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A simple fuzzy logic based robust active power filter for harmonics minimization under random load variation

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Abstract

Widespread applications of power electronic-based loads continue to increase concerns over harmonic distortion. However, it is desired to draw purely sinusoidal current from the distribution network, but this is no longer the case with new generation loads, consisting of power electronic converters. The current harmonics produced by these non-linear loads further result in voltage distortion and leads to various power quality problems. This paper, therefore, deals with a simple fuzzy logic based robust active power filter to minimize the harmonics for wide range of variations of load current under stochastic conditions. The proposed control scheme is very simple and it is also capable of maintaining the compensated line currents balanced, irrespective of the unbalance in the load currents. The proposed methodology is extensively tested for wide range of variable load current under stochastic conditions and results are found to be quite satisfactory to mitigate harmonics and reactive power components from the utility current. The results presented in this paper clearly reflect the effectiveness of the proposed APF to meet the IEEE-519 standard recommendations on harmonic levels.

Keywords: Active power filter; Fuzzy logic controller; Power system harmonics; Limiter; Power quality

1. Introduction

The increased use of power electronic controlled equipments and non-linear electronic devices in power systems has given rise to a type of voltage and current waveform distortion called as ‘harmonics’ [1].

Harmonics causes various problems in power systems and in consumer products, such as distorted voltage waveforms, equipment overheating, blown capacitor fuses, transformer overheating, excessive neutral currents, low power factor, etc. [2–4]. The research has been underway for last three decades to have a control over the harmonics and to supply the consumers with reliable and clean fundamental frequency, sinusoidal electric power that does not represent a damaging threat to their equipments.

To reduce harmonic distortion, both passive and active compensation techniques (filters) can be implemented. Passive filters have the drawback of bulky size, component ageing, resonance and fixed compensation performance. These provide either over- or under-compensation of harmonics, whenever a load-change occurs [5]. Hence, active compensation known as active power filter (APF) is preferred over passive compensation. APF’s are an up-to-date solution to power quality problems, which allow the compensation of current harmonics and unbalance together with power factor improvement.

Artificial intelligence is one of the major fields developed since past four decades, and is popular due to its ability to handle complex problem at difficult situations. These tools of artificial intelligence (fuzzy logic, artificial neural network, genetic algorithms, wavelet theory, optimization methods) are used for improving the power quality effectively since 1980s and produce good performances [6]. Fuzzy logic is one of the alternatives to artificial intelligence originated by Zadeh [7]. Use of fuzzy logic for minimization of harmonics and improvement of power quality is not a new issue rather various authors have introduced some innovative methodologies using these tools [8]. In [9], Dell’Aquila et al. have developed shunt active filter with fuzzy logic estimation of the power devices duty cycle via current

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control of PWM inverter. This scheme was tested for compensating the real line current drawn by an AC induction motor drive using virtual instrumentation and found that the scheme is able to compensate the harmonics pollution. In [10], authors have proposed a Takagi–Sugeno fuzzy model, derived from input–output data by means of product space fuzzy clustering, to predict the future harmonics compensating current. The developed control model is applied to compensate the harmonics produced by the variable non-linear load. An important point of the work is the use of optimization method to minimize the computational steps, which makes the overall scheme complex. Refs. [11–13] are devoted to design the conventional PI and fuzzy logic based PI controller, which is part of the active filter. In [14], the work is focused to minimize the harmonics for unbalanced and voltage sag compensation via fuzzy logic for series APF.

The most important observation from the work reported by various researchers for power quality improvement is the design of active power filter under 'fixed load' condition, however, in practical life the loads are variable. Hence, there is the need to design an active power filter, which is capable of maintaining the THD well within the IEEE norms [15], under variable load conditions. This paper, therefore, presents a simple, robust fuzzy logic based active power filter to control the harmonics under variable load conditions.

2. The shunt active power filter

2.1. Overview

The basic principle of the shunt active filter was originally presented by Sasaki and Machida [16]. Various types of active power filters have been proposed [17–19] and are classified based on the type of converter, different configurations used, control methodologies, the economic and technical considerations and selection for specific applications [20,21]. Among the various topologies of APF developed so far, shunt APF based on the current controlled voltage source type PWM converter has been proved to be very effective even when the load is highly non-linear. The current source inverter as an APF acts as non-sinusoidal current source. It is reliable, but has higher losses and requires higher parallel AC power capacitance. Also, it cannot be used in multilevel configuration to improve the performance at higher voltage ratings. The voltage source inverter as an APF has a self-supporting DC voltage bus with large DC capacitance. It is lighter, cheaper and expandable to multilevel configurations [22]. APF schemes based on the methods of determining compensating current are given in [23–26].

Investigations reported in this paper are performed on a three-phase shunt active filter to compensate harmonics and reactive power requirement of the non-linear loads. The control scheme is based on sensing line currents only, an approach different from the conventional methods. DC link voltage is regulated to estimate the reference current template. Role of DC link capacitor is described to estimate the reference current. Results presented here are based on exhaustive analytical study to investigate the performance of the APF during transients as well as in steady state for variety of loads with different loading conditions, and important parameters (THD, power factor, active and reactive power, etc.) are studied before and after compensation.

2.2. Basic compensation principle

Fig. 1(a) shows the basic compensation principle of the shunt APF. A current controlled voltage source PWM converter with necessary passive components is used as an APF. It is controlled to draw/supply a compensated current from/to the utility, such that it cancels reactive and harmonic currents of the non-linear load. Thus, the resulting total current drawn from the AC mains is sinusoidal. Ideally, the APF needs to generate just enough reactive and harmonic current to compensate the non-linear loads in the line. Fig. 1(b) illustrates the waveform of load current (curve A), source current, after the harmonic compensation (curve B), and compensating current injected by the APF (curve C), to make the source current sinusoidal.

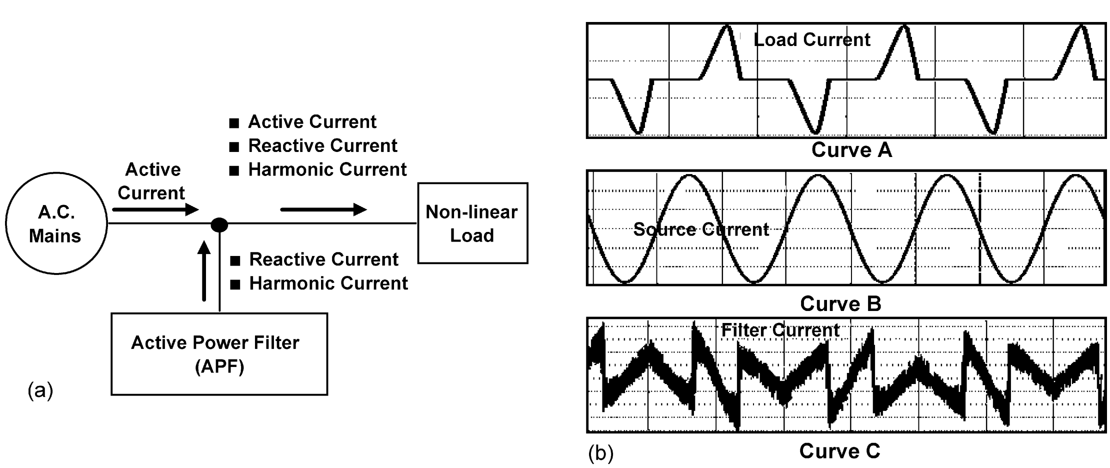

Fig. 1. (a) Basic compensation principle of the shunt APF. (b) Waveform of load current (curve A), desired source current (curve B), and compensating current injected by the APF (curve C).