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Instantaneous Power Compensation in 3-Phase System UsingShunt Active Filter

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***Abstract*—The continuous increasing use of power electronic device in power system creates pollution issues in the system. Most of the power quality issues is power system are due to the use of nonlinear loads as they introduce current harmonics in the system. These loads will continue affecting the quality of power system which can cause problems such as low power factor, distortion of wave shape of supply due to introduction of harmonics. The traditional method for mitigation of harmonics current due to non-linear load that is use of passive filter is proving to be insufficient because of more use of power electronics device in every field and also due to some disadvantage of them such as problem of resonance with the impedance of network. So new approaches were developed to mitigate the effect of harmonics in power system due to non-linear load current, out of which active filters got the attention of engineers for solutions of power quality problems. Shunt active filters are efficient devices to solve for problems related to current harmonics and series active filters are capable to solve problems related to voltage harmonics. Shunt active filters compensate for current harmonics by injecting equal but opposite compensating current. the system with rectifier is simulated and instantaneous power theory (*p-q* theory) for shunt active power filter is validated for harmonic reduction.**

***Keywords*— Power Quality; Harmonics; Active Power Filter; Hysteresis Current Controller; Instantaneous Power Theory.**

I. INTRODUCTION

In modern electrical system, there has been a suddenincrease of nonlinear loads, such as power supplies, adjustablespeed drives etc. These nonlinear loads draw non-sinusoidalcurrents from supply and causes distortion called harmonics.These harmonics further causes' problems such as voltagedistortion, overheating of equipment, excessive neutralcurrent, poor power factor etc. Traditionally, passivefilters have been used for harmonic improvement due to less cost. The performance of passive filter is not muchsatisfactory due to variable load and operating conditions.Therefore, the active power filters have emerged as moreefficient solution to the harmonics. The key advantage ofactive filters over passive filter is their superior response tovarying loads and harmonic variations, additionally; a singleactive filter compensate more number of harmonics, andimprove/mitigate other power quality problems such as flicker, sag, swell[1]

Active power filters (APFs) has emerged as an alternatesolution to passive filters (PFs). For variable harmonic order, magnitude and/or phase angle of nonlinear loads, active elements may be used as an alternative of the passive filter to provide dynamic compensation. This is due to the time dependent harmonic spectrum (e.g. adjustable speed drives) or may be caused by change in the system configuration of nonlinear loads. The active power filters (APF) have series or parallel topology depending upon the type of harmonic sources. [3]

APFs compensate undesirable harmonic currents by providing compensation to it. The compensation is equal and opposite to the harmonics produced by harmonic components of the nonlinear loads. APFs are expensive as compared to passive filters and are feasible for higher rating systems. The main disadvantage of active filters is its higher rating, which can be up to 80% of load in some typical applications; therefore it is a costly option for power quality enhancement in many situations. Moreover, a single APF might not afford a complete solution in many realistic applications due to the presence of voltage and current harmonics. For such cases, combined filter design consisting of both passive and/or active filters, called hybrid power filter (HPF) is preferred [1,2]

Active power filters (APFs) are workable alternative fortraditional passive filters to improve power factor and reduce harmonics in power system. Several APF topologies (series,parallel), including hybrid (active & passive) power filters (HPF), are designed and implemented to meet IEEE 519harmonics standards. The topologyselection depends upon total harmonic distortion, power ratingand cost of passive filter components, power factor, filterlosses, switching losses, capability to provide harmonicisolation between load and supply, control complexity.This paper represents a shunt active power filter (SAPF) usinginstantaneous power theory for reference generation. Theproposed SAPF compensates the harmonic component bygenerating reference and controlling signals by comparing theload current and source current.[3,5,6]

II. SHUNT ACTIVE POWER FILTER

The problem that is introduction of harmonics current due to the nonlinear loads in power system. In this chapter we will study solution to this problem that is Active filters. Firstly classification of active filters is done based on topology and location of connection with power system. Active filter are efficient solution for problems related to voltage and current harmonics. Also they are capable to compensate for reactive power and improve power factor. Due to this reason active filters are also known as active power line conditioners. One of the important facts of active filters is the type of control method that is implemented for active power controller. Performance of active filter depends on the selected method for generating reference compensating currents. Active filters will generate the reference currents that will be used for compensation of harmonics current. These currents will be used to generate the switching signals and these signals will be applied to electronic converter by use of appropriate switching control technique.

One of the important facts of active filters is the type of control method that is implemented for active power controller. Performance of active filter depends on the selected method for generating reference compensating currents.

The shunt topology is more popular as compared to others due to its performance and easy implementation. The shunt APF injects harmonic current in opposition to the load harmonics so as to cancel the effect of harmonics in the system as shown in fig. 1. The instantaneous power (p-q) theory is used for current reference generation and is implemented in Simulink. [4,7]

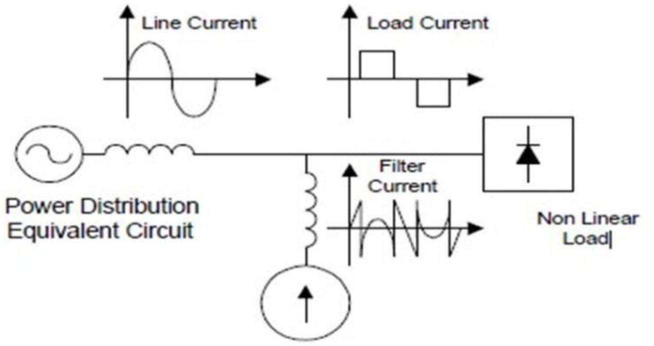

Fig.1 Schematic of Shunt Active powerFilter[8]

III. THE INSTANTANEOUS POWER THEORY

Various techniques are purposed for generation of reference current in shunt active filter. These techniques detect harmonics current in the load and then calculate compensating current which is then injected with the help of voltage fed converter and hysteresis control. [10, 11, 12]

A. *Instantaneous power theory (p-q theory)*

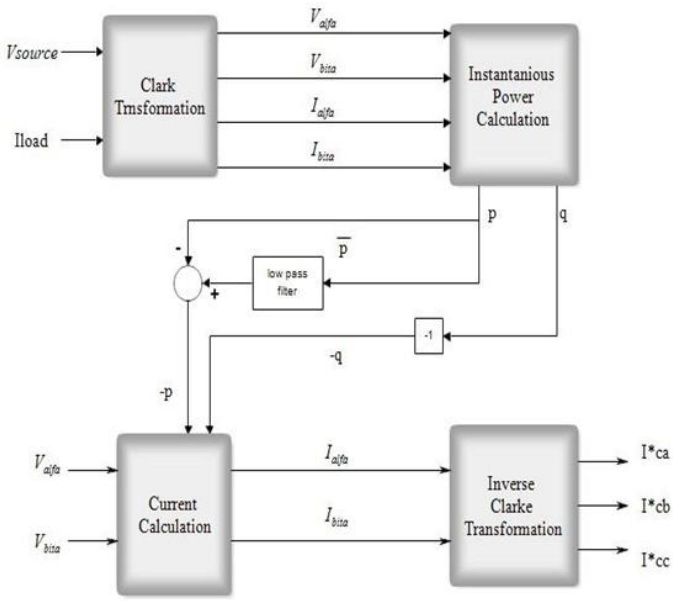

Fig.2 Basic block diagram of SAF

"The Generalized Theory of the Instantaneous Reactive Power in Three-Phase Circuits", also known as instantaneous power theory or p-q theory was proposed by Akagi in 1983. It is valid for steady state and transitory operation and it is based on the instantaneous values with or without neutral wire for three phase power system. Firstly the three phase voltages and current are transformed to α-β-*0* coordinates with the help of Clark"s transformation then the instantaneous values of active and reactive power are calculated. The values of compensating current from the values of active and reactive power are then calculated using Inverse Clarke's transformation. The block diagram for applying p-q theory is shown in Fig. 2.

B. *Control Method Based in p-q Theory*

For a three-phase three wire balanced electrical power system, we measure the mains voltages *(Vsa, Vsb, Vsc)* and the mains current *(Ila, Ilb, Ilc)* which are then transformed into α-β reference frame according to the following equations:[12,13,14]

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{(2/3)} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \qquad (1)$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{(2/3)} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{la} \\ i_{lb} \\ i_{lc} \end{bmatrix} \qquad (2)$$

The p-q theory introduces the instantaneous imaginary power, which is a new quantity and corresponds to the instantaneous reactive power. The instantaneous active and reactive power in matrix form is calculated via the following equation:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \qquad (3)$$

The instantaneous values p and q can be expressed as the sum of the dc and ac components. Equations (4) and (5) give the instantaneous values p and q respectively.

$$p = \bar{p} + \tilde{p} \qquad (4)$$

$$q = \bar{q} + \tilde{q} \qquad (5)$$

Where,
$\bar{p}, \bar{q}$ are the dc components of instantaneous active and reactive power respectively,
$\tilde{p}, \tilde{q}$ are the ac components of instantaneous active and reactive power respectively.

The expression of current in the α-β reference frame as an instantaneous power function is given by the following equation:

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \qquad (6)$$

Through the use of the p-q theory, the harmonics components and the reactive power of the non-linear load can be compensated. This is achieved using a low pass filter. Therefore, the reference current of the active filter in α-β reference frame is:

$$\begin{bmatrix} i_{c,\alpha}^* \\ i_{c,\beta}^* \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{bmatrix} \begin{bmatrix} -\tilde{p} \\ -q \end{bmatrix} \qquad (7)$$

By using the inverse transformation, we can calculate the reference currents in a-b-c reference system.

$$\begin{bmatrix} i_{c,a}^* \\ i_{c,b}^* \\ i_{c,c}^* \end{bmatrix} = \sqrt{(2/3)} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & \sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{c,\alpha}^* \\ i_{c,\beta}^* \end{bmatrix} \qquad (8)$$

Currents i_C^* include all the harmonics and the fundamental harmonics with Φ degree phase shifting.[9]

C. *Advantages of p-q Theory*

- It is inherently a three-phase system theory.

- It can be applied to any three-phase system (balanced or unbalanced, with or without harmonics in both voltages and currents).[9]
- It is based in instantaneous values, allowing excellent dynamic response.
- Its calculations are relatively simple (it only includes algebraic expressions that can be implemented using standard processors).[8]
- It allows two control strategies: constant instantaneous supply power and sinusoidal supply current.[15]

D. Hysteresis Current Control

The hysteresis band current controller for active power filter can be carried out to generate the switching pattern of the inverter. There are various current control methods proposed for such active power filter configurations, but in terms of quick current controllability and easy implementation hysteresis current control method has the highest rate among other current control methods. Hysteresis band current controller has properties like robustness, excellent dynamics and fastest control with minimum hardware. The two-level PWM-voltage source inverter systems of the hysteresis current controller are utilized independently for each phase. Each current controller directly generates the switching signal of the three phases. In the case of positive input current, if the error current e(t) between the desired reference current $i_{ref(t)}$ and the actual source current $i_{actual(t)}$ exceeds the upper hysteresis band limit (+h), the upper switch of the inverter arm is become OFF and the lower switch is become ON as shown in the Fig.3[11]

1) Adaptive Hysteresis Current Controller: In spite of several advantages, the basic hysteresis technique exhibits several undesirable features, such as uneven switching frequency that causes acoustic noise and difficulty in designing input filters. The hysteresis band current controller is composed of a hysteresis around the reference.

Line current. In equation (1), the reference line current of APF is referred to as i_{ref}, and Measured line current of the APF is referred to as 'i'. The difference between i and iref is referred to as δ.

$$\delta = i - i_{ref}$$

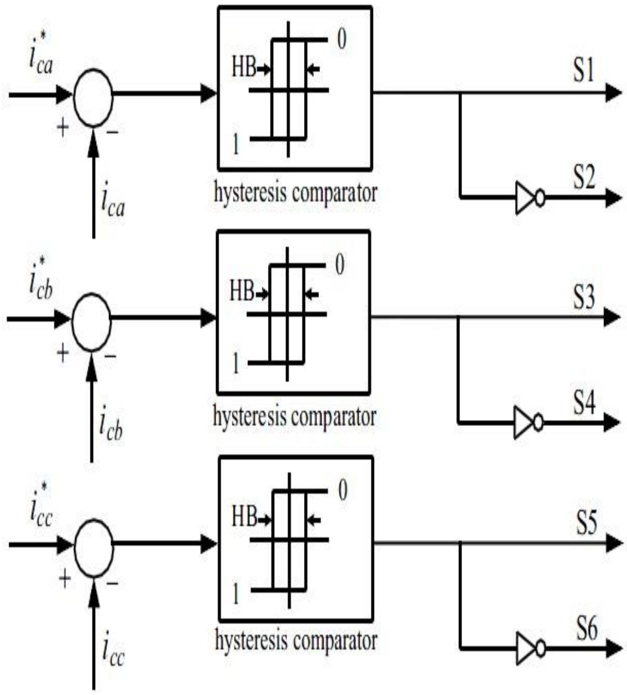

Fig.3 The block diagram of the hysteresis current control

The switching logic is formulated as follows:

If δ >HB upper switch is OFF (S1=0) and lower switch is ON (S4=1).
If δ <-HB upper switch is ON (S1=1) and lower switch is OFF (S4=0).

The switching logic for phase b and phase c is similar as phase a, using corresponding reference and measured currents and hysteresis bandwidth (HB).

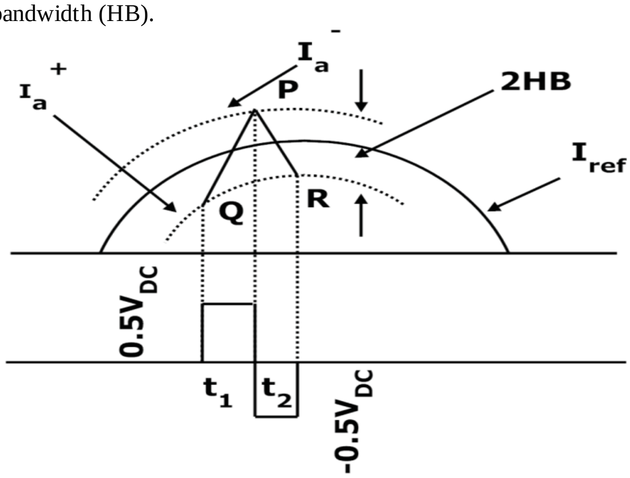

Fig.4 Current and voltage waveform with hysteresis band current controller

In case of Adaptive HCC, the rate of change of the line current vary the switching frequency, therefore the switching frequency does not remain constant throughout the switching operation, but varies along with the current waveform. Furthermore, the line inductance (that interfaces inverter and PCC) value of the APF and the capacitor voltage are the main parameters for determining the rate of change of line currents. Fig.3.2 shows the PWM current and voltage waveforms for phase-a. The currents 'i_a' tends to cross the lower hysteresis band at point Q, where S1 is switched on. The linearly rising current (i_a+) then touches the upper band at point P. [15]

IV. SIMULATION AND RESULTS

The proposed electrical power network was simulated on the computer with MATLAB/Simulink. Parameters of the electrical power system are given by table I.

Table11-1 SYSTEM PARAMETERS

System Parameters	Values
Source Voltage	415V
Supply Frequency	50HZ
Source Impedance :(Inductance Ls)	0.3mH
Non-Linear Load Under Steady State:(Resistance Rs, inductance Ls)	50Ω, 1mH
Filter Impedance:(inductance Ls)	1mH
Reference Dc Voltage	800V

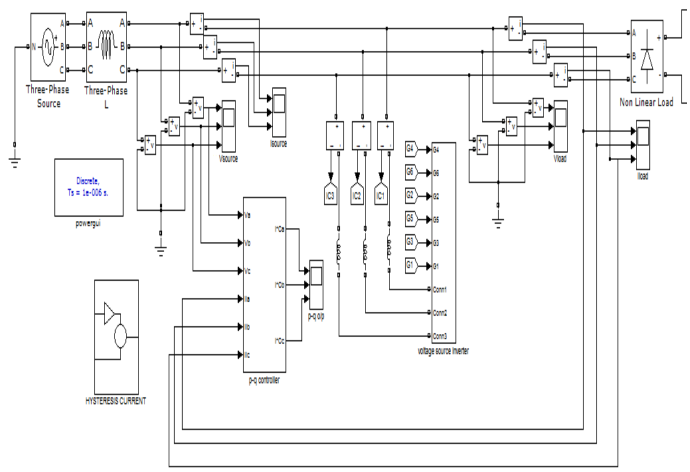

Fig.5 Simulink model of Rectifier R-L Load With SAF

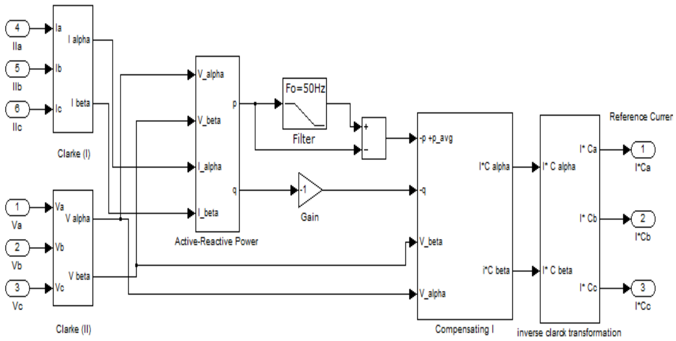

Fig.6 p-q Control Strategy

A. *Simulation result without connecting SAF*

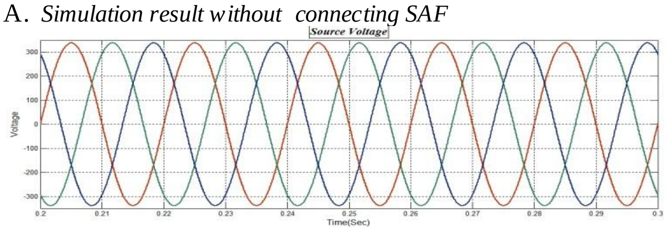

Fig.7 Source Voltage

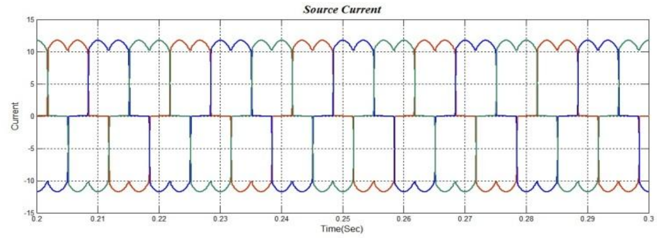

Fig.8 Source Current

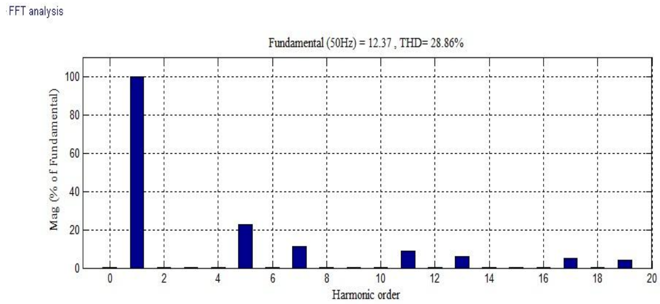

Fig.9 FFT analyses For Non-Linear Load without SAF

B. *Simulation result with connecting SAF*

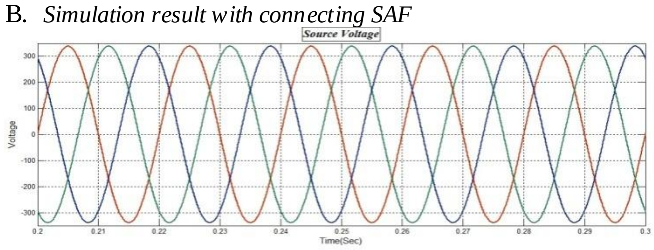

Fig.10Source Voltage

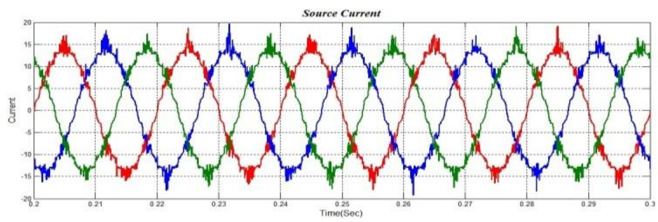

Fig.11 Source Current with SAF

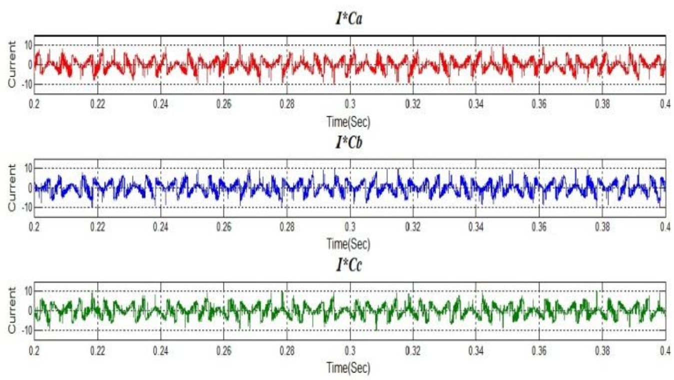

Fig.12 p-q Output Current (Ref Current)

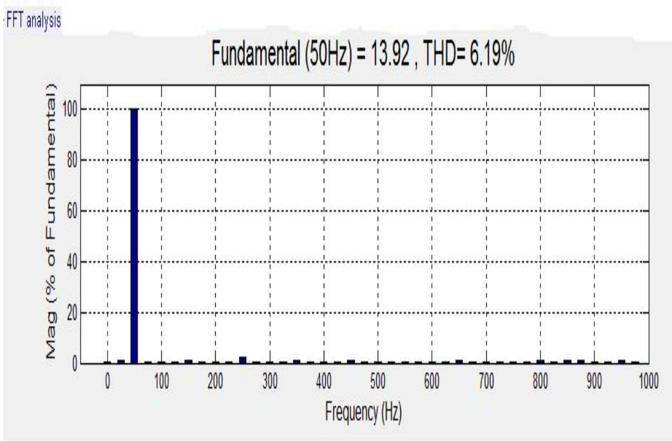

Fig.13 FFT analyses For Non-Linear Load with SAF

C. *Total Harmonics Distortion Result*

Table 2-2 %THD RESULT

Before connecting Shunt Active Filter(SAF)	**After connecting Shunt Active Filter(SAF)**
28.86%	6.19%

V. CONCLUSIONS

A shunt active power filter has been investigated for power quality improvement. Various simulations are carried out to analyze the performance of the system. Here I have done the simulation of Non-linear load. Simulation results show that the use of nonlinear load injects current harmonics in the system. The THD in case of nonlinear load are 28.86% From the simulation it can be conclude that shunt active filter is a useful device for compensation of current harmonics due to non-linear loads. The THD due to non-linear loads can be brought to limits according to IEEE standards by using shunt active filter.

This paper presents the p-q theory as a suitable tool to the analysis of non-linear three-phase systems and for the control of active filters. The implementation of active filters based on the p-q theory are cost-effective solutions, allowing the use of a large number of low-power active filters in the same facility, close to each problematic load (or group of loads), avoiding the circulation of current harmonics, reactive currents and neutral currents through the facility power lines.

REFERENCES

[1] C. Shankaran, “Power Quality”, CRC press, 2002, pp: 1-23.
[2] Francisco C., “Harmonics & Power Systems”, CRC Press.
[3] H Akagi, “Instantaneous Power Theory & Applications To Power Conditioning”, John Wiley & Sons Publication.
[4] Hirofumi Akagi, “New Trends in Active Filters for Power Conditioning”, IEEE Transactions On Industry Applications, Vol 32, No 6, November December 1996.
[5] Hirofumi Akagi, “Active Harmonic Filters”, Proceedings Of The IEEE, VOL.93, NO. 12, DECEMBER 2005.
[6] Bhim Singh, Kamal Al-Haddad, Ambrish Chandra, “A Review of Active Filters for Power Quality Improvement”, IEEE Transactions On IndustrialElectronics, October 1999.
[7] NaimishZaveri, AjitsinhChudasama, “Control strategies for harmonic mitigation and power factor correction using shunt active filter under various source voltage conditions” Science Direct 2012.
[8] VasundharaMahajan, PramodAgarwal, Hari Om Gupta, “Simulation of Shunt Active Power Filter using Instantaneous Power Theory” 978-1-4673-0766-6/12 ©2012 IEEE.
[9] Joao L. Afonso, H. J. Ribeiro da Silva and Julio. S.Martins “Active Filters For Power Quality Improvement” 2001 IEEE Porto Power Tech.
[10] G.Tsengenes, G. Adamidis, “A New Simple Control Strategy for Shunt Active Power Filters under Non Ideal Mains Voltages” 2010 IEEE.
[11] B.Pragathi, G.Bharathi, “Control Of Shunt Active Filter Based On Instantaneous Power Theory” IJERT ISSN: 2278-0181 Vol. 1 Issue 6, August – 2012.
[12] T. Narongrit, K-L. Areerak and K-N. Areerak, “The Comparison Study of Current Control Techniques for Active Power Filters” International Scholarly and Scientific Research & Innovation 5(12) 2011.
[13] MaurícioAredes, Hirofumi Akagi, Edson HirokazuWatanabe,” Comparisons Between the p--q and p--q--r Theories in Three-Phase Four-Wire Systems” IEEE Transactions On Power Electronics, Vol. 24, No. 4, April 2009.
[14] Gerard Ledwich, FiruzZare, “Three Phase Hysteresis Controls-Simple Options for Improvement” IEEE 2007.
[15] B.VenkataRanganadh, A. Mallikarjuna Prasad, MadichettySreedhar “Modeling And Simulation Of A Hysteresis Band Pulse Width Modulated Current Controller Applied To A Three Phase Voltage Source Inverter By Using Mat lab” International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 9, September 2013.