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Current Control Approaches for Shunt Active Power Filters

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Abstract

This paper describes a shunt active power filter with a control system based on the instantaneous active and reactive power method (p-q method), and obtained its performance through simulation results with different types of loads. This method has been broadly used to generate the reference for compensation current in active power filters (APFs). Harmonic control stratagem is applied to compensate the current harmonics in the system. The simulations are passed out with PI controller for the control strategies for different voltage condition. Under balanced and unbalanced voltage condition it is found that the instantaneous active and reactive power component has a better harmonic compensation performance.

Keywords: *Active Power Filters, PI Controller, p-q Method*

I. INTRODUCTION

Shunt active power filters have been acquainted with as a way to overcome the power quality problems caused by nonlinear and reactive loads. The power electronics devices are designed with the goal of obtaining a power factor close to 1 and realizing current harmonics and reactive power compensation. The common methods for the control of shunt active filters are based on two hierarchical control loops: an inner one that declares the desired current and an outer one in charge of determining its required shape and the proper power balance as well. The control structure surveyed in which the current controller is composed of a feedforward action that provides very fast momentary response, and also of a feedback loop which includes an odd-harmonic repetitive control that yields closed-loop permanency and a very good harmonic correction performance. In turn, the outer control law is based on the assumed computation of the amplitude of the sinusoidal current network and, aiming at a strength improvement, this is combined with a feedback control together with an analytically tuned PI controller.

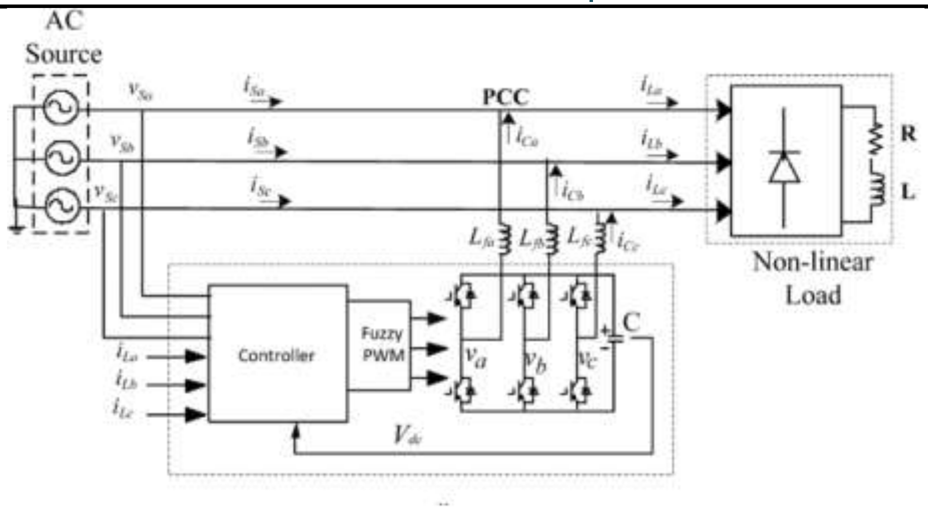

Fig -1 Shunt active power filter

II. BASIS OF THE p-q THEORY

The p-q Theory is based on a set of instantaneous powers defined in the time do- main. No margins are forced on the voltage or current waveforms, and it can be applied to three-phase systems with or without a neutral wire for three-phase general voltage and current waveforms. Thus, it's valid not in the steady state and in the transient state. This p-q theory is very effective and flexible in designing controllers for power conditioners based on power electronics devices.

Other traditional concepts of power are categorized by treating a three-phase system as three single-phase circuits. The p-q Theory transforms voltage and current from the abc to αβγ coordinates, and then defines instantaneous power on these coordinates. This p-q theory always studies the three-phase system as a unit, not a superposition or sum of three single-phase circuits.

III. USE OF THE p-q THEORY FOR SHUNT CURRENT COMPENSATION

The application of the p-q Theory is the compensation of objectionable currents. Demonstrates the basic idea of shunt current compensation. A source supplying a nonlinear load that is being compensated by a shunt compensator. Assumed that the shunt compensator behaves as a three-phase, controlled current source that can draw any set of illogically chosen current references i*Ca, i*Cb, and i*Cc.

A universal control method to be used in the controller of a shunt compensator. The calculated real power p of the load can be divided into its average (p) and oscillating (~p) parts. Likewise, the load unreal power q can be divided into its average (q) and oscillating (q~) parts. Then, undesired portions of the real and unreal powers of the load that should be compensated are selected. The reason for including minus signals in the compensating powers is to accentuate that the compensator should draw a compensating current that produces exactly the opposite of the undesirable powers drawn by the nonlinear load. Note that the espoused current convention such that the compensated current, that is, the source current, is the sum of the load current and the compensating current. Then, the inverse transformation from αβγ to abc is applied to compute the instantaneous values of the three-phase compensating current references i*Ca, i*Cb, and i*Cc.

IV. AN INSTANTANEOUS REAL AND REACTIVE POWER THEORY

The relation of the transformation among each component of the three-phase power system and the orthogonal coordinates are articulated in space vectors shown by the resulting equations in terms of voltage and current as shown in equation 1

$$\begin{pmatrix} v_\alpha \\ v_\beta \end{pmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} v_1 \\ v_2 \\ v_3 \end{pmatrix} \quad (1)$$

The three phase coordinates a-b-c is mutually orthogonal. As a result, the conventional power for three phase circuits can be derivative by using the above equations. An instantaneous active power of the three-phase circuit P can be calculated as shown in equation 2.

$$\begin{pmatrix} i_\alpha \\ i_\beta \end{pmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} i_1 \\ i_2 \\ i_3 \end{pmatrix} \quad (2)$$

and the instantaneous real power is defined as follows in equation 3.

$$p = v_a i_a + v_b i_b + v_c i_c \quad (3)$$

From these equations, the instantaneous power can be reworked as shown in equation 4

$$\begin{pmatrix} p \\ q \end{pmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (4)$$

As the compensator will only compensate the instantaneous reactive power and the real power is permanently set to zero. An instantaneous reactive power is set into opposite vectors in demand to cancel the reactive component in the line current. From the above equation 2 & 3, produce equation 5.

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix}^{-1} \begin{bmatrix} p \\ q \end{bmatrix} \quad (5)$$

By deriving from these equations, the compensating reactive power can be predictable. The compensating current of each phase can be calculated by using the inverse orthogonal transformations as shown below in equation 6

$$\begin{pmatrix} ic_1 \\ ic_2 \\ ic_3 \end{pmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} ic_\alpha \\ ic_\beta \end{pmatrix} \quad (6)$$

This instantaneous reactive theorem achieves instantaneously as the reactive power is detected based on the instantaneous voltages and currents of the three phase circuits. This will supply better harmonics compensations as the response of the harmonic's detection phase is in small delay.

The current control structure plays a significant role in fast response current controlled inverters such as the active power filters. There are three types of current controller. Such as three reliant on hysteresis controllers, three independent hysteresis controllers, predictive and ramp evaluation controllers. However, the hysteresis current control method is the greatest proposed control method in time domain. This method provides instantaneous current helpful response, unconditioned strength to the system and good accurateness. Besides that, this method is said to be the most suitable solution for current controlled inverters.

V. SIMULATION & PERFORMANCE

Simulation is carried out for instantaneous active and reactive power method (p-q). The performance of shunt active power filter under sinusoidal condition, as load is highly inductive; current drawn by the load is rich in harmonics. Under this circumstance control scheme seems to work in similar nature and respective Harmonic distortions are shown. Simulation is protracted to balance and un-balanced sinusoidal conditions with same SAPF.

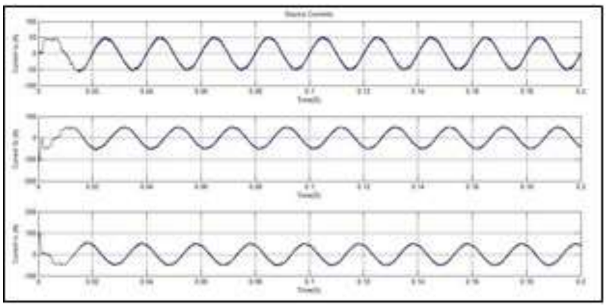

Fig. 1: Source current with filter for RL load

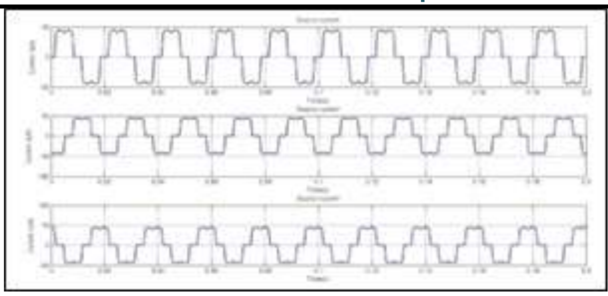

Fig. 2: Source current without filter for RL load

Table -1 THD Value

	Unbalance RL Load	Balanced RL Load
THD Value without filter	26.33%	22.42%
THD Value with filter	2.62%	2.48%

VI. CONCLUSION

In this paper an Active Power filter based on the instantaneous real and reactive power p-q method is premeditated. Current harmonics consist of positive and negative system including the fundamental current of negative system can be compensated. So, it acts as a harmonic and unbalance current compensator. Under balanced main voltage state the equal power compensation are the same. Under unbalanced main voltage condition able to compensate current harmonics faultlessly. The active filter compensation currents are produced by a three-leg VSC with hysteresis current control. In p-q method angle θ can be directly considered from the main voltages and thus enables the method to be frequency independent. The p-q control method which is considered in this paper allows the operation of the AF in variable frequency conditions without adjustment

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