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A comparative study of harmonic currents extraction by simulation and implementation

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ABSTRACT

The aim of the present work is to obtain a perfect compensation by extracting accurate harmonic currents. The objective is to avoid the consequences due to the presence of disturbances in the power system. A comparative study of harmonic currents extraction by simulation and implementation is carried out for two different techniques. The first technique is based on the instantaneous powers, taking advantage of the relationship between current and the power transformed from the supply source to the loads. The second is based on ADALINE neural network. The neural method can estimate the harmonic terms individually and online, therefore, the APF can realise a selective compensation. The developed architectures are validated by computer simulation and experimental tests. The algorithms are implemented in the dSPACE Board in order to show the effectiveness and capability of each technique. The results have demonstrated that the speed and the accuracy of the ADALINE can improve greatly the performances of active power filters.

1. Introduction

The intensive use of power converters as rectifiers produces non sinusoidal current in the a.c. supply. Therefore, the voltage in the point of common coupling will contain harmonic components. Furthermore, harmonic voltages and currents propagate into the supply system, increase losses, generate measurement errors, interfere with other consumers, and cause serious problems of electromagnetic compatibility [1].

Currently, active power filters have been widely used, studied and presented as a solution to cancel harmonics from power network. These filters are classified into shunt active power filter, series active power filter, hybrid filters (parallel passive filter and series active power filter) and finally, Unified Power Quality Conditioner UPQC (series active power filter and shunt active power filter) [1,2].

Shunt active filter [3], injects compensating harmonic currents into the power system to mitigate harmonic contained in the loads.

Actually, several control methods such as sliding mode control [4], wavelet method [5], fuzzy control [6,7], adaptive neural network control [8], neuro-fuzzy control [9], and fundamental magnetic flux compensation [10], have been proposed and used to control harmonic currents and dc voltage of power filters. These controllers are also employed to improve active power filter performances and replace the conventional PID controllers [11].

A perfect compensation is necessary to avoid the consequences due to harmonics. The estimation of current references constitutes an important part in the control of active power filters (APFs) used in power systems. Although many identification techniques and strategies have been developed such as methods based on FFT (Fast Fourier Transformation) in the frequency domain, and the methods based on instantaneous power calculation in the time -domain. Instantaneous active and reactive theory (*p–q* theory) introduced by Akagi et al. [1], is a well-known compensating strategy. This method requires the transformation of both supply and load currents/voltages from the abc reference frame to the α–β reference frame. This method operates very well for harmonics cancellation and reactive power compensation, simultaneously, under balanced source voltages.

However, researchers from many scientific disciplines are developing and designing artificial neural networks (ANNs) to solve problems in pattern recognition, prediction, optimization, associative memory and control [12–15]. Artificial neural networks are successfully applied to power systems, especially for harmonic extraction [16–19].

The ADALINE, which is a type of ANNs, and its new application for analysis of power quality, has the advantages of being simply built and easily implemented through hardware. The results of frequency tracking, [20–22] and especially harmonics detection, [8], [16–18] demonstrate that the ADALINE and its algorithm can be

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applied to the precise analysis for power quality. The learning capacity of the ANNs enables online adaptation to any change in electrical network parameters.

Many applications, such as harmonic monitoring, may require the extraction of a limited number of individual harmonics as the 5th and the 7th harmonics which are the most harmful. The ADALINE proposed by Widrow and Lehr [23], can estimate the harmonic terms individually and online.

In this paper, two techniques for harmonic currents extraction are developed and compared. The first technique is based on the instantaneous powers theory (*p*–*q* theory) and the second technique is based on ADALINE neural method. Simulations and experimental tests are carried out in order to show the effectiveness and the capability of each technique. The results demonstrate that the ADALINE neural method is more efficient and easy to implement.

2. Principle of shunt APF

The APF is a voltage source inverter connected to the three-phase line through the inductor L (Fig. 1). This inverter injects an appropriate current into the system to compensate harmonics currents that are responsible for power network pollution.

3. Instantaneous power theory (*p*–*q* theory)

The instantaneous power method (*p*–*q* theory) [1,2] is defined on the basis of the instantaneous values of voltage and current waveforms in a three phase power system (Fig. 2).

Using the Clarke transformation, these three-phase vectors are transformed to the orthogonal α, β, 0 coordinate system.

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{bmatrix} \tag{2}$$

Since the load is balanced, and there is no neutral line, the system does not have a zero-sequence, v_0 and i_0 are equal to zero and the system equations are simplified as shown below:

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix} \tag{3}$$

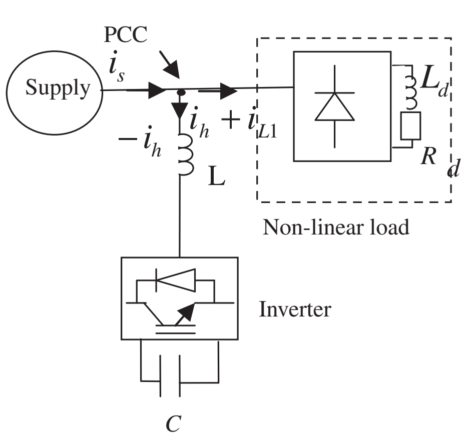

Fig. 1. Principle of APF.

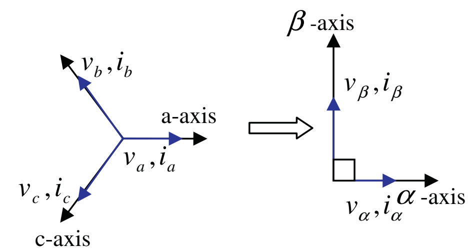

Fig. 2. Instantaneous space vectors.

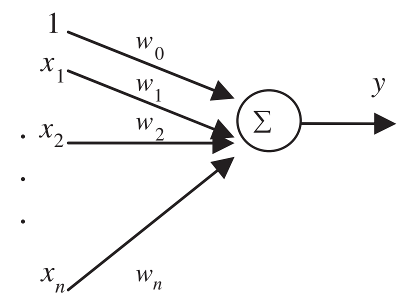

Fig. 3. Basic architecture of ADALINE neural network.

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{bmatrix} \tag{4}$$

The conventional instantaneous power in a three-phase system *p* and *q* is based on the following equation:

$$p = v_\alpha i_\alpha + v_\beta i_\beta \tag{5}$$

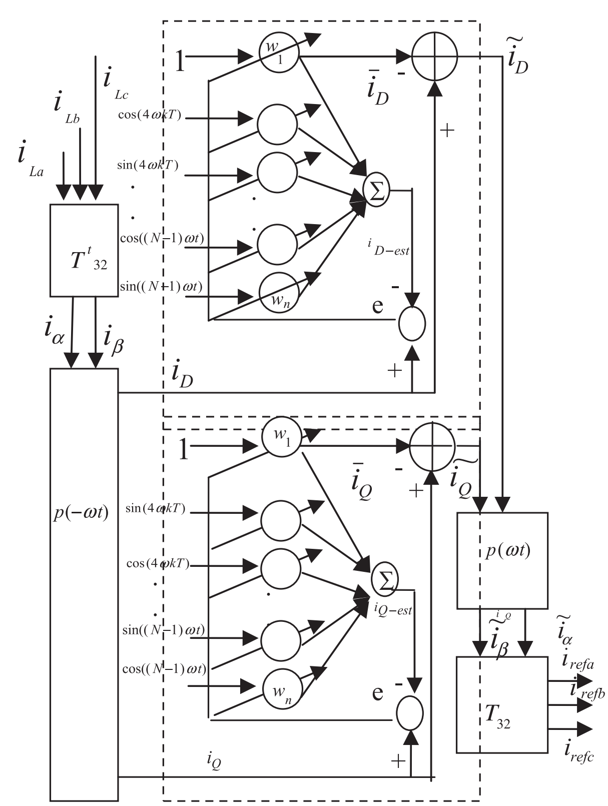

Fig. 4. Diphase method current principle.