Power Quality Improvement In Three Phase System Using Shunt Active Power Filter

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ABSTRACT

The problem of quality electrical energy provided to the users has arisen. This is due to the increasing presence in network of nonlinear loads.They constitute a harmonic pollution source of the network, which generate many disturbances, and disturb the optimal operation of electrical equipments. This work, proposed a solution to eliminate the harmonics introduced by the nonlinear loads. So SAPF can easily eliminate unwanted harmonics frequencies. This paper will discuss and analyze the simulation result for a distribution system using shunt active power filter MATLAB program. this simulation will implement a non-linear load to compensate line current harmonics under balance and unbalanced load.Shunt Active Power Filter play a vital role in present day liberalized energy market. Shunt Active Power Filter are explored for executing different power conditioning function simultaneously along with harmonic elimination due to increase in nonlinear and unbalanced load, at the point of common coupling. The aim of present dissertation is to study different control strategies for Active Power Filter. More importantly to study instantaneous power theory based Shunt Active Power Filter
which is predominantly used in present scenario.

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1. INTRODUCTION

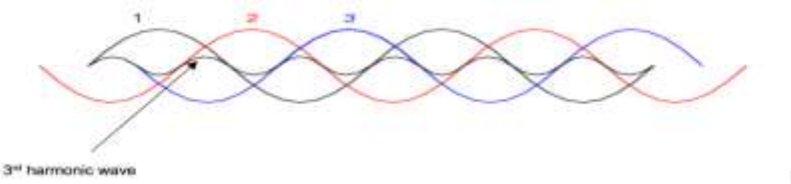
Harmonics current pollution in distribution power system is becoming a serious problem due to the wide use of power electronics devices such as diode or thyristors and vast variety of power electronics based appliances.Traditionally passive LC filter have been used to eliminate the current harmonics and to improve the power factor .however passive LC filter are bulky, they can also cause resonance problem to the system in order to solve this problem SAPF can be introduced.

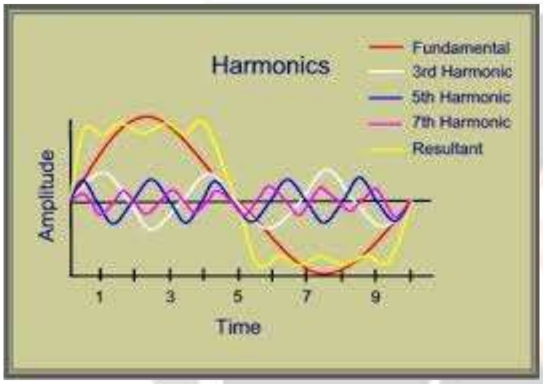
Use of nonlinear harmonic producing loads in the distribution system creates power quality problems for power engineers. The use of power electronics devices at the end user side is increasing tremendously because of the advancements in the semiconductor technology. The use of power electronics devices gives rise to problems like harmonic generation, poor power factor, reactive power disturbance, low system efficiency, disturbance to other consumer, heating of devices, etc. This adverse may become sizable in future year, hence it is very important mitigate this problems. Nearly twenty years ago most of the loads used by the industries and consumers were passive and linear in nature, with a lesser number of non-linear loads thus having less impact on the power system. With the arrival of semiconductor and power electronic devices and their easier controllability have caused wide use of non-linear loads such as chopper, inverter switched mode power supply, rectifier, etc. The power handled by modern power electronics devices like silicon controlled rectifier (SCR), Insulated gate bipolar transistor (IGBT), power diode, Metal oxide semiconductor field effect transistor (MOSFET) are very large, which promotes their industrial as well as domestic applications.

2. HOW HORMONICS ARE PRODUCED

The presence of harmonics in electrical systems means that current and voltage are distorted and deviate from sinusoidal waveforms.

Harmonic currents are caused by non-linear loads such as power electronics devices connected to the distribution system. A load is said to be non-linear when the current it draws does not have the same waveform as the supply voltage. The flow of harmonic currents through system impedances in turn creates voltage harmonics, which distort the supply voltage.



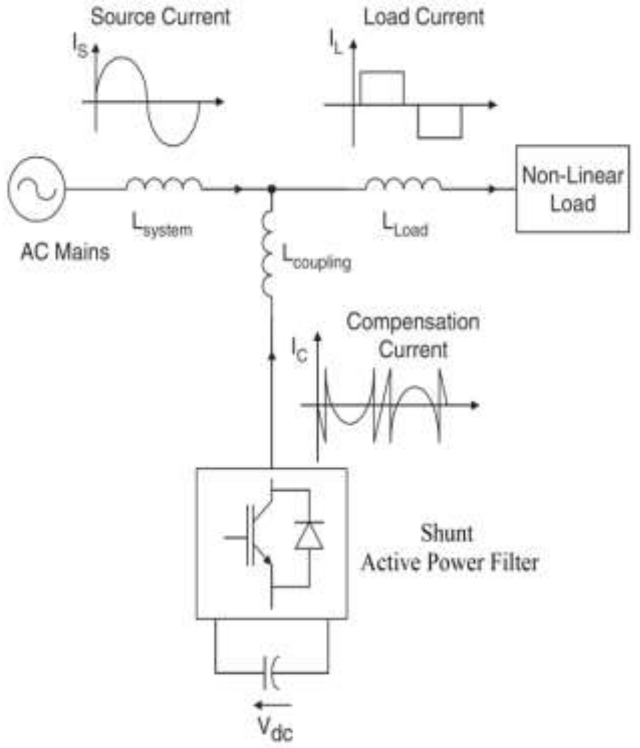


3. SHUNT ACTIVE POWER FILTER

There are basically two types of active filters :the shunt type and series type. It is possible to find the active filter combined with passive filter as well as active filter of both acting together. the electrical scheme of shunt active power filter for distribution system .which is able to compensate for current hormonics

Active power filters is the device which generate the same amount of harmonic as generated by the load but 180o phase shifted. So when these harmonics are inserted into the line at the point of common coupling the load current harmonics are eliminate and utility supply becomes sinusoidal. There are basically two types of active filter: Series active filters and shunt active filters.
It is the dual of the shunt active filter, and is able to compensate for distortion in the power line voltages, making the voltages applied to the load sinusoidal (compensating for voltage harmonics). The filter consists of a voltage-source inverter (behaving as a controlled voltage source) and requires 3 single-phase transformers to interface with the power system. The series active filter does not compensate for load current harmonics but it acts as high-impedance to the current harmonics coming from the power source side. Therefore, it guarantees that passive filters eventually placed at the load input will not drain harmonic currents from the rest of the power system. Another solution to solve the load current harmonics is to use a shunt active filter together with the series active filter , so that both load voltages and the supplied currents are guaranteed to have sinusoidal waveforms
r to compensate reactive power and current harmonics generated by nonlinear loads, the reference signal of the shunt active power filter must include the

values of In this case the reference currents required by the shunt active power filters are calculated with the following expression:



Practically shunt active power filter are more effective and cheaper compared to series active power filters because most of the non linear loads produce current harmonics. Moreover series active power filter requires adequate protection scheme

4.INSTANTANEOUS REACTIVE POWER THEORY:

The *p-q* theory was proposed by Akagi et al. in 1983. The *p-q* theory is based on conversion of *a-b-c* coordinate into *α-β-0* coordinates and *α-β-0* coordinates into *a-b-c* coordinates, popularly known as Clark transformation and inverse transformation respectively. Basic block diagram of *p-q* theory is shown in Fig..Generated compensating current will be:

$$I\ comp = I\ source - I\ load \qquad (1)$$

Where,
I comp = Compensating current
I source = Source current and
I load = Load Current

$$S=V^{*}\, i^{*}= (v\alpha+jv\beta)^{*}(i\alpha-ji\beta) = (v\alpha i\alpha+ v\beta i\beta)+ j(v\beta i\alpha-v\alpha i\beta)$$

From this active and reactive power components are
$p = v\alpha i\alpha+ v\beta i\beta$
$q = v\alpha i\beta-v\beta i\alpha$

5.HYSTERESIS CURRENT CONTROL TECHNIQUE

Hysteresis Current Control (HCC) technique is basically an instantaneous feedback current control method of PWM, where the actual current continually tracks the command current within a hysteresis band. Basic working principle of the HCC technique is shown in Fig below.

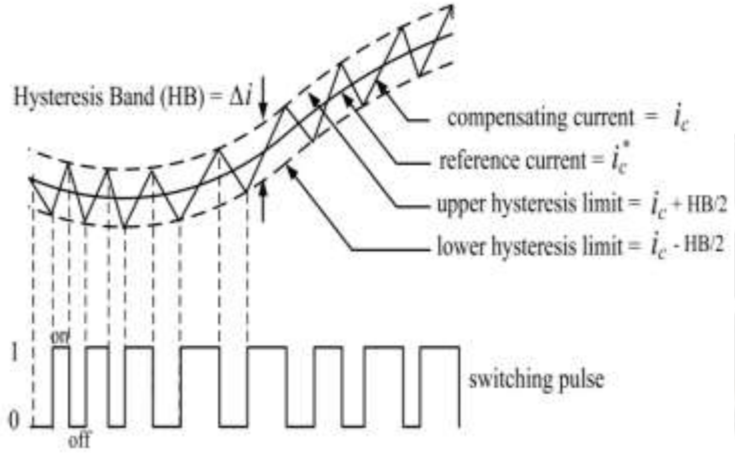


Fig.Principle of Hysteresis Current Control Technique

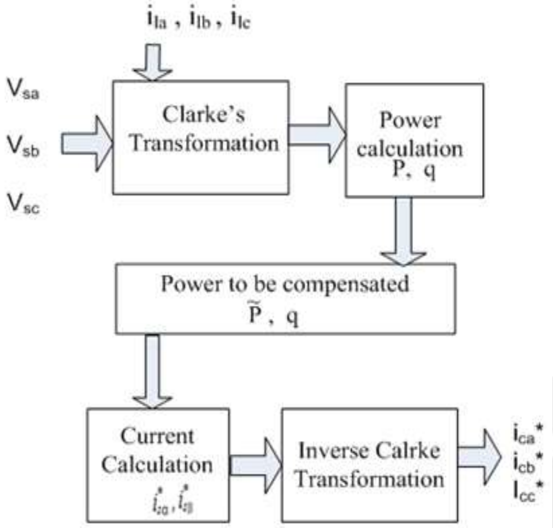
Hysteresis band (HB) is the possible boundary of the compensating current. This current deviates between upper and lower hysteresis limits. For example in phase *a*, if ica is equal or over than the upper hysteresis limit (ica^* + HB/2) then the comparator output is 0 (S1=0, S2=1). On the other hand, if ica is equal or less than the lower hysteresis limit (ica^* - HB/2) then the comparator output is 1 (S1=0, S2=1). From this operating, the ica can deviate inside the hysteresis band following the reference current ica^*. The main advantage of hysteresis current control method is excellent dynamic response, easy implementation and low cost.

. In this method the actual output current generated by inverter is compared with reference current generated using instantaneous reactive power theory. Hysteresis current controller will generate pulses in such a manner that inverter output current will follow the reference current.

6. THE CLARKE TRANSFORMATION

Instantaneous real and reactive power can be decomposed into two components called oscillatory components and average components. Considering completely balanced and sinusoidal main supply conditions average power components represents first harmonic current of positive sequence and oscillatory components are related to all high order harmonic components including first harmonic current of negative sequence. So the shunt active filter should compensate for oscillatory power components, as a result of which average power components remains same in the main supply.

The $\alpha\ \beta\ 0$ transformation or the Clarke transformation converts the three-phase instantaneous voltages in the *a b c* phases, V_a, V_b *and* V_c into the instantaneous voltages on the αβ0 axes $v0$, $v\alpha$, *and* $v\beta$. The Clarke Transformation of three-phase generic voltages is given by:



In this method three phase source voltage and load current are converted into *α-β-0* stationary reference frame.

$$\begin{bmatrix} V_0 \\ V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{sa} \\ V_{sb} \\ V_{sc} \end{bmatrix} \qquad (2)$$

$$\begin{bmatrix} I_0 \\ I_\alpha \\ I_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_{sa} \\ I_{sb} \\ I_{sc} \end{bmatrix} \qquad (3)$$

From this transformed quantities, instantaneous real and reactive power of the load is calculated which consists of average and oscillating component.

$$\begin{bmatrix} P_0 \\ P \\ q \end{bmatrix} = \begin{bmatrix} V_0 & 0 & 0 \\ 0 & V_\alpha & V_\beta \\ 0 & V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} I_0 \\ I_\alpha \\ I_\beta \end{bmatrix} \qquad (4)$$

For three phase three wire systems $I_0 = 0$, so source power P_0 also becomes zero. So power equation becomes as follows.

$$\begin{bmatrix} P \\ q \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V\alpha \end{bmatrix} \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} \qquad (5)$$

Instantaneous active and reactive power of load can be calculated as follows

$$\begin{bmatrix} P_i \\ q_i \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta & I_{i\alpha} \\ -V_\beta & V_\alpha & I_{i\beta} \end{bmatrix} \begin{bmatrix} \\ \\ \end{bmatrix} \qquad (6)$$

In orde components in a, b, c
reference frame in terms of αβ given as

$$\begin{bmatrix} I_{s\alpha} \\ I_{s\beta} \end{bmatrix} = \frac{1}{V_\alpha^2 + V_\beta^2} \begin{bmatrix} V_\alpha & V_\beta & p \\ V_\beta & V_\alpha & 0 \end{bmatrix} \begin{bmatrix} \\ \\ \end{bmatrix} \qquad (7)$$

These are the compensation current injected by the shunt active filter to reduce harmonics in three phase three wire systems.

$$\begin{bmatrix} I_{ca}^* \\ I_{cb}^* \\ I_{cc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 & I_{s\alpha} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & I_{s\beta} \end{bmatrix} \begin{bmatrix} \\ \\ \\ \end{bmatrix} \qquad (8)$$

7.CONCLUSION

In this paper the performance analysis of shunt active power filter using instantaneous reactive power theory have been carried out .SAPF is observed to be excellent as it lead to reduced hormonics,rective power burden.The unbalancing current coused by the unbalanced non-linear loads remedied at the supply mains . The SAPF enhances the system efficiency as it avoids hormonics injection and reactive power burden.

VIII. RESULT ACROSS SAPF

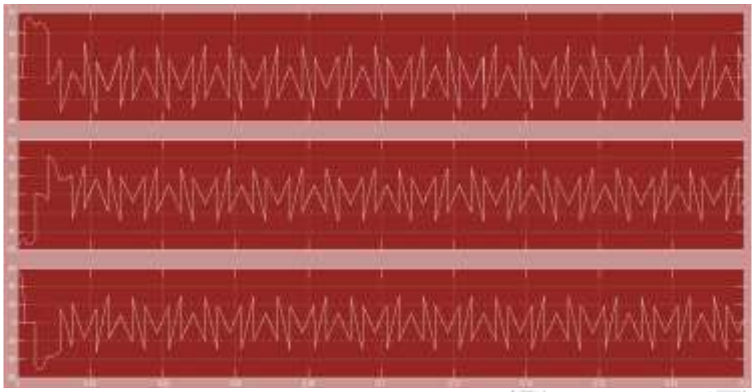


Fig : compensating current waveforms by SAPF injected in line .

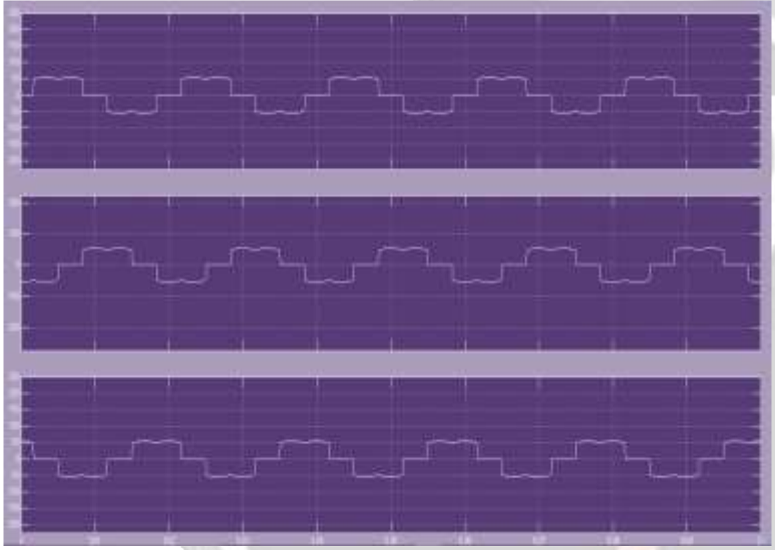


Fig : Waveforms of source current before compensation

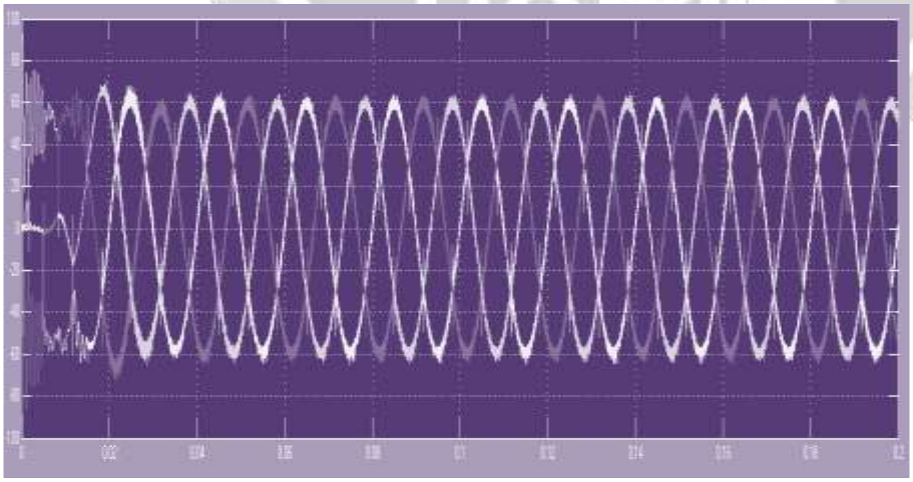


Fig : waveform of source current after compensation

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