Reactive Power Compensation using STATCOM

Niharika Rana
Department of Electrical Engineering
Geeta Institute of Management and technology, KURUKSHETRA

Surekha Aggarwal
Department of Electrical Engineering
Geeta Institute of Management and technology, KURUKSHETRA

ABSTRACT
Flexible ac Transmission system (FACTS) have emerged in power system because of the development of power electronics components for high voltage and power. The FACTS devices provide higher controllability in power system by means of power electronic devices. The Power quality management is the key issue in electrical power system and industries are facing this issue around the world. There are various methods for improving power quality in power system as Hybrid-filter configuration with PI controllers, Three-Phase programmable voltage source with Discrete PWM generator, Voltage Sag & Swell based on SPWM technique, STATCOM, VSC. The system ismodeled by using SIMULINK in MATLAB

Keywords
Powerquality, Voltage Source Converter (VSC), STATCOM, PWM Generator

1. INTRODUCTION
Now-a-days, it can be prove that with growing high power demand andline-length the opportunity for FACTS devices gets more important. Wind is the fastest growing energy in the world.The devices work electrically as fast current, voltage or impedance controllers. In the past 5-6 years the use of wind energy has been grown 28% yearly, and becomes the most developed invention among various technologies in universe. Basically, there are two types of FACTS, one is based on voltage source converters and other is based on Thyristor valve operation. Today, wind power capacity of the world is 50 GW and is assumed up to 160 GW. The FACTS devices based on VSCs gives a controllable voltage magnitude & Phase angle due to a Pulse Width Modulation (PWM) technique. However, the interconnection of grid with the wind turbine causes many problems. The STATCOM (Static Compensator) is a shunt connected device that is capable of providing reactive power support to a network away from the generators. Although, this reactive power injection, the STATCOM can regulate the voltage at the connection node.

Wind turbine systems are classified into two types: variable speed wind-turbines & fixed speed wind Turbines. In Variable speed wind-turbines, by changing the rotor speed fluctuations caused by wind variations can be absorbed. In fixed speed wind- turbines are directly connected to the grid. In this, reactive power cannot be controlled, which affects the power quality. The power quality devices are power electronic converters connected in either series or parallel with the lines and the operation is processed by a digital controller. To develop and sustain the present economy &society, the social,economic, environmental sustainability are required in the emerging future trends of energy. Faults in power system can cause voltage dip at the point of interconnection with wind turbine.Although this situation results in an accidently increase in the rotor as well as the stator winding of generator.For economical & social growth, the prime movers are necessary. The electrical energy is the main prime mover. The sustainability & reliability of the power supply are required for the growth of electrical power systems. Both electrical quantities are mostly required for the power quality of electricity. The issue power quality has turn out to be one of the most necessary issue in the power industry.In the power utility DSs (Distribution systems) the power quality problem are not new, but now-a-days due to the public awareness these problems are at peak point. By invention of the modern technology in these devices has pulled a revolution in power electronics over the last decade and there is a direction to the technocrats to continue this trend.

With more characteristics of power electronics based appliances in the industry, the harmonics arises, which is more serious and dangerous. High-fault currents can also destroy the stator & rotor windings. From the beginning-to-end, harmonic distorted current areinjected into power, Power coupling capacitor (PCC), which occurred by the non-linear loads. The harmonics generatedcause many problems and affect the electrical utility connected with the power supply.
The voltage harmonics produce, when the non –sinusoidal current passes from different impedances in power system the power system devices & components are affected due to propagation of voltage in power system. The essential harmonic source is AC/DC converters &inverters. Hence, due to these above mentioned issues there is a need of power quality improvement techniques which can limit the voltage & current harmonics, also balance the input supply and improve power factor. The power quality problem occurs due to any of the voltage, current or frequency distortion from sinusoidal behavior. These devices generate harmonics and reactive power. Harmonics not only affect the normal work state of electrical utility, but also distort the communication.

1.1 STATCOM
STATCOM is normally a VSC (Voltage Source Converter) , that converts a DC voltage at its input side into three- phase AC voltages at fundamental frequency of controlled Phase-angle & magnitude . Voltage Source Converter use PWM technique, which makes it able to provide high quality AC output voltage to the grid/load .The basic principle ofcontinuous operation of STATCOM, is by connecting VSC to DC capacitor to generate AC Voltage source behind transformer leakage reactance.
It is a custom power device based on VSC shunt connected to the grid. By passing a controllable current, it can enhance the quality of load current. However, a STATCOM can also improve voltage dip by injecting current at the point of connection with the grid.

2. P-Q STANDARDS, ISSUES & ITS CONSEQUENCES
International Electro-Technical Commission specifications - The specifications are provided for measurement of power quality of wind turbine. The International Standards are enhanced by the working group of technical –committee-88 of the International Electro-Technical commission (IEC), IEC standard 61400-21, describes the procedure for obtaining the power quality characteristics of the wind turbine. The norms are specified- [1.] IEC 61400-13: Wind turbine measuring procedure in determining the power behavior.[2.] IEC 61400-12: Wind turbine performance. (B) Harmonics- The harmonic voltage & current could be limited to usable level at the point of connection to the network. The harmonic result due to operation of power electronic converters. To get the harmonic voltage within limit, each source of harmonic can allow only a limited contribution.(C) Variation of Voltage- The variation of voltage issue results from the generator torque & wind velocity. The voltage variation is directly linked to Real & Reactive power variations

The variation of voltage is classified as -
1. Voltage Swell

2. Short Interruptions
3. Voltage Sag
4. Long duration variation of voltage

Consequences of the Issues- The voltage variation, Flicker, Harmonics causes the malfunction of equipment namely Microprocessor based control system, Programmable Logic Controller (PLC), Adjustable speed drives, Flickering of light &screen. It may results to tripping of protection devices, tripping of contractors, stoppage of sensitive equipment like PLC, PC system and may stop all the processing and even can cause damage ofutilities. Thus it degrades the power quality in the grid.

2.1 TOPOLOGY FOR P-Q IMPROVEMENT

The STATCOM based current control voltage source inverter injects current into the grid in such a way that their phase angle with source voltage has desired value and the source current are harmonic free .The injected current will cancel out the harmonic part &reactive part of the load and the current in induction generator, thus it improves the power quality& power factor. To manipulate these goals, the grid voltages are sensed and are synchronized for the inverter in generating current.

3. SYSTEM OPERATION

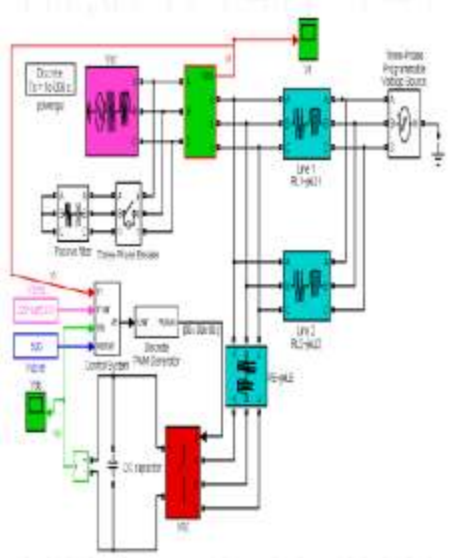


Fig. 1. Three –phase programmable voltage source with discrete PWM generator in STATCOM

The model shown in Fig. 1, where the STATCOM includes the control system. The initial conditions are zero,the reference voltage for the DC capacitor is 500 volts, and the modulation index is mf=15 (900 hz). Here, the passive filter has been connected at bus 1 in order to drain the harmonic currents. The shunt transformer, the line 1 & line 2 represented by RL branches whose impedances are respectively.

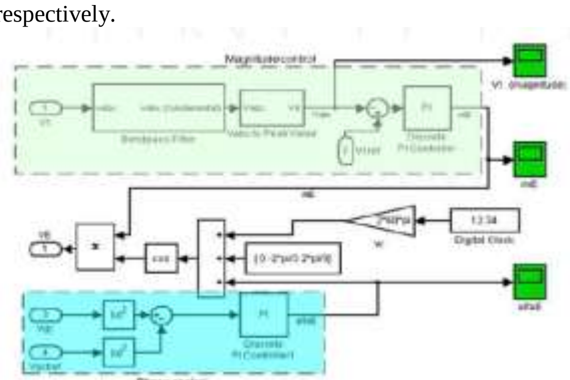


Fig. 2. STATCOM PI Control system (a.) Main Unit

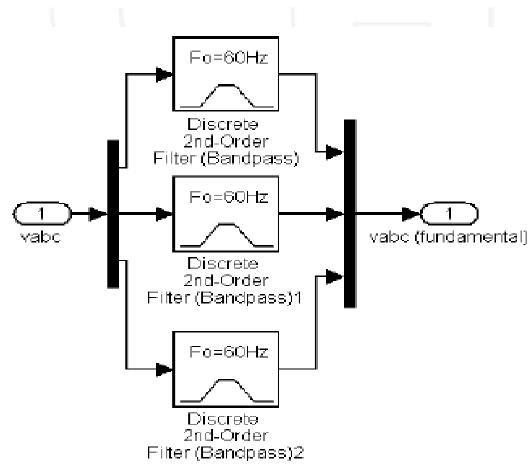


Fig. 2.(b) Band Pass Filter

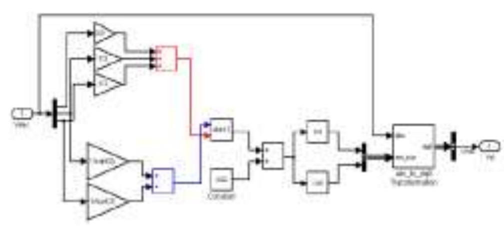
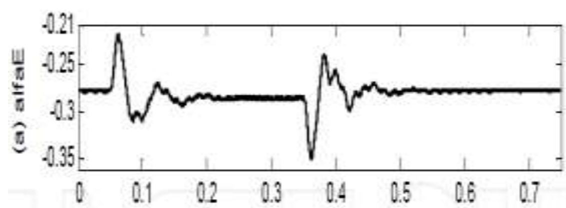


Fig. 2 (c) Vabc to Peak Value

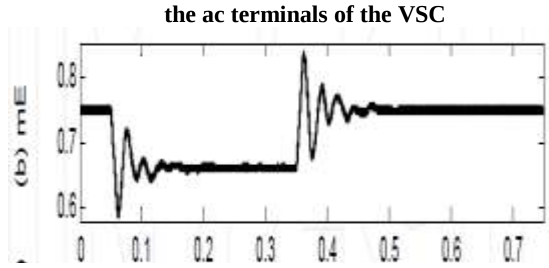
The test case is in periodic steady state, at t=0.05s, the initial operating point is re-established, the voltage magnitude of the three phase programmable voltage source is increased by 15 % and finally t=0.35s. STATCOM is divided into two parts, firstly the three-phase breaker is open, and consequently the passive filter is disconnected. In the second part, allowing the filtering function, the three-phase breaker is closed. The passive filter is represented as a RC branch with R=0.5 ohmC=80 uf.

4. SIMULATION RESULTS



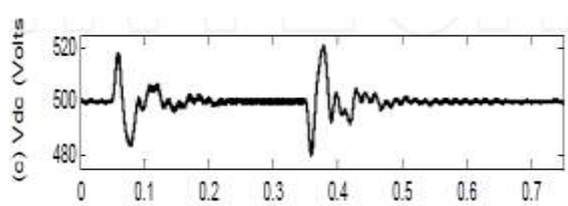
Time (s)

Fig 4. (a) Selected Transient Waveform of the STATCOM without Passive Filter with Phase –angle of the voltage at the ac terminals of the VSC



Time (s)

Fig. 4(b) Amplitude Modulation Ratio



Time (s)

Fig. 4(c) Voltage across the DC Capacitor

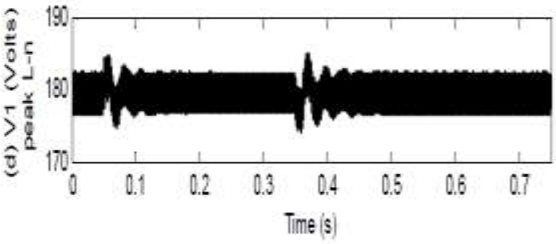


Fig 4(d) Peak line-to-neutral voltage at bus 1

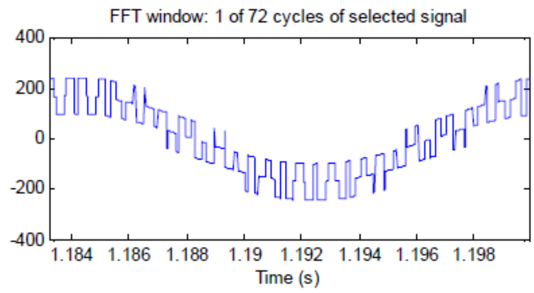


Fig. 5(a) Steady State Waveform of the voltage at bus 1 Without Passive Filter

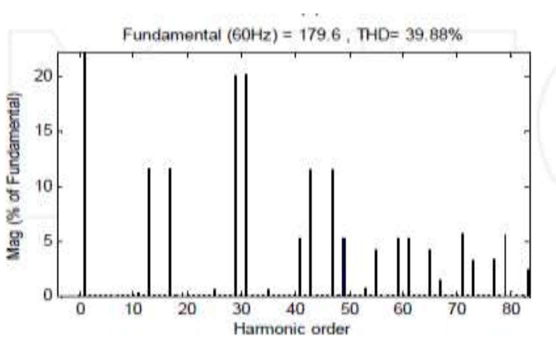
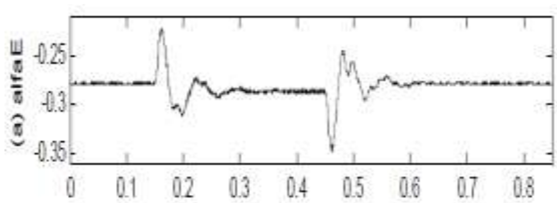
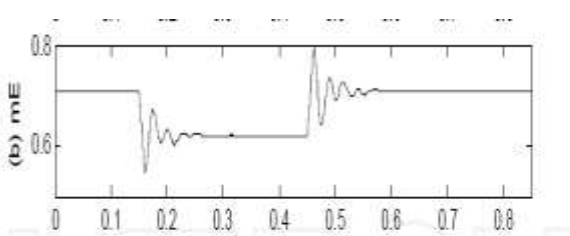


Fig. 5(b) Harmonic Spectrum



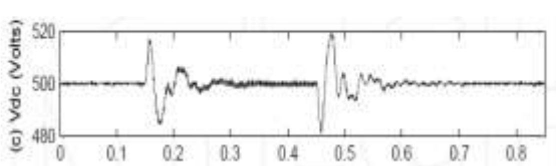
Time (s)

Fig. 6 (a) Selected Transient Waveform of the STATCOM with Passive Filter (Phase-angle of the voltage at the ac terminals of the VSC)



Time (s)

Fig. 6(b) Amplitude Modulation Ratio



Time (s)

Fig. 6 (c) Voltage across the DC capacitor

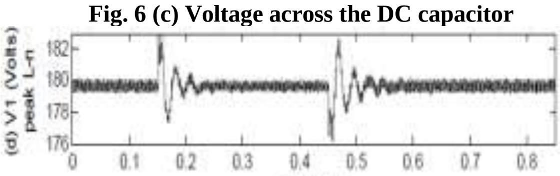


Fig 6 (d) Peak Line- to- neutral voltages at bus 1

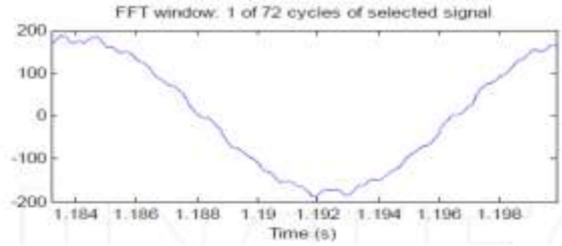


Fig 7 (a) Steady State Waveform of the voltage at bus 1 with Passive Filter

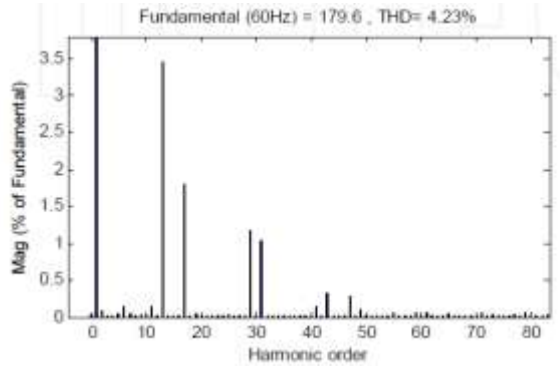


Fig. 7(b) Harmonic Spectrum

5. CONCLUSION

In this paper,STATCOM based FACTS devices based on VSC in SIMULINK has been studied. The presented model can be used in order to analyze the Dynamic and the periodic steady state characteristics of the FACTS components.The implementation has been carried out by taking into account the control systems.

6. REFERENCES

[1] Hamad, A.E., 1986. "Analysis of Power System Stability Enhancement by Static VAR Compensators", IEEE Transactions on Power Systems, 1(4): 222-227.

[2] Hingorani, N.G. and L. Gyugyi, 1999. "Understanding FACTS", IEEE Press, New York.

[3] Hosseini, S.H and O. Mirshekhar, 2001. "Optimal Control of SVC for Subsynchrnous Resonance Stability in Typical Power System", Proc. ISIE, 2: 916-921.

[4] Machowski, J., 1997. "Power System Dynamics and Stability", John Wiley and Sons.

[5] Oliveria, S.E.M., 1994. "Synchronizing and damping torque coefficients and power system steady state stability as affected by static Var compensators", IEEE Transactions on Power Systems, 9(1): 109-116.

[6] Uzunovic, E., 2001. "EMTP, transient stability and power flow models and controls of VSC based facts controllers", PhD Thesis, Waterloo University, Ontario, Canada.

[7] Wang, H and F. Li, 2000. "Multivariable Sampled Regulators for the Coordinated Control of STATCOM AC and DC Voltage", IEE Proc.- Gener. Transm. Distrib, 147(2): 93-98.

[8] Wang, H.F and F. Li, 2000. "Design of STATCOM Multivariable Sampled Regulator", Int. Conf. on Electric Utility Deregulation and Power Tech, City University, London.

[9] Wang, H.F., 1999. "Phillips-Heffron Model of Power Systems Installed with STATCOM and Applications", IEE Proc. Gener. Trans. Distr, 146(5): 521-527.

[10] Hingorani, N. G., & Gyudyi, L. (2000). Undestanding FACTS, IEEE Press, 078033455, New York.

[11] Mahyavanshi, B., & Radman, G. (2006). A Study of Interaction Between Dynamic Load and STATCOM. Proceedings of the 38th southeastern symposium on system theory, 0-7803- 9457-7, Cookeville, TN, march 2006.

[12] Padiyar, K. R. (2007). FACTS Controller in Power Transmission and Distribution, New Age, 978- 81-224-2142-2, NewDelhi.

[13] Segundo-Ramirez, J., & Medina, A. (2009). Modeling of FACTS Devices Based on SPWM VSCs. IEEE Transaction on Power Delivery, Vol. 24, No. 4, (November 2009), pp. 1815-1823, and 0885-8977.

[14] Segundo-Ramirez, J., & Medina, A. (2008). Periodic Steady-State Solution of Electric Systems Including UPFCs by Extrapolation to the Limit Cycle. IEEE Transaction on Power Delivery, Vol. 23, No. 3, pp. 1506-1512.

[15] Zhang, X.-P., Rehtanz, C., & Pal, B. (2006). Flexible AC Transmission Systems: Modelling and Control, Springer-Verlag. 978-3-540-30606-1, Germany.