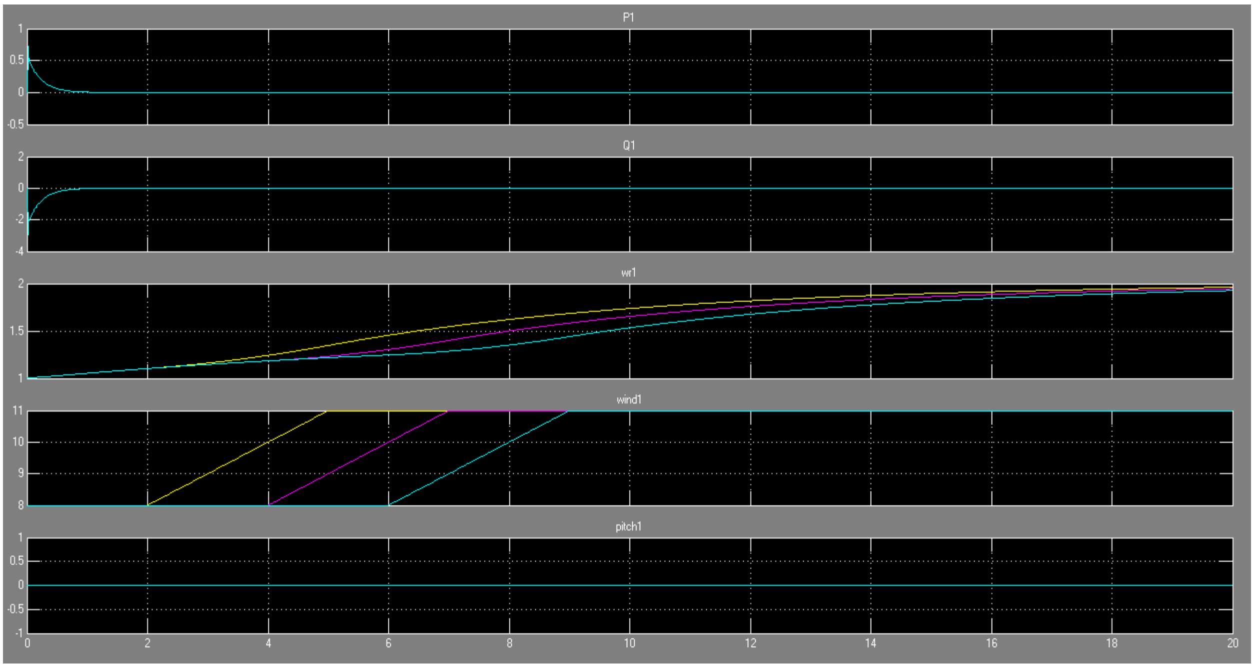

Fig 4 Output voltage bus bar Without STATCOM in wind system

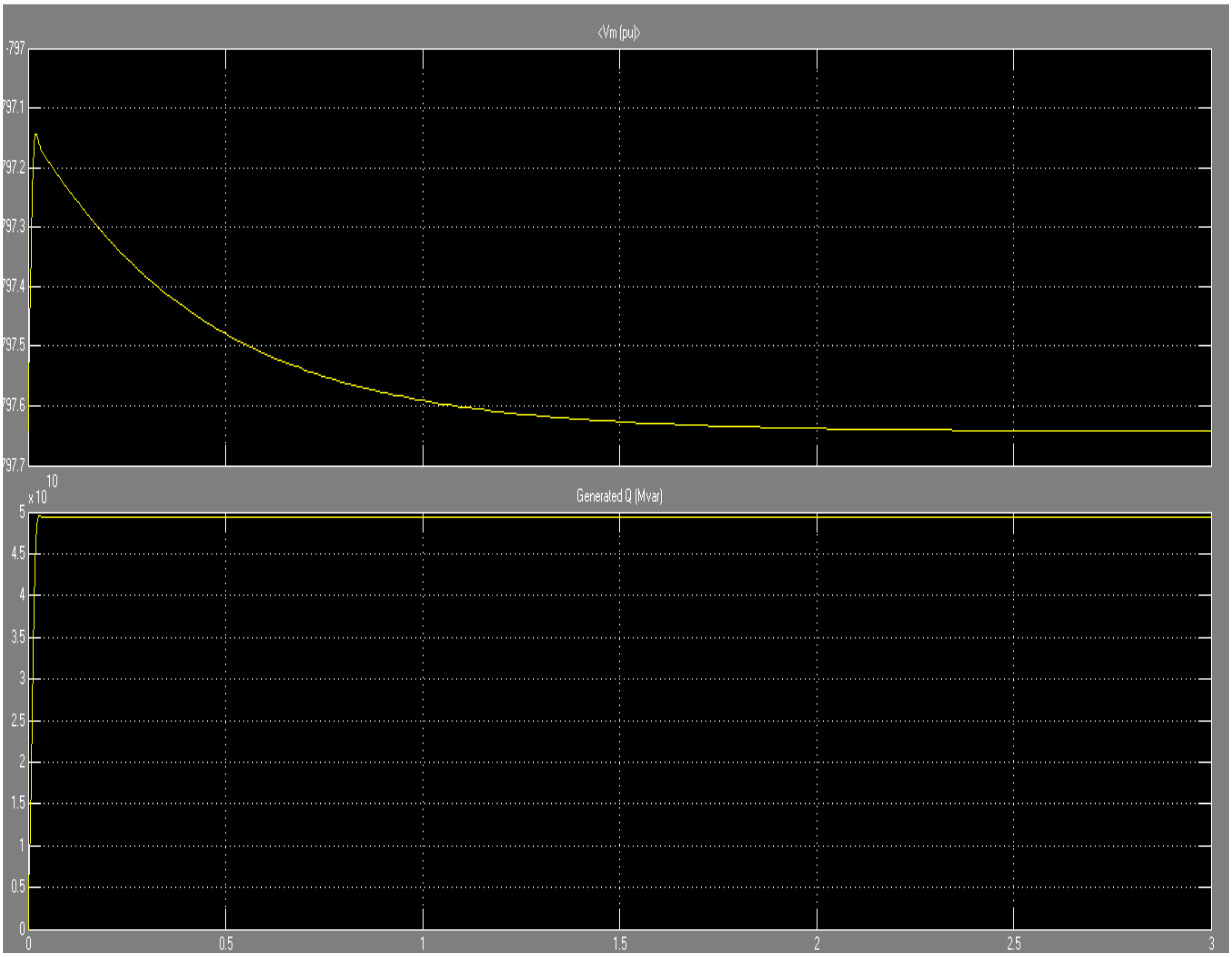

Fig 5 output power with STATCOM in wind system (active and reactive power)

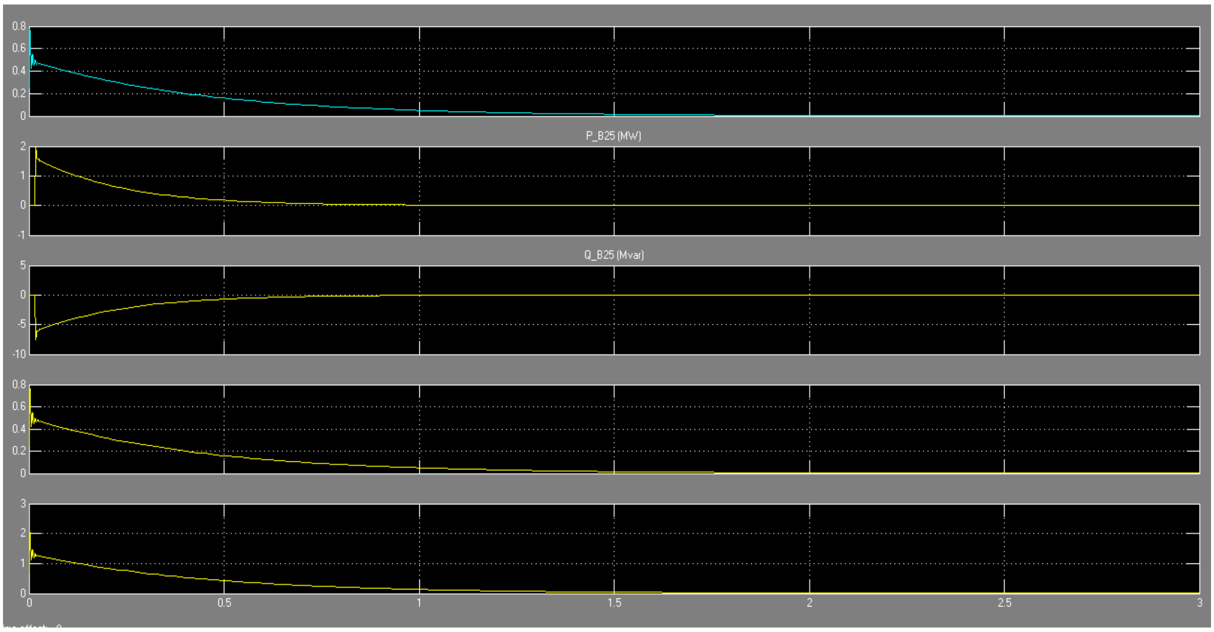

Fig 6 output power with STATCOM in wind system

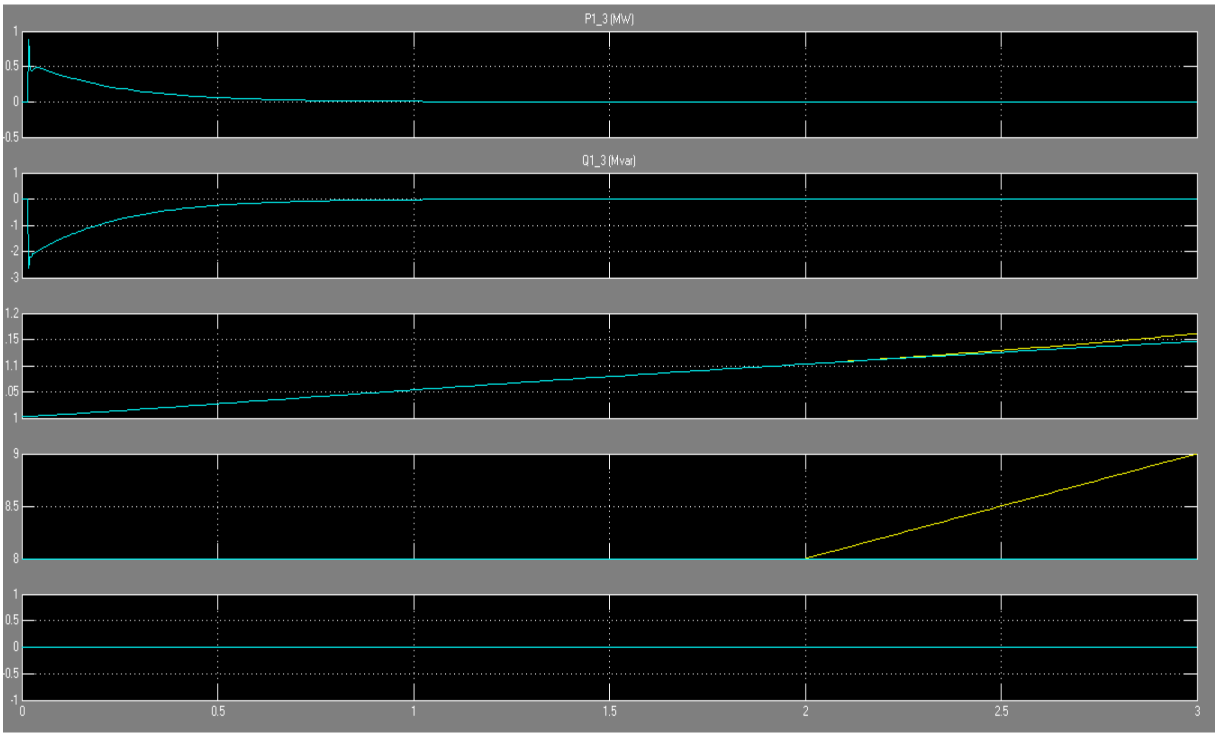

Fig 7 Output power at bus bar without STATCOM in wind system

The STATCOM supplies variable reactive power and supports voltage at the load bus thus reducing the oscillations in the load voltage. Also, the load has some wide power oscillations in the system without the STATCOM that can be reduced with the help of a STATCOM.

5.0 CONCLUSION

In this study, results have been shown for different conditions. In first condition we have shown figure 3 and 4 which are the uncompensated output results here the low power and high reactive power. These are uncompensated outputs (whit out use STATCOM)By comparison of fig (5, 6) and (7) it is clear that power factor improve and reactive power compensated and wind system performance improvement use STATCOM (using STATCOM)

A pressing demand for more electric power coupled with the depleting natural resources have led to an increased need for energy production from renewable sources such as wind and solar energy. The electrical output power generated from these sources of energy is variable in nature and hence, efficient power control is required for these energy sources. Wind power has seen increased penetration in the recent past and certain stringent grid interconnection requirements have been developed. Wind turbines have to be able to ride through a fault without disconnecting from the grid. When a wind farm is connected to a weak power grid, it is necessary to provide efficient power control during normal operating conditions and enhanced support during and after faults. Voltage instability problems occur in a power system that is not able to meet the reactive power demand during faults and heavy loading conditions. Dynamic compensation of reactive power is an effective measure of preserving power quality and voltage stability.

When many wind turbines are added to the system, the grid becomes weaker as these types of generators require additional control equipment since they do not have any self recovery capability like the conventional synchronous generators. This requires a thorough study of the normal and dynamic performance of the wind turbines during and after a disturbance. This thesis explores the possibility of connecting a STATCOM to the wind power system in order to provide efficient control. In this thesis, the wind turbine modeled is a DFIG that is an induction machine which requires reactive power compensation during grid side disturbances. An appropriately sized STATCOM can provide the necessary reactive power compensation when connected to a weak grid. Also, a higher rating STATCOM can be used for efficient voltage control and improved reliability in grid connected wind farm but economics limit its rating. 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 the safety of wind turbine generators. Some of the challenges faced by wind turbines connected to weak grids are an increased number and frequency of faults, grid abnormalities, and voltage and frequency fluctuations that can trip relays and cause generator heating.

The dynamic performance of wind farms in a power grid is improved by the application of a STATCOM. The STATCOM helps to provide better voltage characteristics during severe faults like three phase impedance short circuit faults as well. The response of a wind farm to sudden load changes is improved by the use of a STATCOM in the system.

6.0 Scope for future work

In this study, simulation studies show that the dynamic performance of wind farms is improved with the use of a STATCOM. Future work can involve analyzing the harmonics in the system and evaluate methods to reduce the system harmonics. A multilevel STATCOM can be modeled to reduce lower order harmonics. Three phase high impedance short circuit faults have been studied in this thesis that can be extended to observe the response of the system to other types of faults. The wind turbines here are modeled as individual turbines, which could be extended to represent a wind farm by modeling them as a single equivalent wind turbine. The study has been based on the performance for DFIG that could be further extended to various types of wind turbines. This study can be extended to a larger system to evaluate the support provided by the use of a STATCOM.

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