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Harmonic Compensation Using Shunt Active Power Filter In Non-Linear Load

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Abstract:

The excessive of power electronics devices in distribution system has evolved the problem of power quality. In this paper a custom power device known as shunt active power filter is use. The shunt active power filter is a useful device to eliminate harmonic currents and to compensate reactive power for linear/nonlinear loads. The active filter controller is based on the instantaneous power theory (p-q theory).This paper presents simulation and development of SAPF for mitigation of the power quality problem at ac mains in AC-DC power supply feeding to a nonlinear load. Harmonic contents of the source current has been observed. MATLAB / SIMULINK power system toolbox is used to simulate the proposed system.

Keywords:
Active Power Filter, p-q theory, Total Harmonic Distortion (THD).

I.INTRODUCTION:

Recently, wide application of nonlinear devices has led to distortion of voltage and current waveforms in ac networks. 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. Common devices to deal with the problem are bank capacitors, SVC (static Var compensator), passive filters and some others.Basically there are two approaches for the mitigation of power quality problems. The first approach is load conditioning, which ensures that the load is immune harmonics. Equipments are made less sensitive to harmonics and power disturbance, which is not so possible practically. The other solution is power line conditioning. In this approach line conditioning system is installed at point of common coupling (PCC) that suppresses or counteract for the adverse effect produced by non linear harmonic producing loads.

Passive filters are conventional solutions to mitigate harmonics but the limitation of passive filters for compensating has made active filters attractive. The passive filters have been used as a conventional solution to solve harmonic currents problems, but they present some disadvantages: they only filter the frequencies they were previously tuned for; its operation cannot be limited to a certain load or group of loads; resonance can occur due to the interaction between the passive filters and others loads, with unexpected results. To cope with these disadvantages, recent efforts have been concentrated on the development of active power filters.

II. SHUNT ACTIVE POWER FILTERS:

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. Generally this active power filter control system is based on p-q theory.

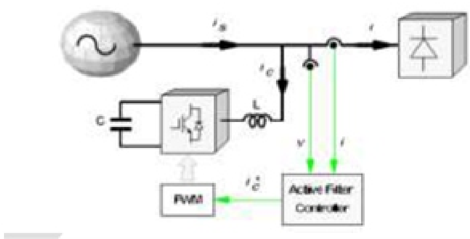

Fig. 1. Schematis Diagram of Shunt Active Power Filter

In 1983, Akagi proposed “The Generalized Theory of the Instantaneous Reactive Power in Three-Phase Circuits”, also known as “Theory of Instantaneous Reactive Power”, or p-q Theory. It was initially developed for three phase three-wire systems, with a brief mention to systems with neutral wire. Later, Watanabe et al. and Aredes et al. extended it to three-phase four-wire systems.

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This theory is based on instantaneous values in three-phase power systems with or without neutral wire, and is valid for steady state or transitory operation. 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 according to the expression (1), where x can be voltages (v) or currents (i).

$$\begin{bmatrix} x_\alpha \\ x_\beta \\ x_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos(\theta) & \cos(\theta - \frac{2\pi}{3}) & \cos(\theta - \frac{4\pi}{3}) \\ -\sin(\theta) & \sin(\theta - \frac{2\pi}{3}) & -\sin(\theta - \frac{4\pi}{3}) \\ {}^{1}/_{\sqrt{2}} & {}^{1}/_{\sqrt{2}} & {}^{1}/_{\sqrt{2}} \end{bmatrix} \begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix} \quad (1)$$

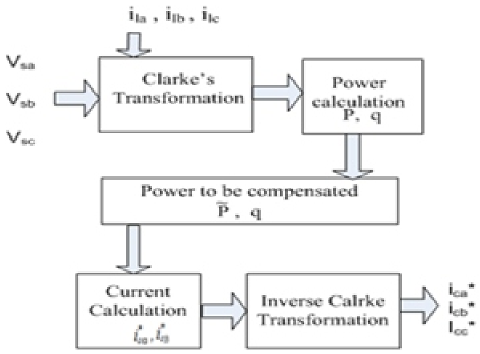

Fig. 2. Basic Block Diagram of p-q Theory

Initially these a-b-c coordinates are transferred to the α-β-0 coordinates. After this transmission the p-q theory components are calculated using the following expressions.

$$p = v_\alpha i_\alpha + v_\beta i_\beta \quad (2)$$

$$q = v_\beta i_\alpha + v_\alpha i_\beta \quad (3)$$

The compensation currents in the a-b-c coordinates are determined by applying the inverse Clarke transformation to the currents in the α-β-0 coordinates, as demonstrated in (4).

$$\begin{bmatrix} i_{ca} \\ i_{cb} \\ i_{cc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 & {}^{1}/_{\sqrt{2}} \\ -{}^{1}/_{2} & {}^{\sqrt{3}}/_{2} & {}^{1}/_{\sqrt{2}} \\ -{}^{1}/_{2} & -{}^{\sqrt{3}}/_{2} & {}^{1}/_{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_{c\alpha} \\ i_{c\beta} \\ i_{c0} \end{bmatrix} \quad (4)$$

The SAPF based on current controlled voltage source type PWM control technique is effective to reduce harmonics even when the load is highly non-linear [5, 4].

III.PWM TECHNIQUE:

Because of advances in solid state power devices and microprocessors, switching power converters are used in more and more modern motor drives to convert and deliver the required energy to the motor.

The energy thata switching power converter delivers to a motor is controlled by Pulse Width Modulated (PWM) signals applied to the gates of the power transistors. PWM signals are pulse trains with fixed frequency and magnitude and variable pulse width. There is one pulse of fixed magnitude in every PWM period. However, the width of the pulses changes from pulse to pulse according to a modulating signal. When a PWM signal is applied to the gate of a power transistor, it causes the turn on and turn off intervals of the transistor to change from one PWM period to another PWM period according to the same modulating signal. The frequency of a PWM signal must be much higher than that of the modulating signal, the fundamental frequency, such that the energy delivered to the motor and its load depends mostly on the modulating signal.

Advantage of PWM:

The advantage of PWM based switching power converter over linear power amplifier is:

1. Easy to implement and control,
2. No temperature variation-and ageing-caused drifting or degradation in linearity,
3. Compatible with today's digital microprocessors,
4. Lower power dissipation, and
5. It allows linear amplitude control of the output voltage/current from previously not present.

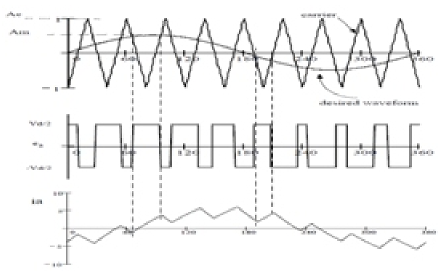

Fig.3. Principle of PWM Control Technique.

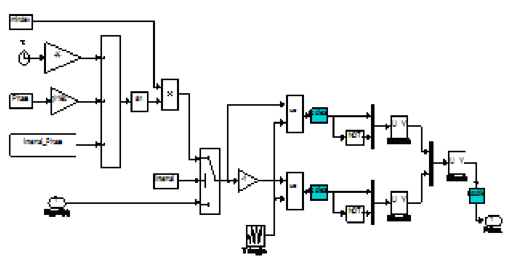

Fig. 4. Matlab Model for PWM Generarion.

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In the most straightforward implementation, generation of the desired output voltage is achieved by comparing the desired reference waveform (modulating signal) with a high-frequency triangular 'carrier' wave as depicted schematically in Fig.3. and Figure 4 shows the Matlab model for the PWM generation of pulses.

IV. SHUNT ACTIVE FILTER COMPENSATION:

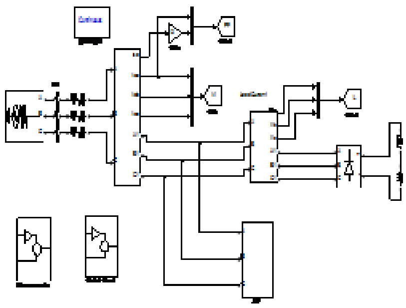

Fig. 5. Simulation model for ShuntActive Power Filter

Fig. 5. Shows the Matlab model for the shunt active power filter with PWM control technique. In this section, the performance of the system will be shown after the connection of shunt active power filter.

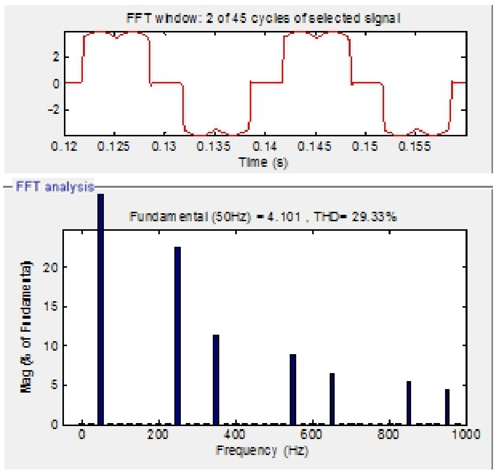

Fig. 6. THD before compensation

In figure 6 it shows that the total harmonic distortion before the shunt active power filter connected to the system. The THD here is 29.39% which is more than the IEEE-519 standard.

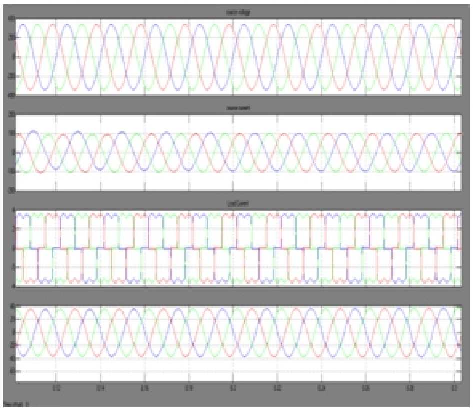

Fig. 7. Source voltage, current, load current and inverter current with PWM Based APF

Fig. 7 shows the three phase source voltages, three phase source currents and load currents respectively with PWM Based APF. It is clear that even though load current is non sinusoidal source current is sinusoidal.

The below figure shows that the total harmonic distortion was reduced from 29.39% to 1.43% after the system connecting to the shunt active power filter.

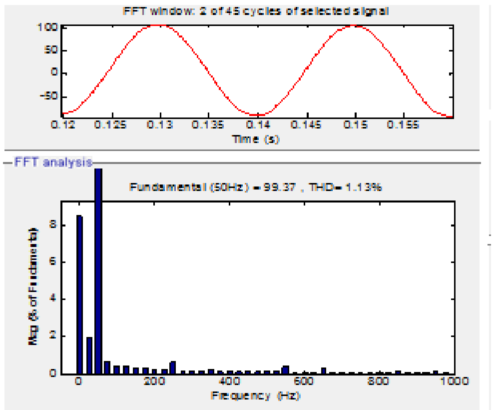

Fig. 8. THD After Compensation

In figure 8 it is clear that the total harmonic distortion was reduced to1.13% by shunt active power filter with PWM control technique.

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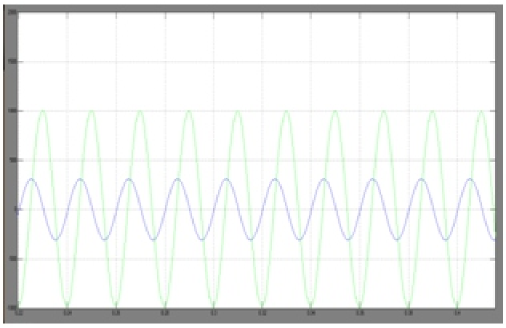

Fig. 8. Phase-A source voltage and current

Fig. 8. shows the three phase source voltages, three phase source currents and load currents respectively with APF. It is clear that with APF even though load current is non sinusoidal source currents are sinusoidal.

V.CONCLUSION:

This paper presents a computational model implemented in Matlab with aims to show the active filter with PWM control technique. The results proved that the system performance was improved after using the shunt active power filter with the PWM control technique. Shunt APF with the proposed controller reduces harmonics and provides reactive power compensation due to non-linear load currents; as a result source current(s) become sinusoidal and unity power factor is also achieved. Simulation results show the effectiveness of shunt active power filter for harmonic elimination in distorted source current. THD of source current reduces from 29.39% and 1.13% which comply with IEEE-519 standard of harmonic control.

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