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Enhancement of Power Quality in Grid Connected Wind Energy System Using STATCOM

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Abstract-- The operating performance of wind electric generators has considerable stress on the quality of electric power and reliability in the performance power systems [1]. Power quality issues such as voltage dip, harmonic distortion and reliability problems are main considerations in this work. The voltage distortion & reactive power issues are also considered. The powerful MAT LAB tool is used to analyse the power quality issues and other reliability problems in this paper and also the performance of induction generator connected with grid is also analyzed for power quality problems. The compensator is designed to inject reactive power to overcome power quality problems and also for better grid operation. There is a continuous variation in terminal voltage because of the varying wind speed. The addition of STATCOM into the system supports to maintain the active power, reactive power and terminal voltage as constant and STATCOM for steady state and dynamic impact study is presented, and the model is validated by comparing with the actual field data.The wind turbine generators have power electronic based converters can be effectively utilized for efficient control of power, but they generate harmonics. The modified STATCOM as shunt active filter which is used for reducing system harmonics and to improve the system performance. The STATCOM model is implemented using PIC controller

Keywords*:* SVC, STATCOM, FACTS, GTO, PV, VQ, *TC.*

I. INTRODUCTION

The number of renewable energy sources and requires a new technique for the operation of electric power systems, in order to reach the power quality norms. Now a day's wind mills are connected to the power system to meet the commonly used device for flicker reduction is the STATIC V AR Compensator [SVC] [1]. On comparing STATCOM with SVC, the STATCOM has some advantages, such as better performance, quick response, smaller in size, less cost, and capable of satisfying both active and reactive power requirements. The proposed compensator consisting of a voltage source
converter, (VSI) uses advanced power semiconductor switches to provide flexibility in voltage control for power quality improvement[l]. This method is suitable for the applications with frequently fluctuating loads and power flow. By using high frequency switching PWM, the high speed switching converter will generate smooth current with low harmonic content. In this thesis, a induction generator is modelled using MATLAB and flicker generation of grid connected wind turbines fed induction generators is analyzed for varying load conditions. The high speed switching power converters, which are used to extract maximum power at the available speed, are connected between the induction generator and grid. Harmonics due to the varying load conditions are reduced by designing compensator as a shunt active filter.

Normally, the low-cost mechanical switched cap [MSC] banks and transformer tap changers [TCs] are used to address these problems related to grid stability and power quality. Even though these devices are very much helpful to improve the power factor and steady-state voltage regulation, the major power quality Issues, such as power fluctuations, voltage flicker and harmonics introduction cannot be reduced effectively by them because these devices are not having fast response. So a fast response shunt VAR compensator is needed to solve these issues more effectively, as has been pointed out in many literatures. The static synchronous compensator [STATCOM] IS suitable for this application, because it provides many advantages, in particular the fast response time and superior voltage support capability with its nature of voltage source. The recent innovations ill high-power, high speed semiconductor switch converter topologies, and efficient digital control technology, fast response ST ATCOM with low cost is emerging, which is promising to help integrate wind energy into the grid to achieve a more cost-effective and reliable renewable wind energy.

II.POWER QUALITY ISSUES

When a varying load is connected to the grid the fundamental sinusoidal waveform of current flowing through system will change. This problem will cause non-sinusoidal voltage drop across the network element connected to the grid that leads to distorting the waveform propagation throughout the grid to buses remote from the source. When a varying load is connected to the grid the fundamental sinusoidal waveform of current flowing through system will change. This problem will cause non-sinusoidal voltage drop across the network element connected to the grid that leads to distorting the waveform propagation throughout the grid to buses remote from the source.

III.VOLTAGE FLICKER

The Voltage flicker in the grid describes dynamic variations in the network terminal voltage. The switching action of heavy inductive loads and other large fluctuating loads like arc furnaces, rock crushing machinery sawmills are the major reason for voltage flickering. However, it is of considerable significance for wind farms connected with the network which are,

(i) Frequent switching actions(ON/OFF)

(ii) Subjected to continuous input power variations

Flicker generation due to switching operations arises from the starting and stopping of the wind turbines. Voltage stability problems and collapse occur on grid that are not able to meet the demand for reactive power, are heavily loaded and/or faulted. Interruption occurs in the network when an interrupts the circuit serving a particular customer.

IV. HARMONICS

A wind electric generator directly connected to the grid without a fast acting power electronic switching converter is not expected to distort the fundamental waveform. The addition of Power electronics switches used for soft start and stop may generate high order current harmonics for short duration but their magnitudes are small. The variable speed wind turbines using power electronic converters for these reasons should be assessed against specified or calculated limits controllers are properly controlled. The FACTS controllers are mainly used to normalize terminal voltage and control power flow through the transmission lines. In STATCOM by connecting power

Electronic switches and switching them at exact angles within each 50 Hz cycle an accurate sinusoidal waveform is developed. If the generated voltage in this method is higher than terminal voltage the compensator will supply reactive power as that of synchronous condenser and improve the voltage level and conversely if lower it will remove reactive power from the system. The proposed STATCOM has the potential to maintain its reactive current at low voltage since it has constant current characteristics while a thyristor SVC is constant impedance. The STATCOM proposed here can provide fast capacitive and inductive for harmonics. Now a day’s wind turbine designs use transistor-based converters, which are operated at very high switching frequencies above 3 kHz and their effect on the voltage waveform is usually negligible.

V.POWER QUALITY IMPROVEMENT

The FACTS controllers are mainly based on power electronic controllers that enhance the transferring ability of the line. The power electronic controllers are fast in response and increase the stability limits of the power transmission systems when their associated controllers are properly controlled. The FACTS controllers are mainly used to normalize terminal voltage and control power flow through the transmission lines. In STATCOM by connecting power electronic switches and switching them at exact angles within each 50 Hz cycle an accurate sinusoidal waveform is developed. If the generated voltage in this method is higher than terminal voltage the compensator will supply reactive power as that of synchronous condenser and improve the voltage level and conversely if lower it will remove reactive power from the system. The proposed STATCOM has the potential to maintain its reactive current at low voltage since it has constant current characteristics while a thyristor SVC is constant impedance. The STATCOM proposed here can provide fast capacitive and inductive compensation. STATCOM has the ability to control its output current independent of the network voltage.

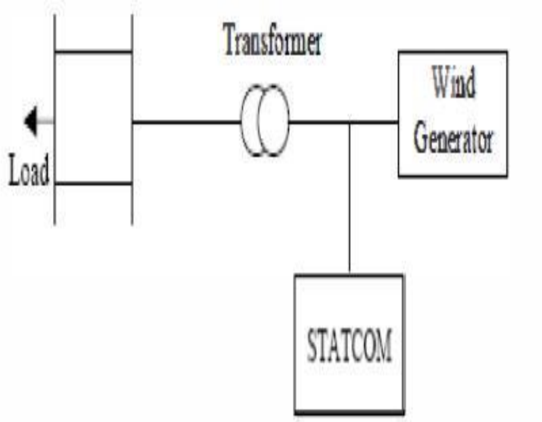

Figure 1. Voltage Fluctuation Mitigation with STATCOM

Figure 1 shows the location of STATCOM to reduce voltage sag. Generally STATCOM is effective shunt compensator used to maintain voltage profile constant. Here the compensator is connected between source and power transformer.

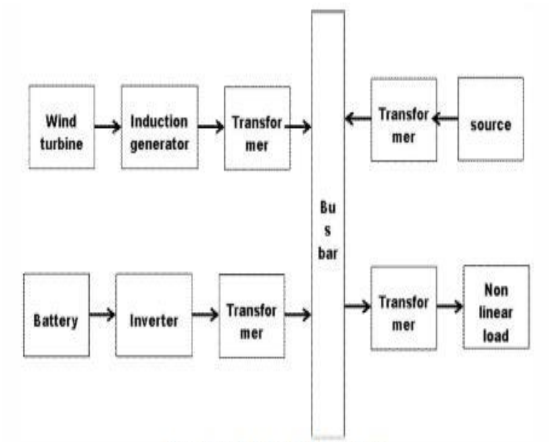

Figure 2. Block Diagram

Figure 2 represents the block diagram of static compensator with non linear load. Normally induction generator IS used in wind energy generating units.

VI. WIND POWER

The first use of wind power was to sail ships in the Nile some 5000 years ago. The Europeans used it to grind grains and pump water in the 1700s and 1800s. The first windmill to generate electricity in the rural U.S.A. was installed in 1890. Today, large wind- power plants are competing with electric utilities in supplying economical clean power in many parts of the world The average turbine size of the wind installations has been 300 kW until the recent past. The newer machines of 500 to 1,000 kW capacities have been developed and are being installed. Prototypes of a few MW wind turbines are under test operations in several countries, including the U.S.A. It is a conceptual layout of modern multi mega watt wind tower suitable for utility scale applicationsMajor factors that have accelerated the wind-power technology development are as follows

- ✓ High-strength fiber composites for constructing large low-cost blades.
- ✓ Falling prices of the power electronics.
- ✓ Variable-speed operation of electrical
- ✓ Generators to capture maximum energy.
- ✓ Improved plant operation, pushing the availability up to 95 percent.
- ✓ Economy of scale, as the turbines and plants are getting larger in size.
- ✓ Accumulated field experience [the learning

A. Conventional Circuit Drawbacks

- ➢ More Voltage fluctuation
- ➢ Reactive power required for magnetization
- ➢ Poor power factor
- ➢ Variable terminal voltage
- ➢ Poor power quality

B.
C. *B. Advantages*

- o Improve the voltage waveform from distortion
- o Improve the power quality
- o Reactive power compensation
- o Maintain constant output voltage

C. Applications

- Power compensation in Grid
- Voltage stability improvement in Grid
- Power and voltage Control in Grid system

D. Simulation

Fig. 6 shows the line model with additional load. It consists source, transformer and main load. Initially load one is connected to the source. At t =0.2 sec additional load is connected to increase the load impedance. Voltage sag occur due to load variation. Fig 3 shows the source side voltage and Fig 4 and 5 shows the peak and RMS load voltage.

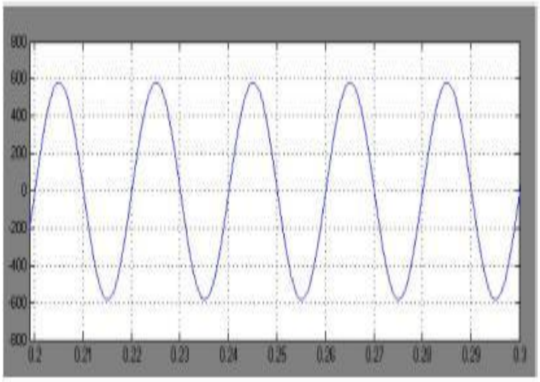

Figure3. Source side voltage

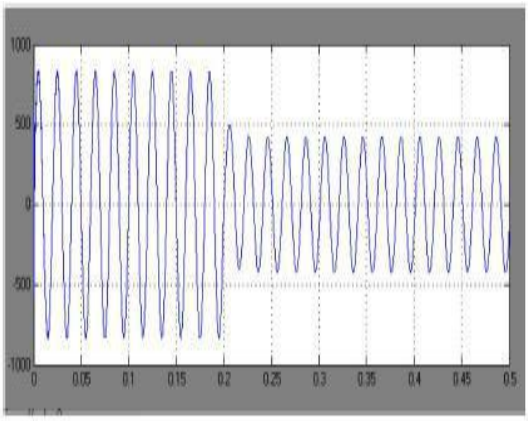

Figure4. Load voltage with sag conditions

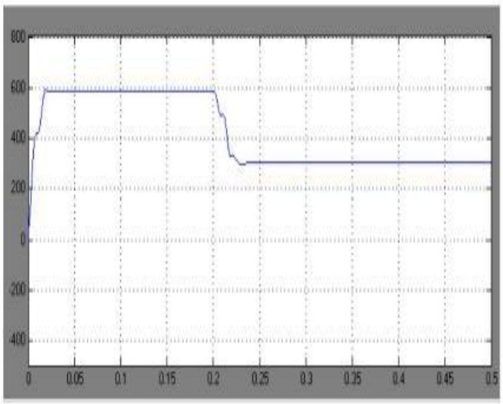

Figure5. RMS Load voltage with sag conditions

Fig 6 shows the line model with additional load and STATCOM model. It consists source, transformer, ST ACOM model and main load. Initially load one is connected to the source. At t =0.2 sec additional load IS connected to increase the load impedance.

Voltage sag occurs due to load variation. At t=0.25 sec the STATCOM IS connected to the system. So that voltage sag is compensated Fig 6 shows the STATCOM model. Fig 7 shows the source side voltage and Fig 8 and 9 shows the peak and RMS load voltage.

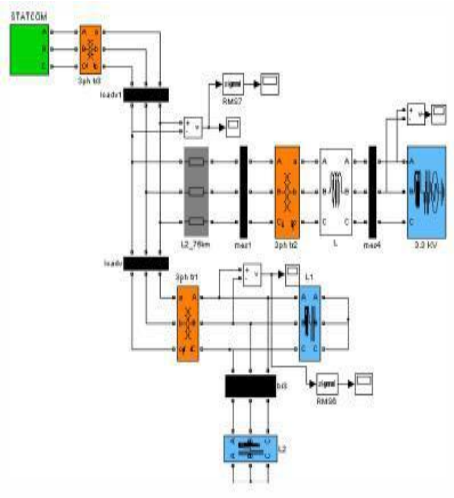

Figure6. Circuit diagram with STATCOM model

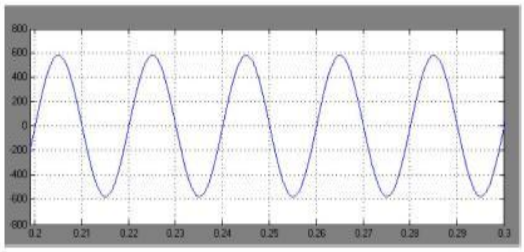

Figure 7.Source side voltage

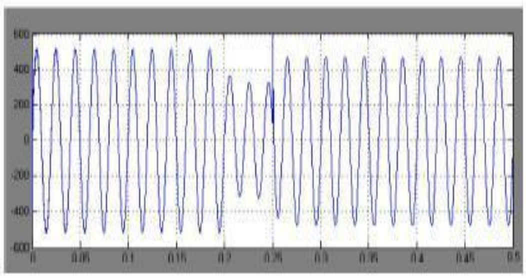

Figure 8.Load voltage with sag conditions

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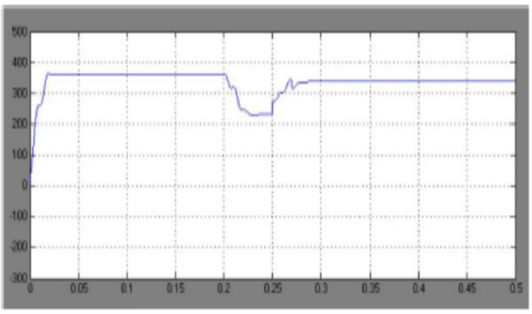

Figure 9.RMS Load voltage with sag conditions

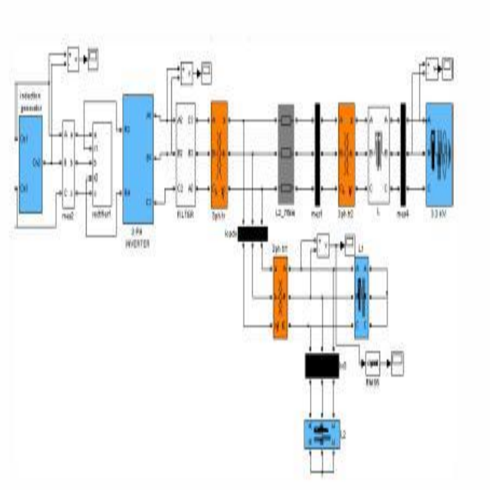

Figure 10.line model with wind and source combination

Fig 10 shows the line model with additional load. It consists wind energy system, source, transformer and main load. Initially load one is connected to the source. At t =0.2 sec additional load is connected to increase the load impedance.

Voltage sag occur due to load variation. Fig 11 shows the source side voltage and Fig 12 and 13 shows the peak and RMS load voltage

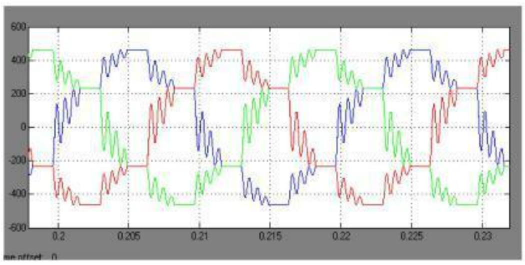

Figure l1.Generator side voltage

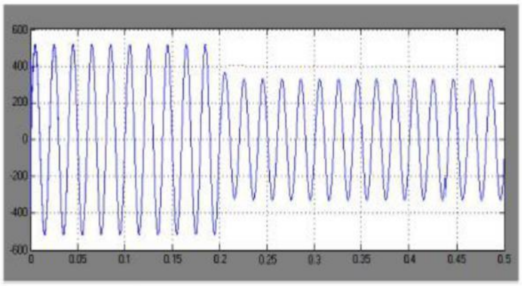

Figure 12.Load voltage with sag conditions

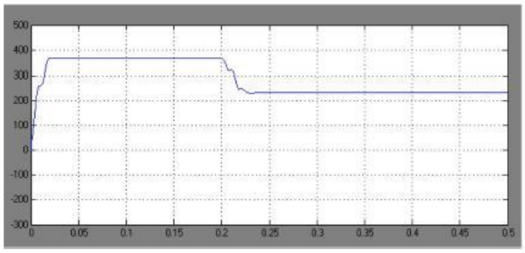

Figure 13.RMS Load voltage with sag conditions

Fig 14 shows the line model with additional load. It consists wind energy system, source, transformer, STATCOM model and main load. Initially load one is connected to the source. At t =0.25 sec additional load IS connected to increase the load impedance.Voltage sag occurs due to load variation. At t=0.3 sec the STATCOM is connected to the system. so that voltage sag is compensated Fig 16 shows the STATCOM model. Fig 15 and 16 shows the wind side and source side voltage and Fig 17 and 18 shows the peak and RMS load voltage.

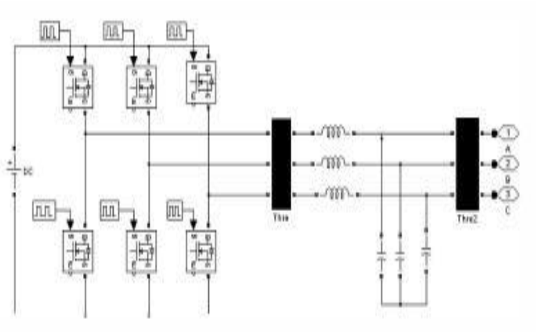

Figure 14.STATCOM circuit diagram

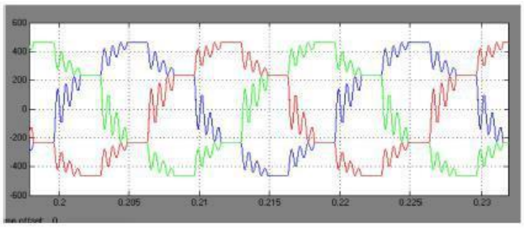

Figure 15.Generator side voltage

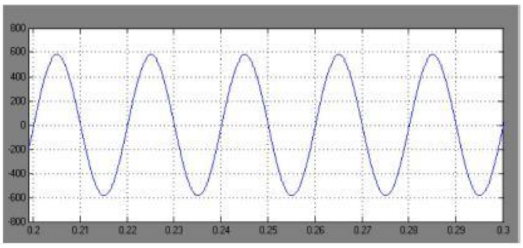

Figure 16.Source side voltage

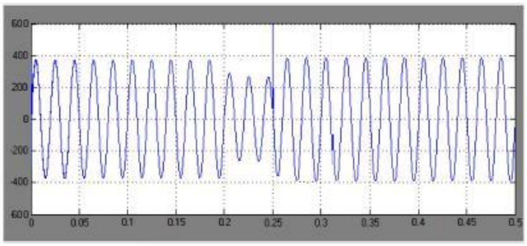

Figure 17. Load voltage with sag conditions

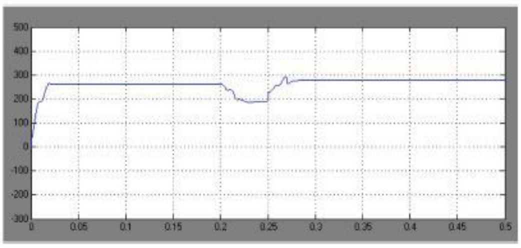

Figure 18.RMS Load voltage with sag condition

VII. HARD WARE IMPLEMENTATION BLOCK DIAGRAM

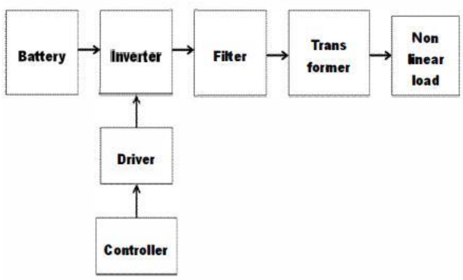

Figure 19.Hardware implementation block diagram

VIII. PIC CONTROLLER

In this paper the hardware is implemented using the PIC- Microcontroller "PIC 16F84A". The advantages of the PIC- microcontroller is that the instruction set of this controller are fewer than the usual micro controller.

The PIC16F84A belongs to the mid-range family of the PIC microcontroller devices.

IX. RESULTS

The distortion caused by the non linear load and wind generator due to wind speed fluctuations are suppressed by the three phase injected currents. The required reactive power for compensation and the compensated current for non linear load are provided by the inverter

X.CONCLUSION

This research presents the STATCOM based control scheme for power quality improvement in grid connected wind generating system and with nonlinear load. The power quality issues and its Consequences on the consumer and electric utility are presented. The operation of the STATCOM in MATLAB/SIMULINK for maintaining the power quality is simulated. It has the capability to cancel out the harmonic parts of the load current. It maintains the source voltage and current in phase and supports the reactive power demand for the wind generator and load at PCC in the grid system, thus it gives an opportunity to enhance the utilization factor of the transmission line. The integrated wind generation and STATCOM have the outstanding performance. Thus the proposed scheme in the grid connected system fulfills the power quality norms as per the IEC standard 61400-21.

In addition, since the STATCOM suppresses the voltage fluctuation, it is apparent that, compared to the case without STATCOM, the switching times of both main transformers and load transformers to address the voltage fluctuation issue in the system shall be significantly reduced. Therefore, the maintenance and replacement cost of and wind turbines can be lowered, and the power quality issues related to the switching of can also be lessened.

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