Improvement of Power Quality with Shunt Active Power Filter

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Abstract - *The key problem of electrical society today is decadence of power efficiency. The use of switching devices in industry as well as in household applications is increased in practice. Non-linearity has negative effects on system performance, power supply utilities, power factor, etc. The decrease in the power factor increases reactive power, which has no contribution to the energy transfer and thus needs compensation. There are efforts to upgrade the quality of electricity, the Filter concept is needed. Active filters are common in comparison to passive filters because of their smaller size and weight. The paper uses the P-Q principle for current harmonic mitigation and reactive energy compensation to operate on shunt active power filter (SAPF). The simulation is well illustrated here, along with its parameters, with or without an active filter. We start the paper with problems of power quality and then better understanding PQ theory, simulation circuits, performance, and conclusion. The THD value of source current below 5% complies with IEEE Requirements. It is important to achieve THD. Instant p-q theory is used here for the extraction of current reference.*

Key Words: **Active filter, Control technique, Current harmonics mitigation, Voltage-source inverter, Distorted source voltage, Power quality**

1. INTRODUCTION

Currently, the most significant issue faced by the power system is the quality of power as it creates a major negative influence on the utilities and customers thus affecting its economic advancements. Power Engineers have been consistently working on this indispensable issue. Harmonics is a related problem which affects the power system operation hence and their moderation should be particularly focused upon. Harmonic filters are help to address this issue. Out of all the harmonic filters, active harmonic filters are considered to be very much feasible and affordable solution. Researchers are working on its marketable execution. The proposed adaptive shunt active filters are able to recompense for harmonic currents.

Modern active harmonic filters have the following roles: harmonic filter, damping, insulation and termination, reactive power regulation for power factor correcting and voltage controlling, load balancing, voltage flicker reduction and /or their combinations, which do not apply to conventional passive harmonic filters. Also power semiconductors as well as signal processing systems have become economical, which has made manufacturers excited about selling active filters.

Classification of active filters based upon the power system connection is done as follows:

- Series Active Power Filter
- Shunt Active Power Filter
- Hybrid Active Power Filter

For current harmonic eradication, active filters are chosen. Active filters hold additional capability of reactive power compensation.

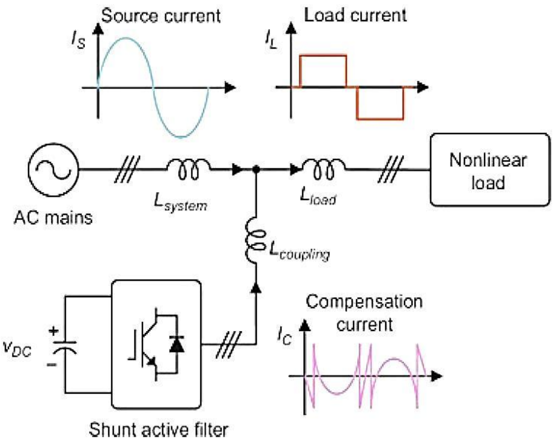

Fig -1: SAPF Base Strategy

The simple Shunt Active Filter scheme graph for harmonic compensation is shown in Fig.1. A three-phase source is used for the non-linear load with the parallel APF. Is the original source, IL is the original load and IC stands for the current pay-out. It injects harmonic current which match the harmonic current of the load, but which has a change of 180 ° to cancel the harmonics of the load current. Sinusoidal is the essence of the source.

2. PROPOSED SCHEME

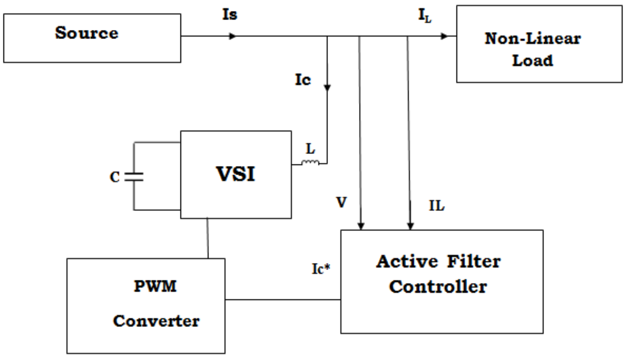

Fig-2: Proposed scheme of SAPF

The proposed scheme of SAPF is shown in Fig.2. The SAPF helps in providing the balanced sinusoidal current while all other non-sinusoidal currents are supplied by the power stage and they contribute to the reactive power.

In the proposed system, input is given to the control block in the form of phase current and phase voltage. With the help of Clarke's transformation, the abc voltages and currents are converted into αβ0 parameters. P-Q theory makes use of αβ0 parameter to compute instantaneous Active power (p) and instantaneous reactive power (q). Closed loop current controller also known as hysteresis band controller is fed with the reference current. Reference current and the actual current fed by the filter are compared by the closed loop current controller to generate gate signal.

Actual current tracks the reference current within the specified band to generate the required output. During each cycle of Load current charging and discharging of two dc link capacitors takes place. These capacitors act as energy storing devices.

3. CONTROL STRATEGY

Instantaneous values of phase voltages and load currents are taken as input to the control block which further realizes the instantaneous p-q theory for computing reference current. An additional input given to the control block is the p signal which is lost from dc regulator.

This input signal indicates the power loss in capacitor during voltage fluctuation across the capacitor. Fig: 2 show the complete modeling of the control block.

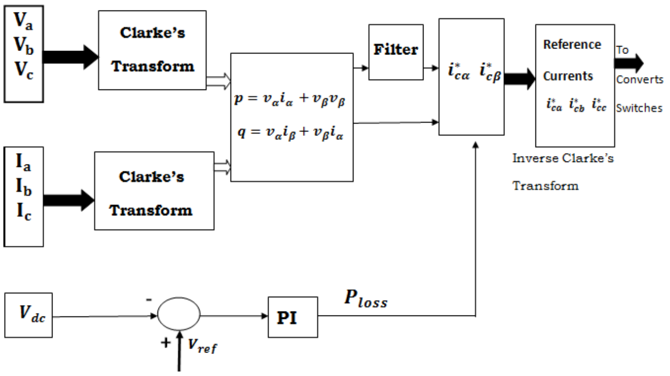

Fig-3: The illustration of reference current calculation

3.1. CLARKE'S TRANSFORMATION

The p-q theory uses a method of Clarke transformation (also called αβ0). This is a true matrix that lines three phase voltages and currents into the αβ0 structure, which describes a stationary frame of reference. The voltage and current in the αβ0 axis can be evaluated through the application of equations (1) and (2)

$$\begin{bmatrix} v_0 \\ v_\propto \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} i_0 \\ i_\propto \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \tag{2}$$

Instantaneous power components on the load side are computed on a frame of αβ0 using voltage and current values as given in the equation (3)

$$\begin{bmatrix} p_0 \\ p \\ q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} v_0 & 0 & 0 \\ 0 & v_\propto & v_\beta \\ 0 & -v_\beta & v_\propto \end{bmatrix} \begin{bmatrix} i_0 \\ i_\propto \\ i_\beta \end{bmatrix} \tag{3}$$

Since, it is only concerning balanced and undistorted source voltage, the above equation reduces to

$$\begin{bmatrix} p \\ q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} v_\propto & v_\beta \\ -v_\beta & v_\propto \end{bmatrix} \begin{bmatrix} i_\propto \\ i_\beta \end{bmatrix} \tag{4}$$

The instantaneous active and reactive power consists of DC and AC component i.e. ***P*** = ***P*** +***P*** and ***q*** = ***q*** +***q***. DC component of p and q consists of the positive sequence components of fundamental load current, whereas AC component of p and q consists of harmonic and negative sequence of load currents.

The aim of p-q theory is to obtain the source, so that the power **P** and **q** is compensated for the constant active power demand by the load. A filter separates the oscillating portion of the active power as well as the reference current, and the equations are determined as follows:

$$\begin{bmatrix} i_{\alpha}^{ref} \\ i_{\beta}^{ref} \end{bmatrix} = \frac{1}{v_{\alpha}^{2} + v_{\beta}^{2}} \begin{bmatrix} v_{\alpha} & -v_{\beta} \\ v_{\beta} & v_{\alpha} \end{bmatrix} \begin{bmatrix} -p + p_{loss} \\ -q \end{bmatrix} \quad (5)$$

$i0\ ref$ = $i0$ from equation (2) since we have $v0$ = 0

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} 1 & 0 & \frac{1}{\sqrt{2}} \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_{\alpha}^{ref} \\ i_{\beta}^{ref} \\ i_{0}^{ref} \end{bmatrix} \quad (6)$$

4. MATLAB BASED SIMULATION

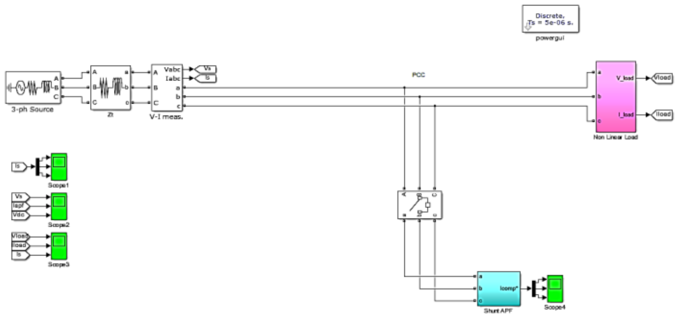

Fig-4: Main block of proposed scheme under MATLAB

MATLAB (Simscape Library) is used to simulate and model the Power Supply, Unbalanced and Non- Linear Load and Shunt Active Filter. Fig. 4 shows the blocks of simulation to study the performance of the APF. The voltage source block comprises of a three-phase voltage supply and its internal impedance. Three diode rectifiers are connected to each phase of the load with a neutral and unequal arm. The load at the rectifier has been modeled as diode rectifier which feeds the resistor and inductor. This is the reason, harmonic and un-balanced current flow causes. Some amount of reactive power will be consumed by this load.

5. RESULT:

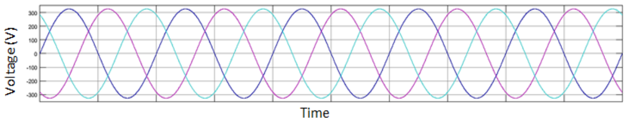

Fig-5: Supply Voltage v/s Time

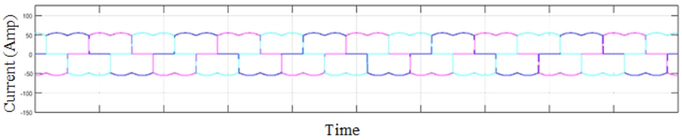

Fig.-6: Non Liner Load current v/s Time

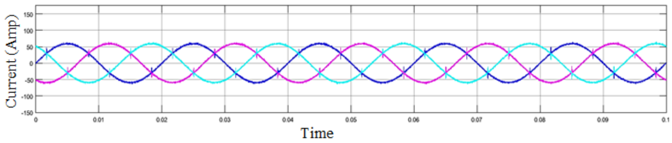

Fig.-7: Source Current v/s Time

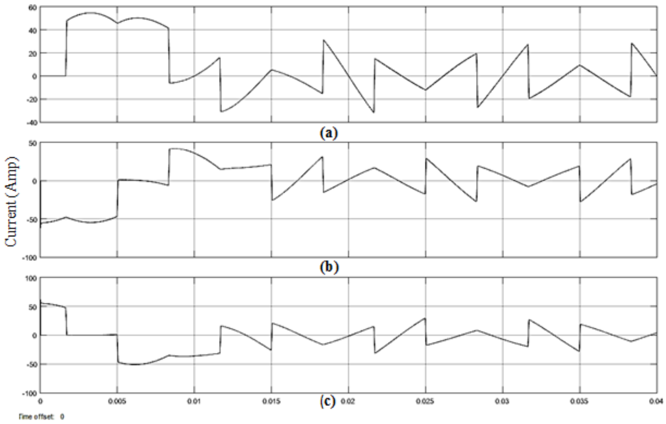

Fig-8: Compensating Current

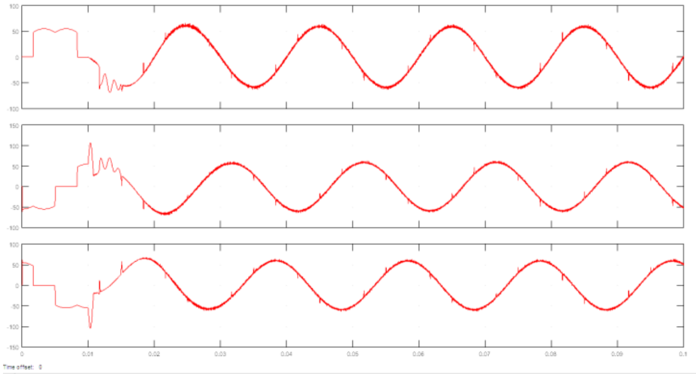

Fig-9: Source Current Before filter and after filter

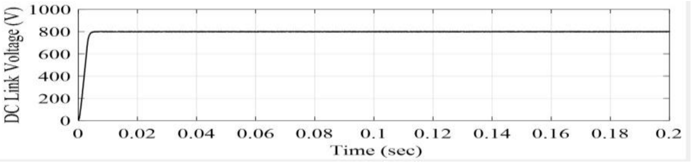

Fig-10: Capacitor voltage of DC side

Fig. 5 implies a balanced voltage of supply v/s time. In balanced state, Fig.5 displays system waveforms. Harmonics are produced in large quantities due to nonlinear load. Fig. 6 & Fig. 7 displays the non-linear load current v/s time waveform and the source current waveform v/s time. The filter injects the compensatory current into the device when the filter is attached. Fig. 8 shows the compensating filter current present. Shunt active filter connected to the device clears the current harmonics from load side to the source side. Source current waveform before and after filter is shown in the fig. 9 which is sinusoidal. The DC side capacitor voltage appears in Fig. 10 that is almost constant.

Fast Fourier Transform (FFT) analysis is used to calculate the harmonics present in the system. In Figure the FFT machine analysis is shown without and with Shunt Active Filter in the Fig. 11 and Fig. 12. Without Shunt Active Filter, there is 16.08 percent total harmonic distortion (THD), not within the IEEE Std limit. 519. When Shunt Active Filter is connected to system THD gets lessen from 16.08 percent to 4.49 percent that is in the limit of IEEE Std. 519.

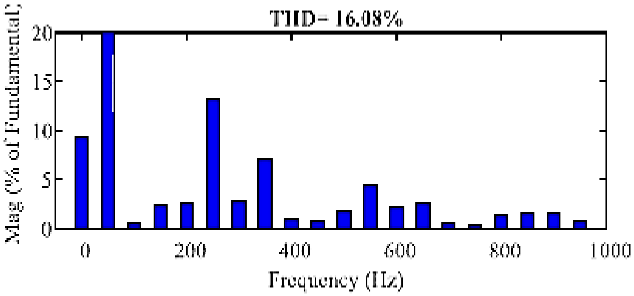

Fig-11: THD analysis without SHAF

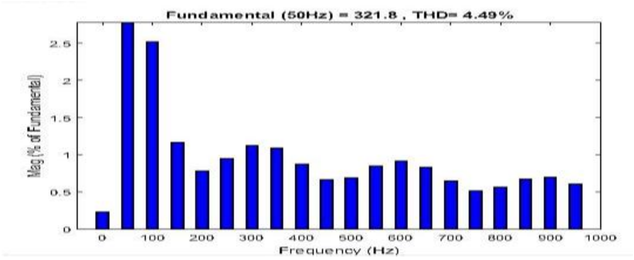

Fig.-12: THD analysis with SHAF

6. CONCLUSION

The proposed APF system is more robust, efficient and stable to improve the feasibility and harmonic propagation of the power distribution system. The control algorithm can ensure the regulated sinusoidal voltage, phase amplitude, and low THD in the power distribution system, along with dc-link voltage control. In this paper, we observed that nonlinear charges are becoming a serious problem for harmonics and reactive power requirements, resulting in pollution of power. A 3-phase SAPF is therefore produced for harmonic compensation. Simulations to research machine output with and without an active shunt filter have been performed. The shunt active filter that has been developed will reduce the THD in the source current much less than 5% by the IEEE-519 Standard. It has also been inferred from the results of Active & Responding Power Waveforms, that if the filter is connected to the grid, only active power must be given by Source when the demand for reactive power is reached. The active filter controller therefore depends on the theory of p-q, which is a powerful tool.

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