POWER QUALITY IMPROVEMENT USING THREE PHASE SERIES ACTIVE POWER FILTER

Shital Sahare[1], Sagar B. Kudkelwar[2]

[1]PG Scholar, Electrical Power System, Electrical Engineering Department, Ballarpur Institute of Technology, Ballarpur, Chandrapur, Maharashtra, India
[2]Assistant Professor, Electrical Engineering Department, Ballarpur Institute of Technology, Ballarpur, Chandrapur, Maharashtra, India

ABSTRACT

Commercial buildings include the office buildings of IT companies, educational institutions, apartments, airports, etc. The typical loads in these commercial buildings comprise of many single- phase and three phase loads which includes non-linear loads like electronic and magnetic ballasts, switched mode power supplies (SMPS), air-conditioning systems, lifts, pumps, server, IT equipment, printers, small and large UPS, refrigerators, photocopier machines, office automation accessories, fire- Fighting systems. These loads are highly sensitive for any input variations in voltage. The performance of the electrical equipment gets worsened if they are supplied with polluted or distorted voltage.
A number of solutions are available in the present day practice like power factor correction system with detuned filter, capacitor banks and series reactors to mitigate harmonics, improve power factor, avoid electrical resonance. Practically passive filters are still used though they have fixed compensation and the threat of resonance.
Solutions to these problems can be of two ways- one is to change the design of the systems so that the problem gets reduced and the other is to find a remedy for the existing system. The different loads are classified according to the problems raised by them and to highlight the various practical solutions that can solve them to a great extent.
This paper focuses on modeling and analysis of Custom Power Device (SAPF). MATLAB/Simulink based models for Series Active Power filter (SAPF) is presented. Among various PWM techniques, hysteresis band voltage control PWM is popularly used because of its simplicity of implementation. This known technique does not need any information about system parameters. The SAPF is simulated for different voltage variations at input generated by the three phase programmable source and the results are presented

Keyword: - *Series Active power filter (SAPF), Power Quality.*

---

1. INTRODUCTION

Power quality phenomena include all possible situations in which the waveform of the supply voltage (voltage quality) or load current (current quality) deviate from the sinusoidal waveform at rated frequency with amplitude corresponding to the rated rms value for all three phases of a three-phase system [1]. The wide range of power quality disturbances covers sudden, short duration variations, e.g. impulsive and oscillatory transients, voltage sags, short interruptions, as well as steady state deviations, such as harmonics and flicker. One can also distinguish, based on the cause, between disturbances related to the quality of the supply voltage and those related to the quality of the current taken by the load [2].
To the first class covers voltage dips and interruptions, mostly caused by faults in the power system. These disturbances may cause tripping of “sensitive” electronic equipment with disastrous consequences in industrial plants where tripping of critical equipment can bear the stoppage of the whole production with high costs associated. One can say that in this case it is the source that disturbs the load. To avoid consistent money losses, industrial customers often decide to install mitigation equipment to protect their plants from such disturbances.

The second class covers phenomena due to low quality of the current drawn by the load. In this case, it is the load that disturbs the source. A typical example is current harmonics drawn by disturbing loads like diode rectifiers, or unbalanced currents drawn by unbalanced loads. Customers do not experience any direct production loss related to the occurrence of these power quality phenomena. But poor quality of the current taken by many customers together will ultimately result in low quality of the power delivered to other customers [3]. Both harmonics and unbalanced currents ultimately cause distortion and respectively, unbalance in the voltage as well.

Therefore, proper standards are issued to limit the quantity of harmonic currents, unbalance and/or flicker that a load may introduce. To comply with limits set by standards, customers often have to install mitigation equipment .

In recent years, both industrial and commercial customers of utilities have reported a rising tide of misadventures related to power quality. The trouble stems from the increased refinement of today's automated equipment, whether variable speed drives or robots, automated production lines or machine tools, programmable logic controllers or power supplies in computers. They and their like are far vulnerable to disturbances on the utility system than were the previous generation of electromechanical equipment and the previous less automated production and information systems. A growing number of loads is sensitive to customers' critical processes which have costly consequences if disturbed by either poor power quality or power interruption.

For the reasons described above, there is a growing interest in equipment for mitigation of power quality disturbances, especially in newer devices based on power electronics called "custom power devices" able to deliver customized solutions to power quality problems. The term Custom Power describes the value-added power that electric utilities and other service providers will offer their customers in the future. The improved level of reliability of this power, in terms of reduced interruptions and less variation, will stem from an integrated solution to present problems, of which a prominent feature will be the application of power electronic controllers to the utility distribution systems and/or at the supply and of many industrial and commercial customers and industrial parks.

The compensating devices are used for active filtering; load balancing, power factor correction and voltage regulation. The active power filters, which eliminate the harmonics, can be connected in both shunt and series. Shunt active power filter can perform power factor correction, harmonic filtering when connected at the load terminals. The harmonic filtering approach is based on the principle of injecting harmonic current into the AC system, of the same amplitude and reverse phase to that of the load current harmonics.

Dynamic Voltage Restorer (DVR) is a series connected device. The main purpose of this device is to protect sensitive loads from sag/swell interruptions in the supply side. This is accomplished by rapid series voltage injection to compensate for the drop/rise in the supply voltage. Since this is a series device, it can also be used as a series active power filter. Unified Power Quality Conditioner (UPQC) [4-8] is a very versatile device that can inject current in shunt and voltage in series simultaneously in a dual control mode. Therefore it can perform both the functions of load compensation and voltage control at the same time.

2. SERIES ACTIVE POWER FILTER (SAPF)

The series active power filter is a power quality device, which can protect these industries against the bulk of these disturbances, i.e. voltage sags and swells related to remote system faults. A series APF compensates for these voltage excursions, provided that the supply grid does not get disconnected entirely through breaker trips

2.1. Principal of operation

Active power filter is a very useful tool to improve the power quality of electrical distribution network. The main function of a series active power filter is the protection of sensitive loads from supply voltage sags, swells and harmonics. The series filter is connected between the supply and load terminals using three single phase transformers. The primary windings of these transformers are star connected and the secondary windings are connected in series with the three-phase supply. In addition to injecting the voltage, these transformers are used to filter the switching ripple of the series active filter. A small capacity rated RC filter [1] is connected across the secondary of each series transformer to eliminate the high switching ripple content in the series active filter injected voltage. The voltage source inverters for both the active filters are implemented with IGBTs (Insulated Gate Bipolar Transistors). The general structure of active power filter under study is presented in Fig.1. Series active power filter is composed of 3-phase voltage source converter, Lf, Cf filter to suppress switching ripples and series transformers which inject the compensating voltage to the line.

The Series Active Power Filter performances will depend essentially on the dynamics of the modulation technique used to control the switches and on the method used to determine active filter voltage references. The control scheme of series active power filter is composed of two main blocks: the disturbance identification block and the voltage control. For identification of voltage references, a robust PLL system is used in this paper.

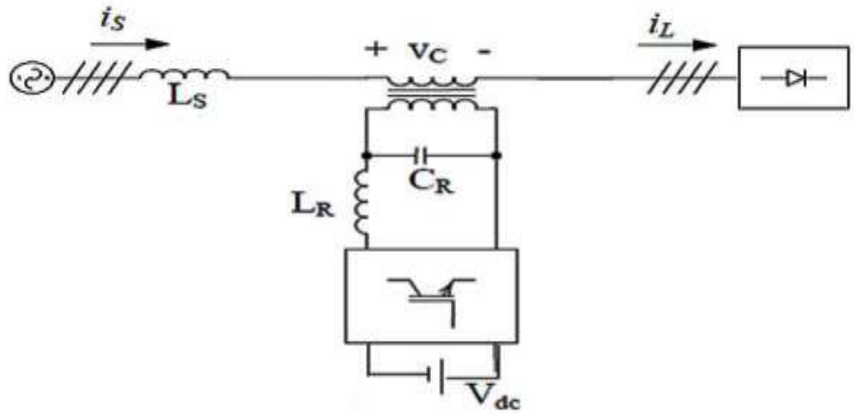

Fig-1: Schematic diagram of series active filter

Among various PWM techniques, hysteresis band current or voltage control PWM is popularly used because of its simplicity of implementation. This known technique does not need any information about system parameters.

2.2. Control Scheme of Series Filter

A simple algorithm is developed to control the series and shunt filters. The series filter is controlled such that it injects voltages (V_{ca}, V_{cb}, V_{cc}) which cancel out the distortions and/or unbalance present in the supply voltages **(***Vsa ,Vsb ,Vsc* **)** thus making the voltages at the PCC (*Vla, Vlb, Vlc)* perfectly balanced and sinusoidal with the desired amplitude. In other words, the sum of the supply voltage and the injected series filter voltage makes the desired voltage at the load terminals. The control strategy for the series AF is shown in Fig. 2.

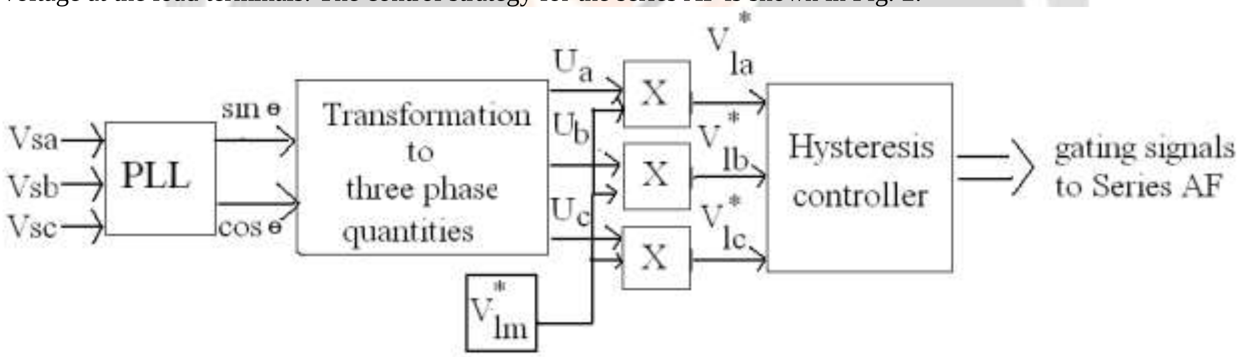

Fig.-2: Control Scheme of Series APF

The hysteresis controller generates the switching signals such that the voltage at the PCC becomes the desired sinusoidal reference voltage. Therefore, the injected voltage across the series transformer through the ripple filter cancels out the harmonics and unbalance present in the supply voltage. The MATLAB/Simulink model of the control scheme for series active filter is shown in Fig. 3.

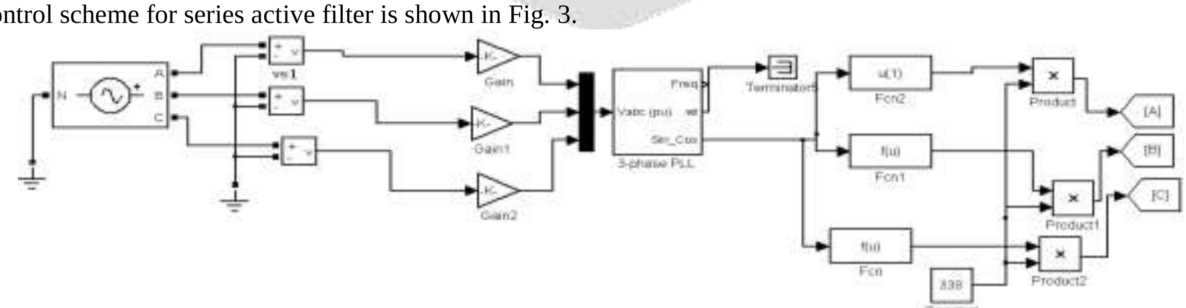

Fig-3: Reference voltage generator

The system voltage which is fully distorted is shown in Fig. 4.

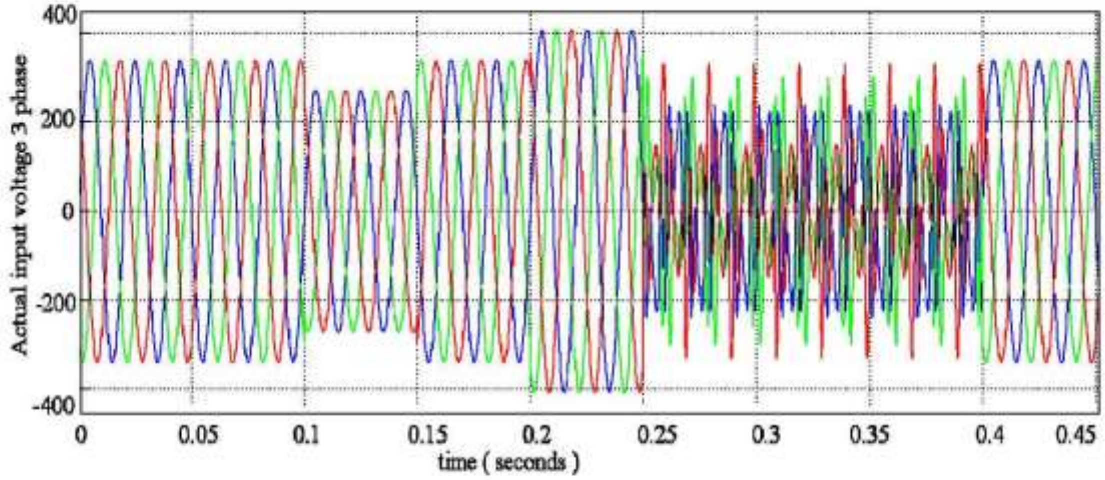

Fig-4: Input voltage with distortions

The reference voltages are generated by the Reference voltage generator block is shown in Fig. 5.

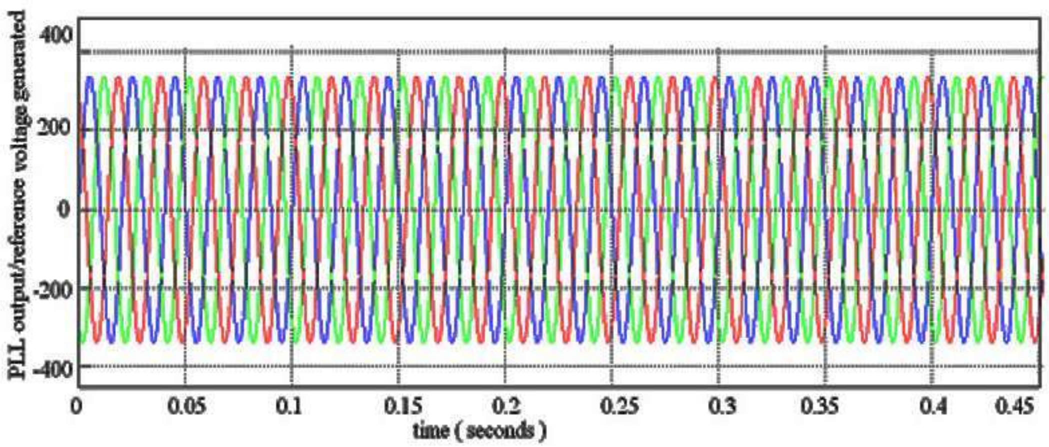

Fig-5: Reference voltage generated

After comparing the reference voltages with the load voltage the error signal is passed through Relay block. Based on comparing the reference voltages with load voltages in a voltage hysteresis controller (Fig. 6), gating pulses (Fig. 9) are generated and given to IGBTs to compensate the disturbances in the system.

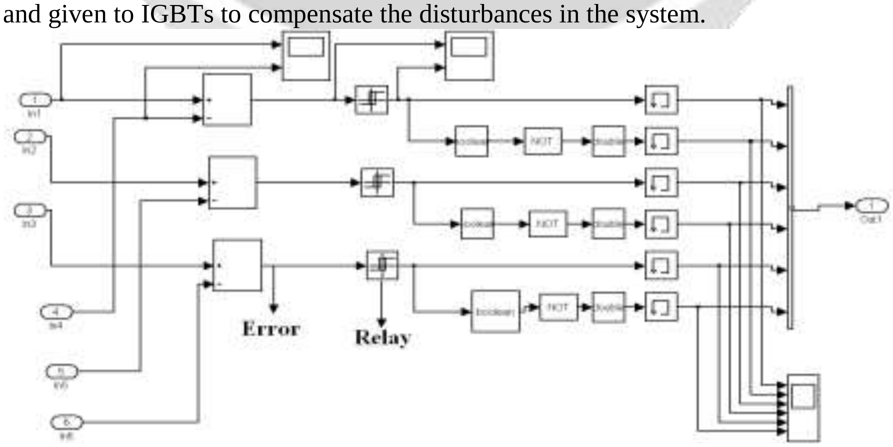

Fig-6: Hysteresis voltage controller

The vector difference between the reference voltage and the actual voltage is error voltage, which is given as the input to the relay block. The Relay function parameters simulated in MATLAB is shown in Fig. 7 and the respective pulses produced for the upper switch, leg1 of SAPF is shown in Fig. 8.

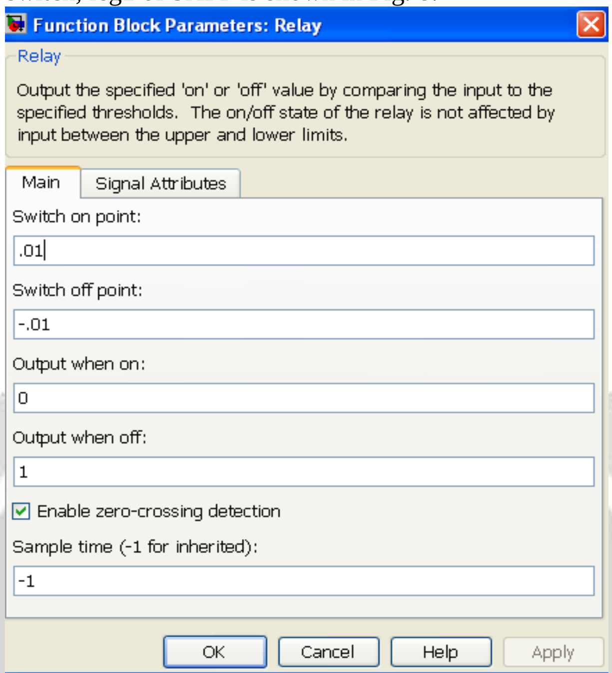

Fig-7: Relay function parameters

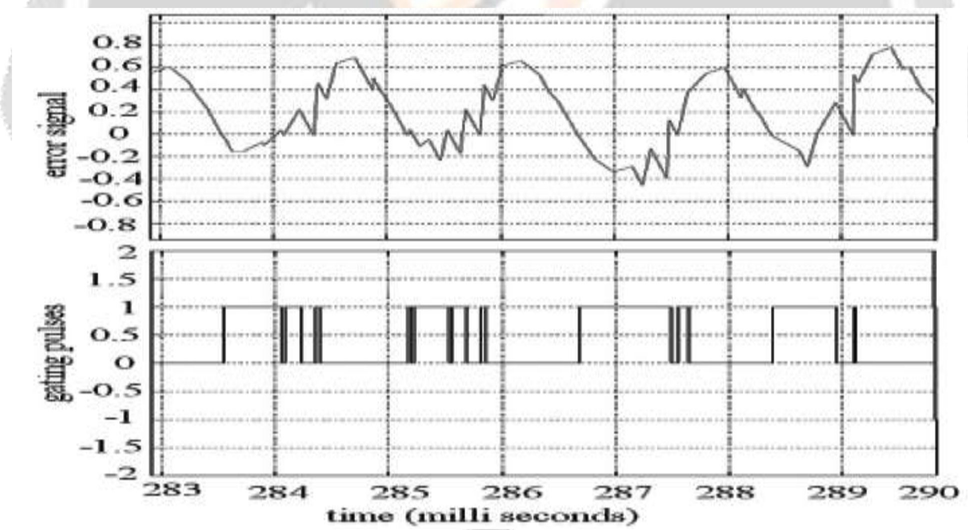

Fig-8: Error signal & PWM pulses generated for the 1st top leg of SAPF

The gating pulses produced by the hysteresis voltage controller are given to the inverter switches as shown in Fig. 9. The main advantage here to use a hysteresis band controller over a P-I controller is that the former does not require the specifications regarding the system parameters i.e. switching frequency, load angle etc. but the latter controller (P-I) requires an additional design criteria for its application.

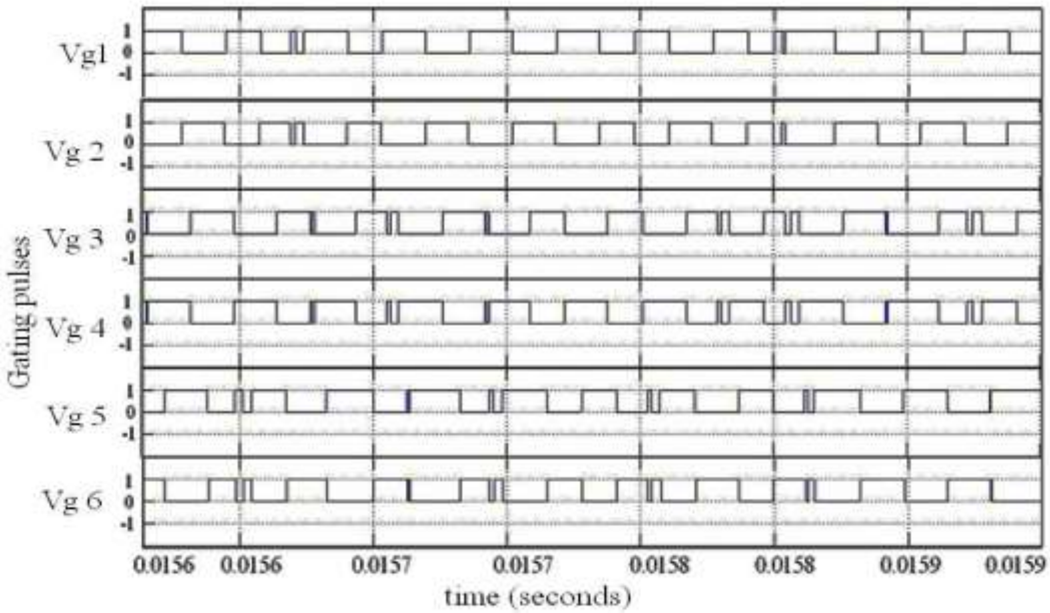

Fig-9: Gating pulses to Inverter

3. CONCLUSION

A Series active power filter has been investigated for power quality improvement. Various simulations are carried out to analyze the performance of the system. Hysteresis controller based Series active power filter is implemented for harmonic and voltage distortion compensation of the non-linear load. The Simulation is even extended for abnormal faults occurring on the power system like L-G & L-L faults. Fuzzy logic and neural network techniques are now being increasingly applied to power electronics. The integration of fuzzy logic with neural networks and genetic algorithms is now making automated cognitive systems a reality in many disciplines.

4. REFERENCES

[1] Bhim Singh and venkateswarlu.P, "A Simplified Control Algorithm for Three- Phase, Four-Wire Unified Power Quality Conditioner" Journal of Power Electronics, Vol. 10, No. 1, January 2010 pp.91-96.

[2] B.Singh,K.Al-Haddad,and A.Chandra, "A review of active power filters for power quality improvement," IEEE Trans.Ind.Electron.,vol.45,no.5,pp.960- 971,Oct 1999.

[3] V.Khadkikar,A.Chandra,A.O.Barry,and T.D.Nguyen, "Application of UPQC to protect a sensitive load on a polluted distribution network," in Proc.IEEE PES General Meeting,Montreal,QC,Canada,2006,6pp.

[4] V.Khadkikar,A.Chandra,A.O.Barry,and T.D.Nguyen, "Conceptual analysis of unified power quality conditioner(UPQC)," in proc.IEEE ISIE,2006,pp.1088- 1093.

[5] Vinod Khadkikar and Ambrish Chandra, "A Novel Structure for Three-Phase Four-Wire Distribution System Utilizing Unified Power Quality Conditioner (UPQC)" IEEE Transactions on Industry Appl., Vol. 45, No. 5, September/October 2009.

[6] Yash Pal, A. Swarup, and Bhim Singh, " A Comparison of Three Topologies of Three-Phase Four-Wire UPQC for Power Quality Improvement" 16th National Power systems conference, 15th-17th December, 2010 pp.227-232.

[7] S. Chakraborty and F. A. Farret, " A Single Phase High Frequency AC Microgrid with an Unified Power Quality Conditioner," Proceedings on IEEE 2003, pp.952-967.

[8] Active power filter with automatic control circuit for neutral current harmonic minimization technique by mohd izhar bin a bakar

[9] Handbook of Power Quality by Angelo Baggini.

[10] S.K. Jain, P. Agrawal and H.O. Gupta, "Fuzzy logic controlled shunt active power filter forpower quality improvement"IEEE Proceedings on Elect.Power.Appl.Vol 149.No.5,September 2002.