A review of harmonic and reactive power compensation using shunt active filter

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Abstract- This paper discusses about a survey of harmonic compensation using shunt active filter. The presence of harmonics in the power lines results in greater power losses in distribution, interference problems in communication systems and sometimes, in operation failures of electronic equipments. p-q theory is applied to reduce harmonic distortion in shunt active filter. The research work involves discussion of the p-q technique for active shunt filter is developed to enhance power quality and improve distribution system reliability.

***Index Terms*- active filter, harmonic compensation, p-q theory.**

I. INTRODUCTION

One of main points in the development of alternating current transmission and distribution power systems at the end of the 19th century was based on sinusoidal voltage at constant-frequency generation. Sinusoidal voltage with constant frequency has made easier the design of transmission and transformers. If the voltage were not sinusoidal, complications would appear in the design of transformers, machines, and transmission lines. These complications would not allow, certainly, such a development as the generalized “electrification of the human society.” Today, there are very few communities in the worlds without ac power systems with “constant” Voltage and frequency. Then the concept of reactive power, if the current is not in phase with the voltage, and the average of this power over the cycle is zero, so reactive power will not contribute any power, it is wattles, and the power factor of the circuit should be high, it will be efficient and economical to have higher power factor, higher the power factor better the utilization of the circuit.

Unlike traditional passive filters, modern active filters have the following multiple functions; harmonic filtering, damping, isolation and termination, reactive-power control for power factor correction and voltage regulation, load balancing, voltage-flicker reduction, and/or their combinations[1]. Significant cost reductions in both power semiconductor devices and signal-processing devices have inspired manufactures to put active filters on the market .A instantaneous reactive power compensator comprising switching devices is proposed which requires practically no energy storage components.[2] The instantaneous reactive power compensator comprising switching devices, which requires practically no energy storage components, was proposed, according to the theory of the instantaneous reactive power. The hybrid filter consists of a small-rated active filter and a 5th-tuned passive filter. The active filter is characterized by detecting the 5th-harmonic current flowing into the passive filter. It is controlled in such a way as to behave as a negative or positive resistor by adjusting a feedback gain from a negative to positive value, and vice versa.[3]

The p-q theory can be used with success in the implementation of shunt active power filters controllers [4]. The fundamental terms related to harmonics, sources of harmonics, effects of harmonics and reactive power compensation and harmonic control are related to active filters[5]. Shunt active filters allow the compensation of current harmonics and unbalance, together with power factor correction, and can be much better solution than the convectional approach[6]. The principles of operation of shunt, series, also a brief description of the state of the art in the active power filter market has been described. The shunt active power filter performance under fault power distribution system was discussed.[7] The p-q theory provides complete analysis of different power components for analysis and compensation. The time-domain calculation allows deciding about the exact instant and amount of compensation to be provided for elimination.[8]

II. HARMONICS

Increased use of power electronics in the applications power systems, drives, computer industry and lightening applications led to development of more efficient power converters and efficient switching devices. And these power converters are non linear loads, because switching devices form heart of the power converters and power electronic devices, and these devices operate in the saturation mode to have very low power loss as compared to active mode, and in the saturation mode the devices act as switches, and during saturation conditions these devices form non linear characteristics, during switch on there is drop in voltage and rise in current, and during switch off mode, reverse breakdown voltage increases and current decreases rapidly, and gives non linear characteristics.

And they draw reactive power from the source, and the entire system is polluted with harmonics, and harmonic current increases the temperature of transformers, conductors and cables, and it leads to malfunctioning of switching devices. Sinusoidal sources are of 50 Hz systems, but due to the pollution of harmonics, system comprises of frequencies if integral multiply of natural frequency. It consists of 150th, 250th, 350th, etc that distort the voltage and current waveforms. And third harmonics and its multiples can be removed by three phase sources.[9]

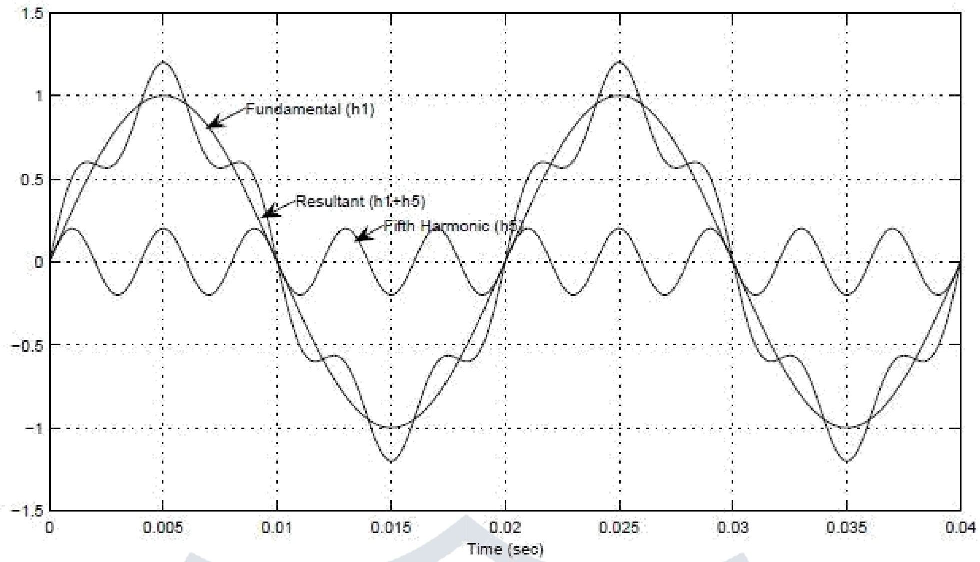

Figure 1. Typical 50 Hz waveform along with 5th harmonic component

III. SHUNT ACTIVE FILTER

It is most commonly used filters in A.C. power system network and offers very low impedance path to harmonics. Shunt type of filters are cheaper than series type because the shunt connected filters are designed for graded insulation levels which makes the components cheaper than the series filter components. The control algorithm implemented in the controller of the shunt active filter determines the compensation characteristics of the shunt active filter. Different types of controller use in shunt active filter. Here we use current minimization controller. The algorithms based on the synchronous reference frame can be considered as a subset of those based on the pq theory if the fundamental positive-sequence voltage component is extracted and considered in the shunt active filter controller. The major oppositions in accepting the active filter controllers based on the pq theory are firmed on the following arguments.[6]

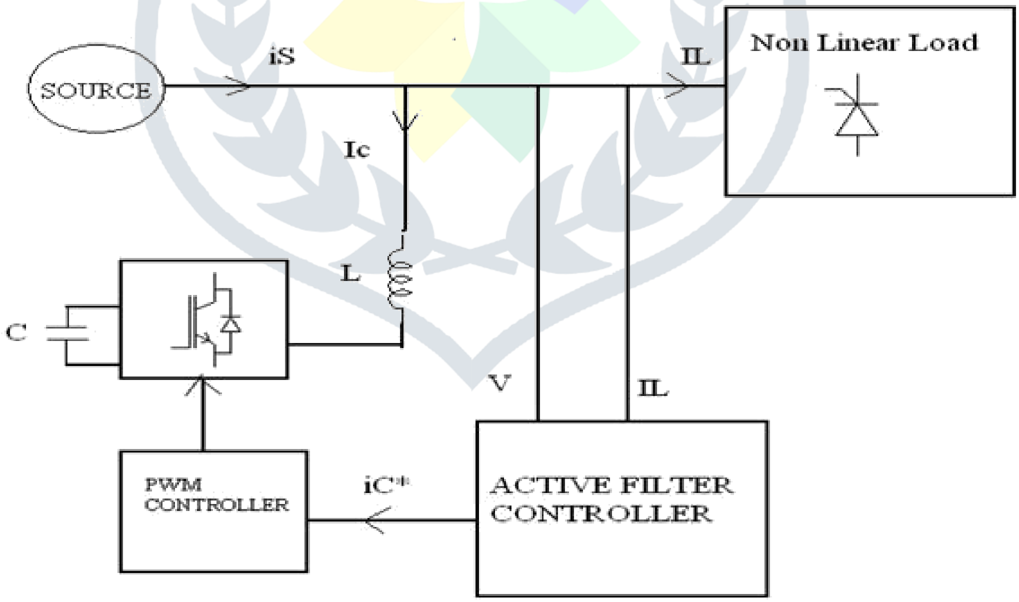

Fig 2. Concept of shunt active filter

IV. PQ THEORY

It is based on instantaneous values in three-phase power systems with or without neutral wire, and is valid for steady-state or transitory operations, as well as for generic voltage and current waveforms. The p-q theory consists of an algebraic transformation (Clarke transformation) of the three-phase voltages and currents in the *a-b-c* coordinates to the α- β-*0* coordinates, followed by the calculation of the p-q theory instantaneous power components:[6]

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \qquad \text{(i)}$$

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \qquad \text{(ii)}$$

$p_0 = v_0 \, . \, i_0$ instantaneous zero-sequence power (iii)

$p = v_\alpha \, . \, i_\alpha + v_\beta \, . \, i_\beta$ instantaneous real power (iv)

$p = v_\alpha \, . \, i_\alpha - v_\beta \, . \, i_\beta$ instantaneous imaginary power(by definition) (v)

The power components *p* and *q* are related to the same α-β voltages and currents, and can be written together:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \cdot \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \qquad \text{(vi)}$$

These quantities are illustrated in Fig. 2 for an electrical system represented in *a-b-c* coordinates and have the following physical meaning:

*p*0 = mean value of the instantaneous zero-sequence power – corresponds to the energy per time unity which is transferred from the power supply to the load through the zero-sequence components of voltage and current.

*p*0 ~ = alternated value of the instantaneous zero-sequence power – it means the energy per time unity that is exchanged between the power supply and the load through the zero-sequence components. The zero-sequence power only exists in three-phase systems with neutral wire. Furthermore, the systems must have unbalanced voltages and currents and/or 3rd harmonics in both voltage and current of at least one phase.

p = mean value of the instantaneous real power – corresponds to the energy per time unity which is transferred from the power supply to the load, through the *a-b-c* coordinates, in a balanced way (it is the desired power component).

p~ = alternated value of the instantaneous real power – It is the energy per time unity that is exchanged between the power supply and the load, through the *a-b-c* coordinates.

q = instantaneous imaginary power – corresponds to the power that is exchanged between the phases of the load.

This component does not imply any transference or exchange of energy between the power supply and the load, but is responsible for the existence of undesirable currents, which circulate between the system phases. In the case of a balanced sinusoidal voltage supply and a balanced load, with or without harmonics, *q* (the mean value of the instantaneous imaginary power) is equal to the conventional reactive power ($q = 3 \cdot V \cdot I1 \cdot \sin\varphi 1$).[6]

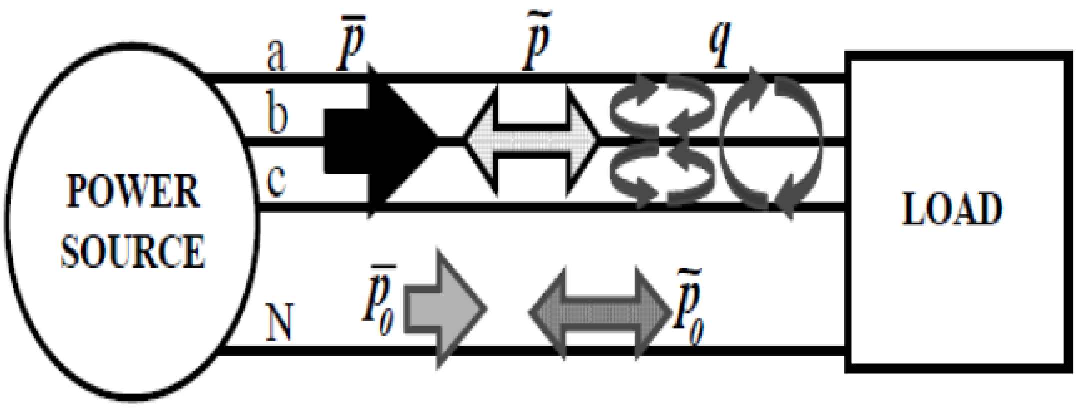

Fig. 3 Power components of the p-q theory in *a-b-c* coordinate

V. CONCLUSION

Active filters are an up-to-date solution to power quality problems. Shunt active filters allow the compensation of current harmonics and unbalance, together with power factor correction. This paper presents the p-q theory as a best control strategy 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 ,avoiding the circulation of current harmonics, reactive currents and neutral currents through the facility power lines.

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