

STATCOM Based Power Quality Improvement Of Hybrid System

¹Prashant S. Khandekar, ² Asst Prof. Sneha Tibude

¹M.Tech

¹ Department of Integrated Power System

¹Abha Gaikwad Patil College Of Engineering, Nagpur, Maharashtra, India

Abstract : This paper substantiate the conventional energy depleting very fast and the power demand increasing every passing day, it has become absolute necessary to focus on renewable energy. Lots and lots of project are being undertaken which are capable to make use of power from the renewable energy resources like, wind, sun, water etc . The synthesis of these systems (hydro energy, wind energy, solar power etc.) discover different kinds of problems in the grid like system stability problems or power quality issues which needs to be resolved. The most prevailing passive filters were used but at the present time active filters such as Static Synchronous Compensator (STATCOM) and Dynamic Voltage Restorer (DVR) are select for the task. Static synchronous comparator is a device that regulates the voltage level or the reactive power in the system. It is predominantly used to maintain voltage stability, enlargement of critical clearing time. Dynamic Voltage Restorer (DVR) is a voltage restorer that can solve the voltage power quality issues. The purpose of this work to integrate the STATCOM and the DVR for voltage control and harmonics filtering. The simulation will be carried in MATLAB/SIMULINK and results will be presented to validate the claim.

Keywords - STATCOM, DVR (Dynamic Voltage Restorer), WTIG (Wind Turbine Induction Generator)

I. INTRODUCTION

Electrical energy is the most efficient and saleable form of energy and the modern society is heavily dependent on the electric supply. The human existence cannot be imagined without the supply of electricity. At the same time the quality of the electric power supplied is also very important for the efficient functioning of the end user equipment and use of renewable energy has increased through time and integration of renewable energy such as wind, photovoltaic, fuel cell, and tidal to the grid solved many and replenished the exceeding and ascending need for electrical energy. Synthesis of the renewable energy with the grid has lead to a more complex electrical network or "Grid". This enlargement and enrichment in equipment has caused problems such as stability, reliability and power quality and . The issue of power quality is of great importance to the to the wind turbine and there's a need to find solutions to these problems, using different technologies such as smart meters, monitoring system, controllers, remote ability. The synthesis of wind energy into a weak system is a challenge; voltage fluctuation, voltage dips, swells and swags are created due to the uncontrollable resource and the nature of the Distributed Wind Induction Generator (DWIG) on the already weak system. This causes reliability ,stability issues and power quality issues which need to be solved .

The issues are

- 1) Power Quality
- 2) Voltage Variation
- 3) Harmonics

Consequently the power quality issues damage equipment such as Microprocessors, Programmable Logic Controllers (PLC's), Variable Speed Drives (VSD's) and delicate control systems. It may cause the tripping of Contactors and protection devices. It can lead to stopping sensitive equipment such as PC's, and it may stop the process of plant an power quality . The integration of Non conventional energy into a weak system is a challenge; voltage fluctuation, voltage dips, swells and swags are created due to the uncontrollable resource and the nature of the Distributed Wind Induction Generators (DWIG) on the already weak system. This causes reliability, stability issues, and power quality issues which need to be solved.

II. THEORETICAL FRAMEWORK

RENEWABLE ENERGY

Classically passive filters were used but nowadays active filters such as Static Synchronous Compensator (STATCOM) and Dynamic Voltage Restorer (DVR) are chosen for the task. STATCOM is a device that regulates the voltage level and reactive power in the system. It is used to maintain voltage stability, enlargement of critical clearing time. DVR is a voltage restorer that can solve the voltage power quality issues. This objective in this work is to integrate the STATCOM and the DVR for voltage control and harmonics filtering. The simulation will be done in MATLAB/SIMULINK and the combined work of the STATCOM and the DVR in improving the power quality will be shown. The objective of this paper is to define a system at the grid which will help to have an idea of the system at grid level. In this work WTIG along with a non-linear load for harmonics generation is intended to be used. The DVR and STATCOM are used for Active filtering. They cancel the effect of voltage sags and voltage swells by injecting a voltage into the system, and remove the harmonics in the system by injecting a current into the system.

III. LITERATURE SURVEY

[1] M. El- Habrouk, M. Darwish, and P. Mehta, "Active power filters: a review," *IEE Proceedings-Electric Power Applications*, vol. 147, pp. 403-413, 2000.

To overcome the problems caused by harmonics, filters are used. There are different filter topologies present in the literature for this purpose. At first passive filters are used but they are dependent heavily on the system parameters. They also have the problems of resonance with system impedance and are suitable for filtering out a particular frequency harmonics. Therefore, to overcome the problems of passive filters, active filters are used. These are used since 1970's to compensate the reactive power, negative sequence currents. The use of active power filters for power quality improvement is discussed in [2]. In this paper a review of active filter configuration for power quality improvement is presented along with control strategies. It is found that the active filters are facing some drawbacks

when employed for power quality improvement. They are-

- High converter ratings are required
- Costlier when compared to its counterpart, passive filter
- Huge size
- Increased losses

Therefore, to overcome these drawbacks a hybrid power filter which is a combination of active and passive filters is proposed in [3]. This paper discusses how a combination of both active and passive filters is an economical solution for power quality improvement. To enhance the characteristics of passive filter and also the system, the active filter should be controlled properly. There are different control techniques for this purpose.

The main aim of any control technique is to make active filter inject a voltage in to the system that compensates the harmonics. To achieve this output voltage of the active filter is controlled such that it is equal to a pre-calculated reference value. The active filter is controlled better with instantaneous reactive power theory. This is presented in [4] and it discusses the different control algorithms from the formulations of instantaneous reactive power theory. Finally it concludes that Vectorial based theory yields better results with sinusoidal currents when compared with other algorithms. The control of series active in conjunction with shunt passive filter using dual instantaneous reactive power tectorial theory is presented in [5]. In this paper the proposed theory is validated by simulating it in MATLAB SIMULINK environment. The proposed control strategy is simulated for both balance and unbalanced load conditions Power quality are long duration voltage variations (overvoltage, under voltage, and sustained interruptions), short duration voltage variations (interruption, sags (dips), and swells), voltage imbalance, waveform distortion (DC offset, harmonics, inter harmonics, notching and noise), voltage fluctuation (voltage flicker) and power frequency variations. Most reasons of these concerns stems from loads connected to electric supply systems [1], [2]. Measurements for active filter as well as the behaviour of inverter systems with UPS functionality during grid faults where discussed at the end of utility side. Under without APF the total harmonic distortion is 32.8% and by using APF in a DG unit the THD is reduced around 10.2% in non linear loads .By using series APF, the THD value almost reduced to 9.5% [3]. It improves the controlling of excitation and input power of a synchronous generator. PID Controller is used in a generator governor control in frequency of a system. By using Bacteria foraging optimization technique to optimize, the PID gain is used to improve the PQ with the help of MATLAB [4]. Photo voltaic – Fuel cell combination system comprises a PV Panel. A battery bank was connected to the DC bus. Power flow is present in two way of the battery if it is present in charged condition the fuel cell will be turned off. In this case the battery supplies the power to the load. It was verified by Virtual Test Bed (VTB) [5]. A technical review of power quality problems and how the custom devices used to improve the PQ in grid connected renewable energy systems at the point of Common Coupling were discussed [6]. The performance analysis of a shunt active filters with VSI Topology using synchronous frame theory in grid connected PV Panel were discussed. It reduced the harmonic level at the point of common coupling for 3.94% by using shunt active filters [7]. From This study was describes the detailed analysis of different control strategies for a standalone wind energy conversion system using induction generator and It was simulated by MATLAB [8]. An adequate control strategy with a simple three-leg four-wire system is possible to mitigate the power quality disturbances like voltage unbalance, THD and others [9]. The comparative study of two PWM controller techniques is briefly discussed. The current harmonic controls and reactive power compensation was done by using converter as an active shunt filter and the other converter is used to control the voltage sag and swell also it describes about the cost analysis of PV systems .

IV. SYSTEM OPERATION

1) DVR Operation

2) When a wind turbine will be initially connected to the grid, it will needs reactive power for the induction generator to start producing electric power. This will causes the voltage to drop at the Grid. At this instant the (DVR) dynamic voltage restorer should start its operation and compensate for the voltage drop at the critical load.

3) STATCOM Operation

After the wind turbine is initialized and will be running when the Non-Linear load will be connected to the system, the voltage and current at the Grid side will be distorted and will need to be filtered. Here the STATCOM (Active filter) will be activated and will inject the exact existing current into the system needed to cancel the effect of the harmonics. This reference injected current will be generated by the hysteresis control technique.

V. POWER QUALITY ISSUES

Various power quality issues that normally occur in a power system are listed below

a) Voltage Sag Description: A decrease of the normal voltage level between 10 and 90% of the nominal rms voltage at the power frequency, for durations of 0,5 cycle to 1 minute

Causes: Faults on the transmission or distribution network (most of the times on parallel feeders). Faults in consumer's installation. Connection of heavy loads and start-up of large motors.

Consequences: Malfunction of information technology equipment, namely microprocessor-based control systems (PCs, PLCs, ASDs, etc) that may lead to a process stoppage. Tripping of contactors and electromechanical relays. Disconnection and loss of efficiency in electric rotating machines.)

b) Very Short Interruptions Description: Total interruption of electrical supply for duration from few milliseconds to one or two seconds.

Causes: Mainly due to the opening and automatic enclosure of protection devices to decommission a faulty section of the network. The main fault causes are insulation failure, lightning and insulator flashover.

Consequences: Tripping of protection devices, loss of information and malfunction of data processing equipment. Stoppage of sensitive equipment, such as ASDs, PCs, PLCs, if they're not prepared to deal with this situation.

c) Long Interruptions Description: Total interruption of electrical supply for duration greater than 1 to 2 seconds

Causes: Equipment failure in the power system network, storms and objects (trees, cars, etc) striking lines or poles, fire, human error, bad coordination or failure of protection devices.

Consequences: Stoppage of all equipment.

d) Voltage Spike Description: Very fast variation of the voltage value for durations from a several microseconds to few milliseconds. These variations may reach thousands of volts, even in low voltage.

Causes: Lightning, switching of lines or power factor correction capacitors, disconnection of heavy loads.

Consequences: Destruction of components (particularly electronic components) and of insulation materials, data processing errors or data loss, electromagnetic interference.

e) Voltage Swell Description: Momentary increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than one cycle and typically less than a few seconds.

Causes: Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers (mainly during off-peak hours).

Consequences: Data loss, flickering of lighting and screens, stoppage or damage of sensitive equipment, if the voltage values are too high.

f) Harmonic Distortion Description: Voltage or current waveforms assume non-sinusoidal shape. The waveform corresponds to the sum of different sine-waves with different magnitude and phase, having frequencies that are multiples of power-system frequency.

Causes: *Classic sources:* electric machines working above the knee of the magnetization curve (magnetic saturation), arc furnaces, welding machines, rectifiers, and DC brush motors. *Modern sources:* all non-linear loads, such as power electronics equipment including ASDs, switched mode power supplies, data processing equipment, high efficiency lighting.

Consequences: Increased probability in occurrence of resonance, neutral overload in 3-phase systems, overheating of all cables and equipment, loss of efficiency in electric machines, electromagnetic interference with communication systems, errors in measures when using average reading meters, nuisance tripping of thermal protections.

g) Voltage Fluctuation Description: Oscillation of voltage value, amplitude modulated by a signal with frequency of 0 to 30 Hz.

Causes: Arc furnaces, frequent start/stop of electric motors (for instance elevators), oscillating loads.

Consequences: Most consequences are common to under voltages. The most perceptible consequence is the flickering of lighting and screens, giving the impression of unsteadiness of visual perception.

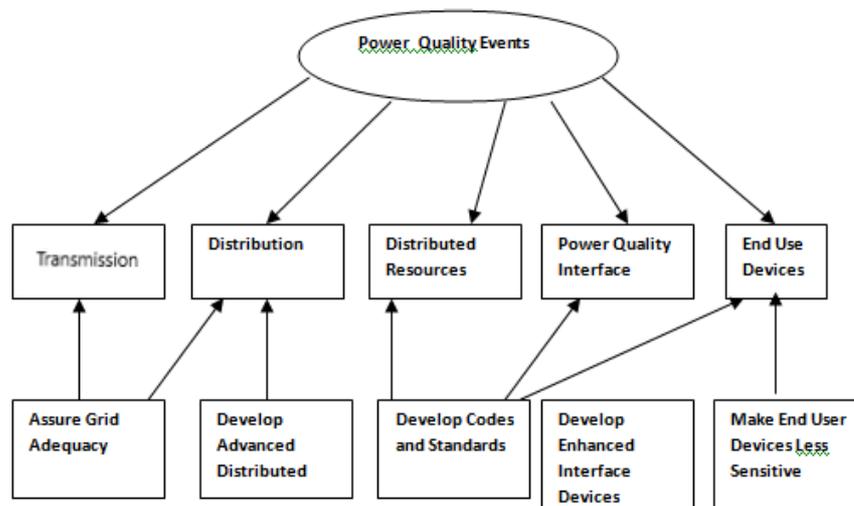
h) Noise Description: Superimposing of high frequency signals on the waveform of the power-system frequency

Causes: Electromagnetic interferences provoked by Hertz an waves such as microwaves, television diffusion, and radiation due to welding machines, arc furnaces, and electronic equipment. Improper grounding may also be a cause.

Consequences: Disturbances on sensitive electronic equipment, usually not destructive. May cause data loss and data processing errors.

VI. POWER QUALITY IMPROVEMENT TECHNIQUES

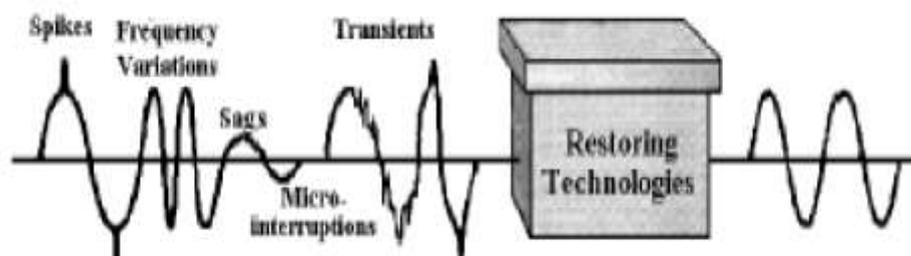
The mitigation of PQ problems may take place at different levels: transmission, distribution and the end use equipment. Several measures can be taken at these level



Figure(1): Power quality issues and solutions

1. Grid Adequacy Many PQ problems have origin in the transmission or distribution grid. Thus, a proper transmission and distribution grid, with adequate planning and maintenance, is essential to minimize the occurrence of PQ problems.

2. Distributed Resources – Energy Storage Systems Interest in the use of distributed energy resources (DER) has increased substantially over the last few years because of their potential to provide increased reliability. These resources include distributed generation and energy storage systems. Energy storage systems, also known as restoring technologies, are used to provide the electric loads with ride-through capability in poor PQ environment.



Figure(2): Principle of power restoration

Recent technological advances in power electronics and storage technologies are turning the restoring technologies one of the premium solutions to mitigate PQ problems. The first energy storage technology used in the field of PQ, yet the most used today, is electrochemical battery. Although new technologies, such as flywheels, super capacitors and superconducting magnetic energy storage (SMES) present many advantages, electrochemical batteries still rule due to their low price and mature technology.

A. Flywheels A flywheel is an electromechanical device that couples a rotating electric machine (motor/generator) with a rotating mass to store energy for short durations. The motor/generator draws power provided by the grid to keep the rotor of the flywheel spinning. During a power disturbance, the kinetic energy stored in the rotor is transformed to DC electric energy by the generator, and the energy is delivered at a constant frequency and voltage through an inverter and a control system. The flywheel provides power during a period between the loss of utility supplied power and either the return of utility power or the start of a back-up power system (i.e., diesel generator). Flywheels typically provide 1-100 seconds of ride-through time, and back-up generators are able to get online within 5-20 seconds.

B. Supercapacitors

Supercapacitors (also known as ultra-capacitors) are DC energy sources and must be interfaced to the electric grid with a static power conditioner, providing energy output at the grid frequency. A supercapacitor provides power during short duration interruptions or voltage sags. Medium size supercapacitors (1 M Joule) are commercially available to implement ride-through capability in small electronic equipment, but large supercapacitors are still in development, but may soon become a viable component of the energy storage field.

VI.

PROPOSED HYBRID MODEL

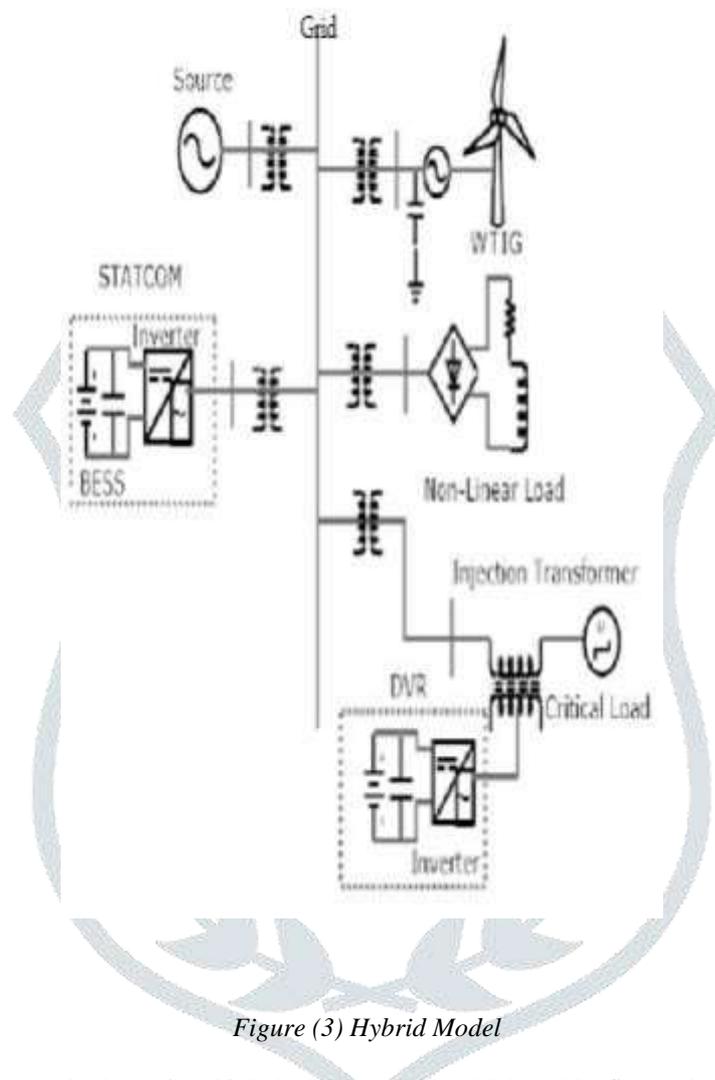


Figure (3) Hybrid Model

The above block shows the proposed scheme in which the DVR and STATCOM. The figure above shows the grid or the infinite bus connected to the grid, it shows the WTIG, a non-linear load for harmonics generation. The static asynchronous compensator (STATCOM) .DVR are used for Active filtering. They cancel the effect of voltage sags and voltage swells by injecting a voltage into the system, and remove the harmonics by injecting a current into the system.

The STATCOM has been identified a fact acting device which can quickly respond to aid in improving the power quality and stability of the wind farms. Previous studies have been limited to reactive power control only. STATCOM supplemented with a Battery storage system can provide more advantage to the wind farm and the associated power systems. Battery energy storage scores over other technologies in terms of low losses. Other technologies, e.g. flywheels, are also suitable and when lifetime and maintenance costs are included, may be preferable. When power fluctuation occurs in the system, the battery energy storage system can be used to level the power fluctuation by charging and discharging operation. Also, during a sag or fault the system can be used to boost the stability margin by absorbing active power from the wind farm. Many STATCOMs have a (limited) transient overload capability and this can be used during sags or faults. We have been able to develop a hybrid system.

VII. RESULT

In this work it is intended to examine the STATCOM hysteresis control technique for harmonic cancellation with load tracing in a system where a wind turbine is present. It will examine the work of the SVPWM operated dynamic voltage restorer (DVR) when connected to a critical load from the same system. A separate control for the STATCOM and the DVR interchanging their roles can be used.

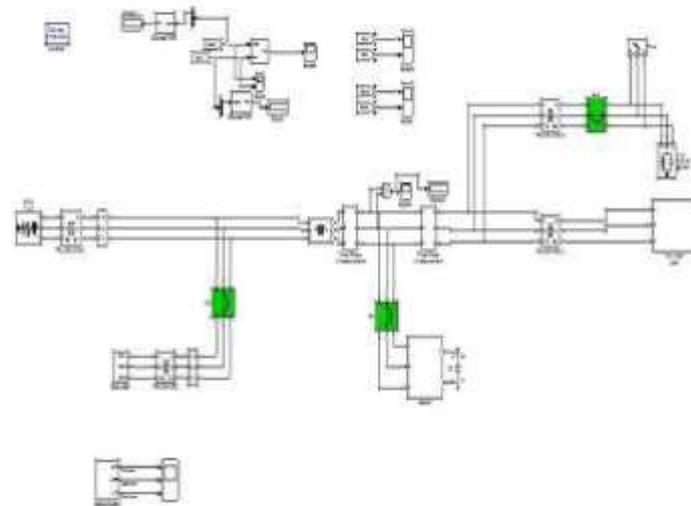


Figure (4): Proposed MATLAB simulation model

We have connected a STATCOM for removal of harmonics and the result of the simulation are given below

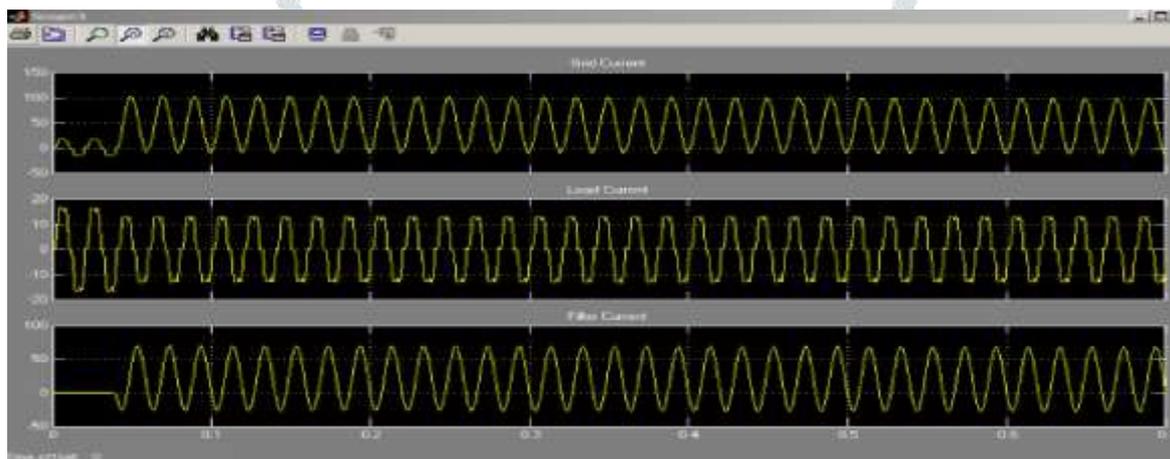
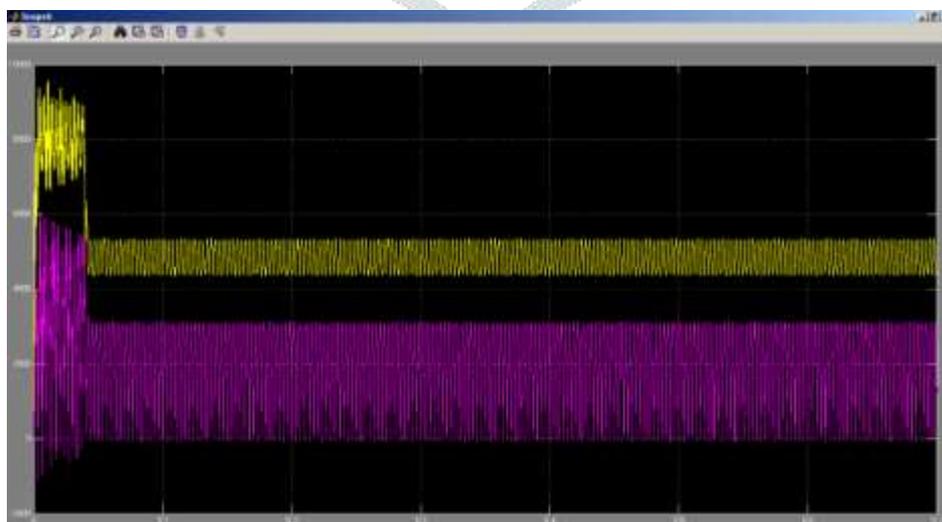
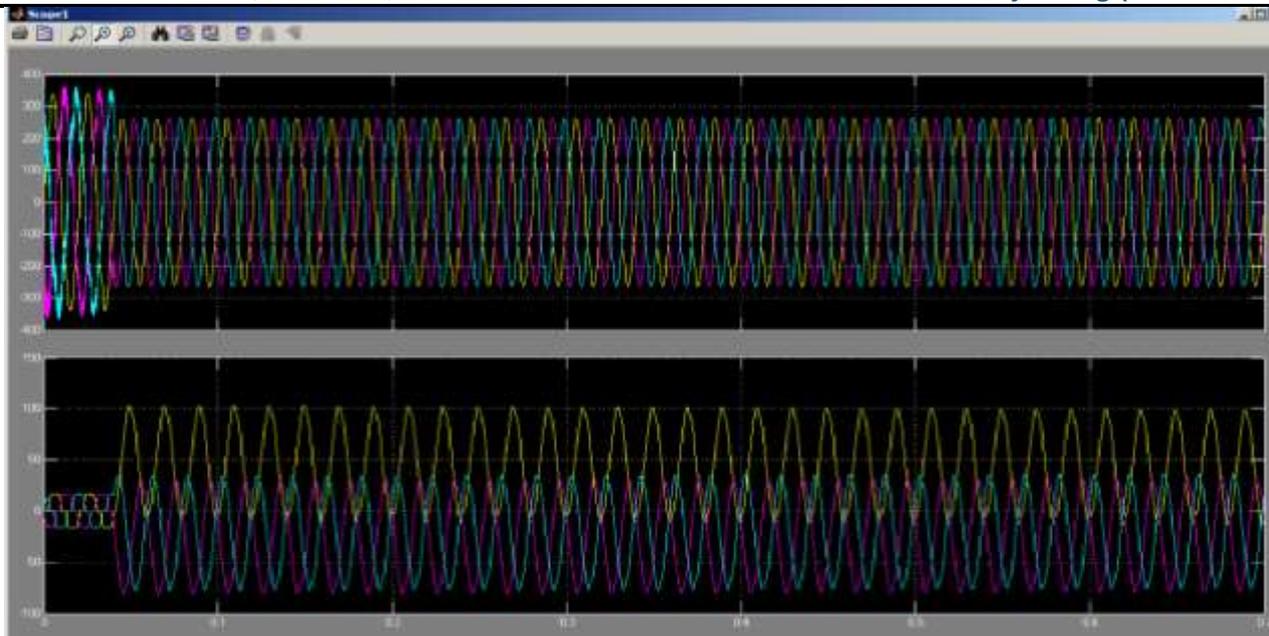


Figure (5): Waveform of Grid Current, Load Current and Filter current



Figure(6): Active power and reactive power of system



Figure(7): Waveform showing harmonic elimination

In above figure we observe that when the STATCOM comes into play at time 0.05 sec, then the harmonics are reduced.

VI. CONCLUSION

After the wind turbine is initialized and will be running and when the Non-Linear load will be connected to the system, the voltage and current at the Grid side will be distorted and will need to be filtered.

Here the STATCOM (Active filter) will be activated and inject the exact existing current into the system needed to cancel the effect of the harmonics. This reference injected current will be generated by the hysteresis control technique, and wind turbine is present and we observe that the STATCOM is able to reduce harmonics.

VII. REFERENCES

- [1] M. El-Habrouk, M. Darwish, and P. Mehta, "Active power filters: a review," *IEE Proceedings-Electric Power Applications*, vol. 147, pp. 403-413, 2000.
- [2] S. K. Jain and P. Agarwal, "Design Simulation and Experimental Investigations, on a Shunt Active Power Filter for Harmonics, and Reactive Power Compensation," *Electric Power Components and Systems*, vol. 31, pp. 671-692, 2003
- [3] Y. Ali, (2012, May 10). Hawa Akkar plans 60-MW wind farm project in Lebanon – See News Renewable. Retrieved February 26, 2015, from <http://renewables.seenews.com/news/hawa-akkarpans-60-mw-wind-farm-project-in-lebanon-274601>
- [4] Bruce G. Colpitts, "Teaching Transmission Lines: A Project of Measurement and Simulation", *IEEE TRANSACTIONS ON EDUCATION*, VOL. 45, NO. 3 AUGUST 2002
- [5] S. W. Mohod and M. V. Aware, 'Power quality issues & its mitigation technique in wind energy generation', 2008 13th International Conference on Harmonics and Quality of Power, pp. 1–6, 2008.
- [6] S. Mohod and M. Aware, 'A STATCOM-Control Scheme for Grid Connected Wind Energy System for Power Quality Improvement', *IEEE Systems Journal*, vol. 4, no. 3, pp. 346-352, 2010.
- [7] M. I. M. Montero, E. R. Cadaval, and F. B. Gonzalez, 'Comparison of Control Strategies for Shunt Active Power Filters in Three-Phase Four-Wire Systems', *IEEE Transactions on Power Electronics*, vol. 22, no. 1, pp. 229–236, 2007.
- [8] A. Ghamri, M. T. Benchouia, and A. Golea, "Sliding-mode Control Based Three-phase Shunt Active Power Filter: Simulation and Experimentation," *Electric Power Components and Systems*, vol. 40, pp. 383-398, 2012.
- [9] M. Popescu, A. Bitoleanu, and V. Suru, "A DSP-Based Implementation of the pq Theory in Active Power Filtering under Non ideal Voltage Conditions," *IEEE Transactions on Industrial Informatics*, vol. 9, pp. 880-889, 2013.
- [10] P. Salmeron and S. P. Litran, "A control strategy for hybrid power filter to compensate four wires three-phase systems," *IEEE Transactions on Power Electronics*, vol. 25, pp. 1923-193, 2010.
- [11] P. Dey and S. Mekhilef, "Synchronous reference frame based control technique for shunt hybrid active power filter under non ideal voltage," *2014 IEEE Innovative Smart Grid Technologies Asia (ISGTASIA)*, Kuala Lumpur, 2014, pp. 481-486.