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Novel schemes used for estimation of power system harmonics and their elimination in a three-phase distribution system

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ABSTRACT

Estimation of power system harmonics and their elimination is an interdisciplinary area of interest for many researchers. This paper presents Variable Step Size Least Mean Square (VSS-LMS) approach for harmonics estimation and Shunt Active Power Filter (SAPF) with two-level Hysteresis Current Control (HCC) technique for their elimination in a three-phase distribution system. In the estimation process, the weight is updated using VSS-LMS algorithm. Harmonics components are estimated from the updated weights. In order to mitigate harmonics produced by the nonlinear load connected in a three-phase distribution system, SAPF with two-level HCC is proposed. A three-phase insulated gate bipolar transistor (IGBT) based current controlled voltage source inverter (CC VSI) with a dc bus capacitor is used as an active power filter. The first step is to calculate SAPF reference currents from the sensed nonlinear load currents by applying the synchronous detection method and then the reference currents are fed to the proposed controller for generation of switching signals. The nonlinear load consists of one three-phase and one single-phase diode rectifier feeding *R–L* load, so that the effectiveness of the two-level HCC scheme to compensate for unbalanced nonlinear load can be tested. Various simulation results are presented to verify the good behavior of the SAPF with proposed two levels HCC.

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1. Introduction

Advanced power semiconductor technology, power electronics based devices are widely employed in various applications. Because of their nonlinear *V–I* characteristics these devices draw current with harmonic content and reactive power from AC mains. Current harmonics drawn by nonlinear loads disturb the waveform of the voltage at the point of common coupling (PCC) and lead to the voltage harmonics that the other linear loads and sensitive electronic equipments have to deal with.

Conventionally, passive filters are used for compensating current harmonics but it suffers from the problem of series, parallel resonances as well as its performance dependency on source impedance. These demerits can be overcome by using active power filters which have been widely investigated for compensation of harmonics. The active power filter topology can be connected in series or shunt and combination of both. Series active power filters are intended to reduce voltage harmonics, it can also reduce voltage at the load terminals in abnormal conditions but it cannot reduce current harmonics [1,2]. Shunt Active Power Filters (SAPFs) have been designed and extensively used in practice as a cost effective solution for compensation of current harmonics. So many combinations of active power filters have been discussed in the literatures [3–5]. A compensation current equal but opposite to the harmonic current produced by the nonlinear loads is suppressed by active power filters so as to make the source current sinusoidal and in phase with supply voltage.

The methods of extracting harmonics references from the measured load currents are basically classified as two types one is compensation techniques in frequency domain and other is compensation techniques in time domain. The frequency domain techniques are mainly based on the use of Fourier harmonic analysis [6]. During steady-state operation, these methods provide an accurate reference value but more computational effort is required for the implementation and a long time delay is also introduced in the system response. Due to this reason many time domain based techniques have been researched. Out of these most common are employing PQ theory which is based on measuring the instantaneous active and reactive power [7] and which use one or more synchronous rotating frames (SRFs) of reference alternatively called *d–q* methods [8]. These methods provide faster response than frequency domain techniques and also more effective

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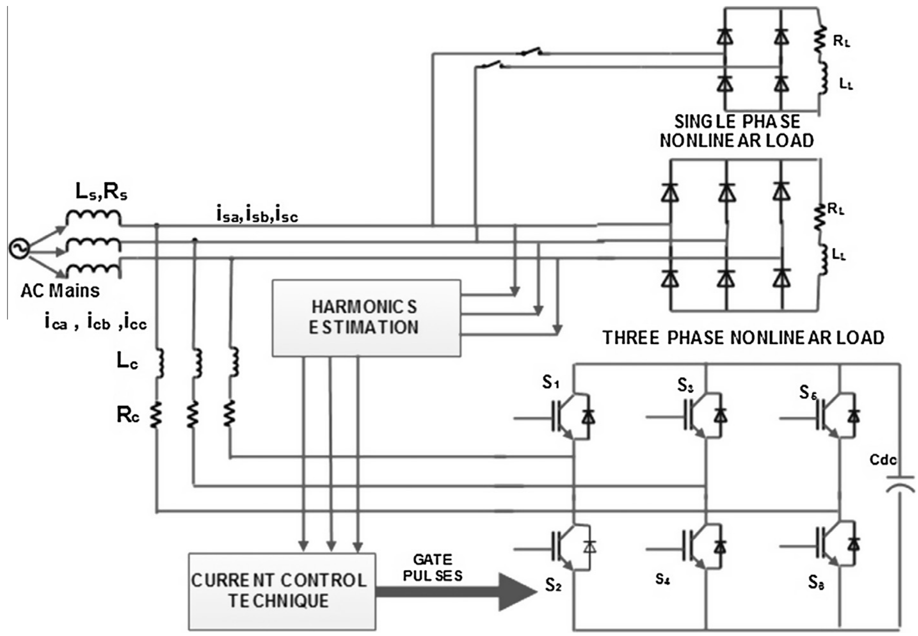

Fig. 1. Three-phase shunt active power filter.

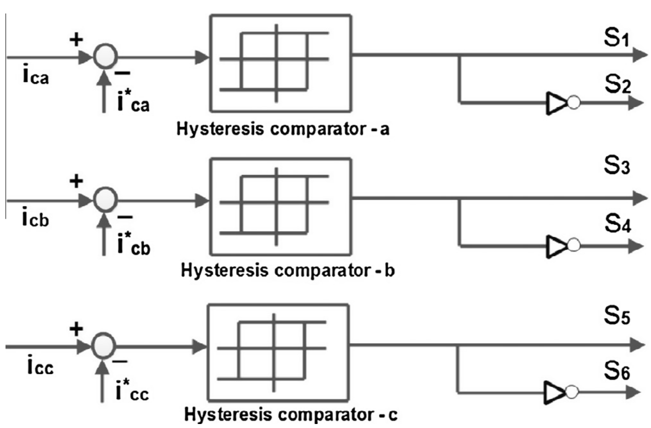

Fig. 2. Block diagram of the hysteresis current control.

Table 1
System parameters.

System parameters	Values
Line voltage	380 V
Line frequency	60 Hz
Supply impedance	$R = 0.5\ \Omega$, $L = 1$ mH
DC voltage	750 V
Load	Active power = 10 kW
	Inductive power = 100 VAR
APF inductor	30 mH

compensation under all operating conditions. After the determination of current reference, APF is capable of tracking such reference even in presence of sudden slope variations.

Several current control approaches, namely instantaneous reactive power theory [9,10], ANN based controller [11–13], DSP based controller [14], hysteresis and sliding mode control techniques [15], selective harmonics elimination PWM method [16], adaptive notch filter [17], improved PSO [18] have been implemented to control the APF for elimination of harmonics. However in most of these techniques, have limitations due to limited accuracy, difficulties in training and noisy environment. Therefore it is justified to

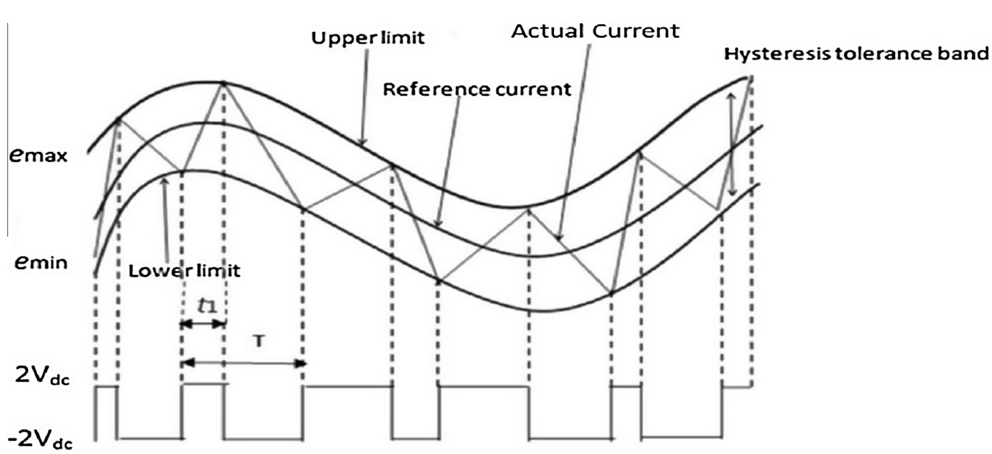

Fig. 3. Diagram of two-level hysteresis current control.

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