Research Paper Engineering

Shunt Active Power Filter with Hysteresis Current Control for three Phase Ac-Dc Converter

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ABSTRACT

This paper represents the simulation of Shunt Active Power Filter(SAPF) based on p-q theory and using hysteresis current control to obtain the gating signals for three phase ac-dc converter. The proposed active power filter is employed to reduce the current Total Harmonic Distortion (THD) drawn by the non-linear load and compensate the reactive power. The PI controller is employed to reduce the ripple voltage of the dc capacitor of the inverter. Simulation of a shunt active power filter is done in PSIM software. Simulation results have been obtained, FFT analysis of source current and load current is also presented and Total harmonic distortion of source current is calculated before and after compensation and THD of the source current after compensation is below 5% which is in permissible limit imposed by IEEE-519 standard.

KEYWORDS Fast Fourier Transformation (FFT), p-q theory, Reactive power compensation, Shunt active power filter, Total harmonic distortion(THD)

1. INTRODUCTION

Thyristors converters and diode rectifiers with smoothing dc capacitors are a common source of harmonic currents. The distortion of the current results from the switching operation of thyristors and its harmonic amplitude is greatly affected by the impedance of the ac side. This type of harmonic source behaves like a current source. Therefore, they are called harmonic current source. These types of loads are a matter of serious problem as they cause flicker or harmonic interference in industrial applications, transmission and distribution systems[1-7].

The APF controlled on the bases of instantaneous p-q theory have a good dynamic compensation characteristic for load current. It improves the utility supply system power-factor as the ac source provide only the fundamental frequency of current, in addition to that reactive power compensation and harmonic mitigation. At the same time it have some drawbacks such as it is difficult to realize high power PWM inverters with a rapid current response, some resonance at specific frequency occurs between the source impedance and the APF initial cost is high when compared with passive filter[1-7].

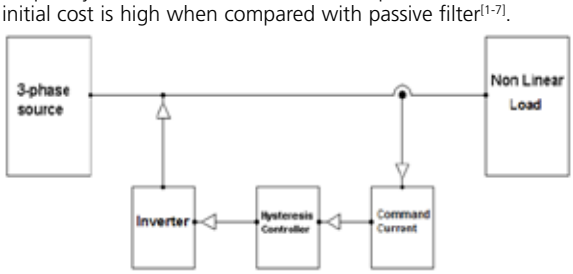

Figure 1. Shunt active power filter with Hysteresis Current Controller

The design and analysis of this work, uses instantaneous power theory along with PI controller for APF. The sensed voltages and currents of the load have been used for instantaneous power calculation to generate reference currents.

A hysteresis band current controller generates switching signals for APF to follow the reference current within specified band limits. The THD and the PF of the load have been investigates for the non linear load system before and after using the proposed filter at different load conditions. Figure 1 summarizes the simulation procedure of shunt active power filter controlled by hysteresis current controller.

2. SHUNT ACTIVE FILTER WORKING WITH PQ THEORY

(a) p-q Theory

The p-q Theory implements a transformation from a stationary reference system in a-b-c coordinates, to a system with co-ordinates α–β–0. For 3-phase 3-wire system zero sequence component will be zero. It corresponds to an algebraic transformation, known as Clarke transformation, which also produces a stationary reference system, where coordinates α–β are orthogonal to each other, and coordinate 0 corresponds to the zero-sequence component. The zero-sequence component calculated here differs from the one obtained by the symmetrical components transformation, or Fortescue transformation by a $\sqrt{3}$ factor.

The voltages and currents in α–β, coordinates are calculated as follows:

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (1)$$

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

Instantaneous real power (p) and Instantaneous imaginary power (q) are defined by following equation.

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} \quad (3)$$

From equation (3) following equation can be obtain

$$\begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix}^{-1} \begin{bmatrix} p \\ q \end{bmatrix} \quad (4)$$

$$\begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix}^{-1} = \frac{1}{V_\alpha^2 + V_\beta^2} \begin{bmatrix} V\alpha & -V\beta \\ V\beta & V\alpha \end{bmatrix} \quad (5)$$

From equation (4) compensating current, in α–β coordinates, are defined as following

$$\begin{bmatrix} ic_\alpha^* \\ ic_\beta^* \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix}^{-1} \begin{bmatrix} \tilde{p} \\ q \end{bmatrix} \quad (6)$$

From equation (6) compensating current in a-b-c variables are defined as following

$$\begin{bmatrix} ic_a^* \\ ic_b^* \\ ic_c^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} ic_\alpha^* \\ ic_\beta^* \end{bmatrix} \quad (7)$$

(b) Power Components:

The p-q Theory power components are then calculated from voltages and current in the α–β–0 coordinates. Each com-

ponent can be separated in its mean and alternating values which present physical meanings. In general, when the load is nonlinear the real and imaginary powers can be divided in average and oscillating components.

Real Power $p = \bar{p} + \tilde{p}$

Imaginary Power $q = \bar{q} + \tilde{q}$

Where, Average Power=$\bar{p} + \bar{q}$ and Oscillating Power = $\tilde{p} + \tilde{q}$

(c) Advantages of p-q theory :

- Since the p-q Theory is based on the time domain, it is valid both for steady state and transient operation, as well as for generic voltage and current waveforms. Allowing the control of the active filters in real-time.
- Another advantage of this theory is the simplicity of its calculations, since only algebraic operations are required.
- When the supply voltage is balanced and the load is not varying continuously then active filter operating on p-q Theory gives the best result.

3. HYSTERESIS BAND CURRENT CONTROL

The hysteresis band current control technique has been proven to be most suitable for all the applications of current controlled voltage source inverters in active power filters. And it's implemented to generate the switching pattern in order to get precise and quick response. The hysteresis band current control is stable, very fast response, and good accuracy[8-9].

The conventional hysteresis band current control scheme used for the control of active power filter, in which error of the reference line current (I_L*) and actual line current of the APF is referred to as (I_L) is given to hysteresis comparator. The hysteresis band current controller decides the switching pattern of active power filter. The switching logic is formulated as follows[8]. Conventional Hysteresis Current Controller is shown in Figure 2.

-- If I_L< (I_L*- HB) upper switch of the leg is OFF and lower switch of the leg is ON.

-- If I_L > (I_L *+ HB) upper switch of the leg is ON and lower switch of the leg is OFF.

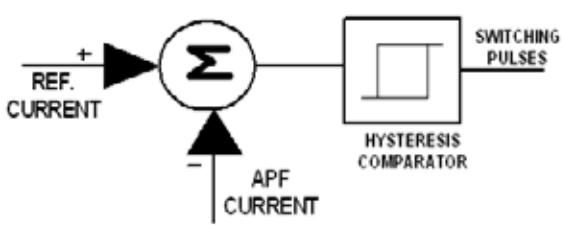

Figure 2. Conventional Hysteresis Current Controller

The hysteresis current control technique has certain advantages (i) The Hysteresis Current Controller is intrinsically robust to the load parameters variation, exhibits very fast transient performance and it is suitable for simple implementation. The conventional Hysteresis Current Controller has a major drawback when applied to the three phase PWM voltage source inverter, inter-phase dependency leads to very high switching frequencies in the inverter.

4. SIMULATION RESULT

Simulation parameters are given below,

- Supply Voltage and Frequency : 400V (L-L) and 50 Hz
- Source Resistance and Source Inductance : 0.5 ohm and 0.1 mH
- Switching Frequency : 10 kHz
- DC Load : R_{dc} = 4 ohm, L_{dc} = 6 mH

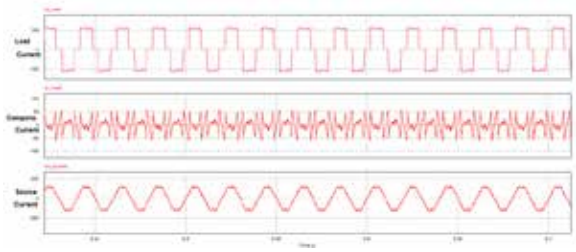

Figure 3. Load Current, Compensating Current, and Source Current

Simulation result shown in Figure 3 Load current, Compensating current and source current waveform. Source Current Waveform is nearly sinusoidal in shape.

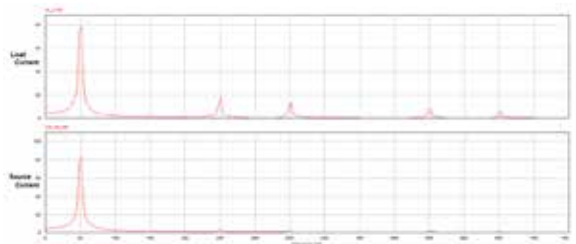

Figure 4. FFT analysis of Load Current and Source Current

Simulation result in Figure 4 shows the FFT analysis of Load current and Source Current. In Load current FFT, there is a 5th , 7th , 11th and 13th order harmonics are present, after compensation provide by SAPF Source current FFT shows only fundamental component is present and all other harmonics are removed.

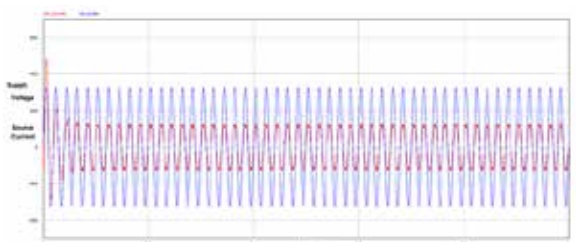

Figure 5. Supply Voltage and Source Current after compensation

Simulation result in Figure 5 shows the supply voltage and source current and result shows that the power factor is improved by the use of active filter and power factor is 0.96 with Non linear load.

5. CONCLUSION :

This paper describes the analysis of Shunt Active Power Filter based on p-q theory with hysteresis current control to obtain the gating signals for inverter. The simulation result shows an effective solution for power quality problems. The proposed SAPF reduces harmonics and reactive power components of load currents. With proposed SAPF a sinusoidal source current and closed to unity power factor is achieved. The total harmonic distortion(THD) of Load Current is 29% and after compensation by SAPF is 4.7% which is in permissible limit specified in standards IEEE-519. Here also present the FFT analysis so one can get idea about the order of harmonic present in source current without the active filter and with active filter.

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