# Review on Three Phase Shunt Active Filter for Compensation of Non Linear Load Currents Based On p-q Theory

[1]Anoop H. Budhrani, [2] Raghuvaran Naidu, [3]Amit R Pathak
[1,2,3]Assistant Professor
[1]Electrical Engineering Department,
[1]V. V. P. Engineering College, Rajkot, India

***Abstract*— This paper deals with the analysis of three phase shunt active filter based on PQ theory. Normally PQ theory is used for 3 phases 3 wires and 3 phases 4 wire system but here it is used for 3 phase 3 wire system. This paper also concentrates on reduction of THD of load current [1]. Here p-q theory is explained which is one of the methods for reference compensating current detection. Also this paper explains hysteresis current control method for control of compensating current. Analysis of SAF is done and idea of its working is presented.**

***Index Terms*—Shunt active filter, THD (Total harmonic distortion), PQ theory, Hysteresis current control.**

## I. INTRODUCTION

In past years the use of power electronics device has continuously increased. So problem of current harmonics in power system started as power converters and electronics devices are the major cause of introducing harmonics in system. [3] As a result control of harmonics has become a major issue as there should be some solution to deal with the problems related to current harmonics. Earlier passive methods of compensation were used to deal with problems related to harmonics but they somehow are not able to completely compensate for number of harmonics at a time. So the newer methods were introduced to compensate for current harmonics. Active power filtering is used now a day to detect the amount of harmonics and compensate for the same efficiently. This paper explains the working of three phase shunt active filter having non linear load using p-q theory. Active filters have good dynamic response as compared to passive filters. [4]. Also active filters provide selective harmonic compensation. Active filter consists of active filter controller and PWM controller. In order to make APF work properly, DC-link voltage must be maintained in a sufficiently high value and keep stable, which ensures APF produce the compensating currents strictly follow the control requirement and achieves the desired compensation effect. [5]

Power quality issues are increasing day by day as the use of power electronics is increasing in power system. Both users and utility are concerned about the methods to reduce harmonics in power system. Active filters are becoming popular solution to deal with the problems related to current and voltage harmonics. Shunt active filter are capable to compensate for current harmonics and series active filters are capable to compensate for problems related to voltage harmonics. This paper will explain the use of shunt active filter for compensation of current harmonics in power system. First step for compensation is the detection of current harmonics in power system. Many methods are proposed for detection of harmonics but p-q theory is most suitable method for detection of harmonics during the dynamic condition and different load conditions. The most significant part of the APF control is the detection circuit which is responsible for extracting the reference currents for compensating the load harmonics current and keeping the dc voltage at a specified level. This paper explains performance analysis of SAF for compensation of current harmonics using p-q theory [1].

After detection of harmonics the next step is the control of signals that are to be given to the voltage source converter of active filter which is given through PWM technique. Here voltage source converter along with DC voltage regulator is used to generate the compensating current which will produce the same harmonics as that are produced by load but 180 degree out of phase. This will make the source current sinusoidal in nature. Out of many PWM techniques available for control of current Hysteresis current control has good dynamic response. In this paper hysteresis current control method is used for control of compensating current.

## II PRINCIPLE OF SHUNT ACTIVE FILTER

The control circuit of SAPF is responsible for measuring the distortion current, calculating the reference current, keeping the dc voltage constant and generating the gating signals for the inverter switches. Figure 1 shows the block diagram of shunt active filter. Here a non linear load, which is responsible for harmonics generation is connected to power system. Main parts of shunt active filter are the active filter controller block and PWM control block. Three phase source voltage and load current reference signals are given to active filter controller which then calculated and detects the harmonics from load current. Figure also shows voltage source converter IGBT is connected with a DC capacitor. The voltage across DC capacitor should maintain required minimum voltage because the performance of shunt active filter depends on proper functioning of voltage source converter as it generates the correct compensating current. [2]

The shunt active filter is normally connected with the transformer or inductor is connected in parallel with the harmonic-producing load. This inductor is known as coupling inductor. The function of coupling inductor is to limit the rate of change of compensating current which is generated by VSC. [6]. Coupling inductor is shown by L in the below figure. Many methods are proposed for control of current in SAF. Here hysteresis current control method is used as it has dynamic response capability. In hysteresis current control actual current follows reference current by a hysteresis band. Switching frequency of IGBT of VSC should be kept high so as to make proper functioning of SAF. Reference current detection in active filter controller is done with the help of p-q theory. SAF will generate compensating current that will be used to compensate the current harmonics so as to make the source current sinusoidal. SAF will generate the current having same harmonics as load current but 18o degree out of phase.

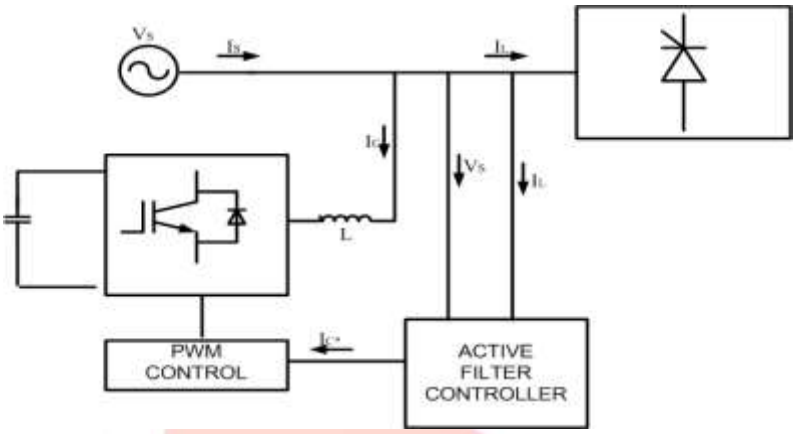


Fig. 1: Three phase shunt active filter

### III. P-Q THEORY

"The Generalized Theory of the Instantaneous Reactive Power in Three-Phase Circuits", which is also knwon as instantaneous power theory or p-q theory was presented first by Akagi in 1983[4].This theory is applicable to both steady state condition and transient condition. Initially three phase voltages and current are transformed to α-β-*0* coordinates so as to get the values in stationary reference frame with the help of Clark's transformation then the instantaneous values of active and reactive power are calculated.

Using Inverse Clarke's transformation the values of compensating current are found from values of active and reactive power. Three phase source voltages and load currents are transformed in α-β coordinates using Clark's theory which are then utilized to calculate instantaneous values of powers. Active and reactive power consists of average component as well as oscillating component. Oscillating component show the presence of harmonics in current. So oscillating component are separated with the help of low pass filter which are then added to calculation for compensation.

This theory proves to be flexible and efficient in designing controllers for power quality conditioning using power electronics devices. The derivation of this theory starts from αβ*0* transformation which is known as Clarke transformation. The three phase voltage and the line currents are transformed into αβ axes by following equations so as to transform them to stationary frame.

$$\begin{bmatrix} V\alpha \\ V\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} \quad (3.1)$$

$$\begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix} \quad (3.2)$$

From equations (3.1) and (3.2) the instantaneous real power and instantaneous imaginary power on αβ axes can be expressed as

$$\begin{bmatrix} p = \bar{p} + \tilde{p} \\ q = \bar{q} + \tilde{q} \end{bmatrix} = \begin{bmatrix} V\alpha & V\beta \\ -V\beta & V\alpha \end{bmatrix} \begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} \quad (3.3)$$

As discussed, two powers consists of average values as well as superposition of oscillating values so they are to be separated into two parts as shown in equation (3.3). As shown $\bar{p}$ and $\tilde{p}$ are the average and the oscillating parts of $p$, whereas $\bar{q}$ and $\tilde{q}$ are the average and the oscillating parts of $q$. Both the oscillating real $\tilde{p}$ and imaginary $\tilde{q}$ powers represent the presence of harmonics in load current. By knowing the undesirable values of current in real time, they can be eliminated. Using shunt active filter harmonics content in the load can be compensated and the source current can be made sinusoidal.

The equations for compensating current reference in αβ axes can be written as equation (3.4)

$$\begin{bmatrix} i_\alpha{}' \\ i_\beta \end{bmatrix} = \frac{1}{V\alpha^2+V\beta^2}\begin{bmatrix} V\alpha & V\beta \\ V\beta & -V\alpha \end{bmatrix}\begin{bmatrix} \tilde{p} \\ \tilde{q} \end{bmatrix} \quad (3.4)$$

Finally by Inverse Clarke transformation the compensating current reference are expressed as equation (3.5)

$$\begin{bmatrix} i_{ca}\,* \\ i_{cb}\,* \\ i_{cc}\,* \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (3.5)$$

## IV. Hysteresis current control

There are many PWM methods of control of current in VSC. These methods have different static and dynamic responses. Hysteresis current control method proves to be one of the best suitable methods for control of current reference in SAF.[7].In this method a feedback system is used where the actual current continuously follows its reference current limited by a hysteresis band . Figure 2 explains working of hysteresis controller for a half bridge inverter. Compensating current reference is continuously compared with actual current limited by a hysteresis band..As the current exceeds a prescribe hysteresis band, the upper switch in half bridge is turned off and lower switch is turned on. As a result, the output voltage transition from +0.5 Vd, and -0.5Vd, and the current starts to decay. In same way as current crosses the lower band limit, the lower switch is turned off and the upper switch is turned on. Hysteresis technique gives quick current controllability and good stability, so it is preferred over other available control techniques.

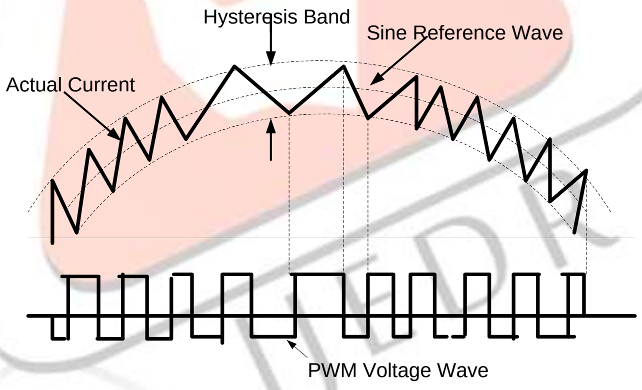


**Figure 2.**Hysteresis Current Control

## V Conclusion

Shunt active filter for compensation of non linear load current has been explained. Shunt active filter is able to compensate for current harmonics is load which are produced as a result of switching operations of power electronics devices. Papers reviewed here have given idea about working of SAF along with application of p-q theory for detection of compensating reference current. Also we can prove using simulations that p-q theory has good dynamic response when applied to SAF for compensation of current harmonics. Active filters have many advantages as compared to passive filter as they are able to provide selective harmonic compensation. Hysteresis current control technique has been explained which too has a good dynamic response.

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