

Fuzzy Logic Controller Based Three-Phase Shunt Active Power Filter for Compensating Harmonics and Reactive Power under Unbalanced Mains Voltages

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Abstract

In this paper, a shunt Active Power Filter (APF) is proposed for the compensation of harmonic currents and reactive power in polluted environment and under unbalanced mains voltage. For this purpose, a fuzzy logic controller is developed to adjust the energy storage of the dc voltage. The reference current computation of the shunt APF is based on the instantaneous reactive power (p-q) theory. We applied the system based on PLL (Phase Locked Loop) in order to control the shunt APF under unbalanced mains voltage. Hysteresis Controllers is used to generate switching signals of the voltage source inverter. MATLAB/SIMULINK power system toolbox is used to simulate the proposed system. The results show the effectiveness of fuzzy logic control to optimize the energy storage of the DC capacitor, the sinusoidal form of the current and the perfect of the reactive power compensation. The proposed system has achieved a low Total Harmonic Distortion (THD) which demonstrates the effectiveness of the presented method.

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Key words: Shunt active power filter, Harmonics, Fuzzy logic control, Reactive power, (p-q) theory, PLL, Hysteresis Controllers and THD.

1. Introduction

The power quality (PQ) problems in power utility distribution systems are not new, but only recently their effects have gained public awareness. Advances in semiconductor device technology have fuelled a revolution in power electronics over the past decade, and there are indications that this trend will continue [1]. However the power electronics based equipments which include adjustable-speed motor drives, electronic power supplies, DC motor drives, battery chargers, electronic ballasts are responsible for the rise

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in PQ related problems [2-3]. These nonlinear loads appear to be prime sources of harmonic distortion in a power distribution system. Harmonic currents produced by nonlinear loads are injected back into power distribution systems through the point of common coupling (PCC). These perturbations (harmonics) are the origin of many problems and affect electrical equipments connected to the power supply.

These harmonics induce malfunctions in sensitive equipment, Voltage stresses, increased heating in the conductors and harmonic voltage drop across the network impedance that affects power factor. Traditionally passive filters have been used to compensate harmonics and reactive power; but passive filters are large in size, aging and tuning problems exist and can resonate with the supply impedance. Recently active power filters are designed for compensating the current-harmonics and reactive power simultaneously. The shunt APF based on Voltage Source Inverter (VSI) structure (a DC energy storage device in this case is capacitor) is an attractive solution to harmonic current problems. The shunt APF is designed to be connected in parallel with the nonlinear load. It detects the harmonic current of nonlinear load and injects into the system a compensating current, identical with the nonlinear load harmonic current but in opposite phase. Therefore, the net current drawn from the distribution network at the point of coupling of filter and the load will be a sinusoidal current of only fundamental frequency.

One of the important tasks in the shunt APF design is the maintenance of constant DC voltage across the capacitor connected to the inverter. This is necessary because there is energy loss due to conduction and switching power losses associated with the controllable switches of the inverter, which tend to reduce the value of voltage across the DC capacitor. Generally, PI controller [6] is used to control the DC bus voltage. The PI controller based approach requires precise linear mathematical model which is difficult to obtain. Also, it fails to perform satisfactorily under parameter variations, non-linearity, and load disturbances [7]. Recently, fuzzy logic controller has generated a great deal of Interest in various applications and has been introduced in the power electronics field [3-5]. The advantages of fuzzy logic controllers over the conventional PI controller are that they do not need an accurate mathematical model, they can work with imprecise inputs, can handle nonlinearity, and may be more robust than the conventional PI controller. In the other hand, In APF design and control, p-q theory was often served as the basis for the calculation of compensation current [8]. In this theory, the mains voltage was assumed to be an ideal source in the calculation process. However, in most of time and most of industry power systems, mains voltage may be unbalanced and/or distorted, in this case the control using the p-q theory does not provide good performance [9-10].

This paper presents an analysis and simulation of a shunt APF topology that achieves simultaneously harmonic current damping and reactive power compensation under unbalanced mains voltages. To optimize the energy storage, a fuzzy logic controller is developed to adjust the energy storage of the dc voltage to its reference and to attenuate harmonic frequencies resulting from power fluctuations. For the reference current computation of the shunt APF, we used a new technique with p-q theory based on PLL as a suitable method to unbalanced mains voltages and for the control of shunt APF. Hysteresis Controllers is used to generate switching signals of the voltage source inverter.

Figure 1 shows the proposed system; the three phase shunt APF system is based on a three-phase inverter with six controllable switches, each of the switches in the switching network is IGBTs with anti-parallel diode to allow current flow in both directions. The shunt APF is designed to be connected in parallel with the nonlinear load. It is connected to the distribution network in the PCC. The network is represented as an unbalanced voltage source.

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