J. Automation & Systems Engineering 8-3 (2014): 141-150

Regular paper

Enhance Performance of Current Harmonic Detection Using Wavelet Transform

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Journal of Automation & Systems Engineering

All over the world, harmonics current has been increased and injected by nonlinear loads, such as rectifier equipment used in telecommunication system, power suppliers, domestic appliances ect...To make the transient behaviors' of Shunt Active Power Filter (SAPF) system better, researchers improved the system construction, detection method, control strategy and so on. This paper presents a novel method and design to identify the harmonic and reactive component using Wavelet Transform (WT), in order to eliminate the undesired harmonics as well as compensate reactive power. To investigate the performance of this identification method, the study has been accomplished using simulation with the MATLAB Simulink. The simulation study results of the new (SAPF) identification technique compared to other similar methods are found quite satisfactory by assuring good filtering characteristics and high system stability.

Keywords: Shunt Active Power Filter, harmonics, Wavelet transform, power quality.

1. INTRODUCTION

IN the latter-decades, the extensive use of electronic devices technology and nonlinear loads, which make use of switching systems, such as high-power diode/thyristor rectifiers, arc furnaces, cyclo-converters, and variable speed drives, have given rise to signal deterioration in the electrical distribution network. Consequently, the problem of harmonic treatment takes on great significance .the flow of these harmonics through sensitive electronic equipment cause power losses. So, it is recommended to overcome this problem [1], [2].

So as to trap these harmonics, the power passive filters (PPF) have been traditionally used; which are simple and low costs. However, this traditional solution has major drawbacks, which decrease its flexibility and reliability, such as the large size, the risk of resonance.

Owing to the (PPF)disadvantages and the rapid improvement in the semiconductor device technology that makes high-speed, high-power switching devices[3], direct the researchers toward shunt active power filter (SAPF).Consequently (SAPF) has become more attractive, and has been developed and gradually recognized as a practically way out of the problems created by non-linear loads[4-6].

In order to determine harmonic and reactive component of load current, reference source current generation is needed [5]. Thus, reference filter current can be obtained when it is subtracted from total load current. For better filter performance, generation of reference source current should be done properly [4]. For this purpose, several methods such as pq-theory, dq-transformation [8], multiplication with sine function and Fourier transform have been introduced in literature [6].

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Recently, some modern methods have been applied in order to improve processing detecting time of harmonic current [7, 8]. The past decade has seen a remarkable interest increase in Wavelet Transform (WT) which is characterized by their simple structure; the (WT) has been applied in many uses in the power electronic part of filters devices [9] where they have justified their effectiveness. The results obtained with (WT) are often better than those of traditional methods.

In this paper, a detection method using Wavelet Transform (WT) which can be utilized in harmonic current detection from distorted wave is presented. This method can optimally obtain the reference current of each phase.

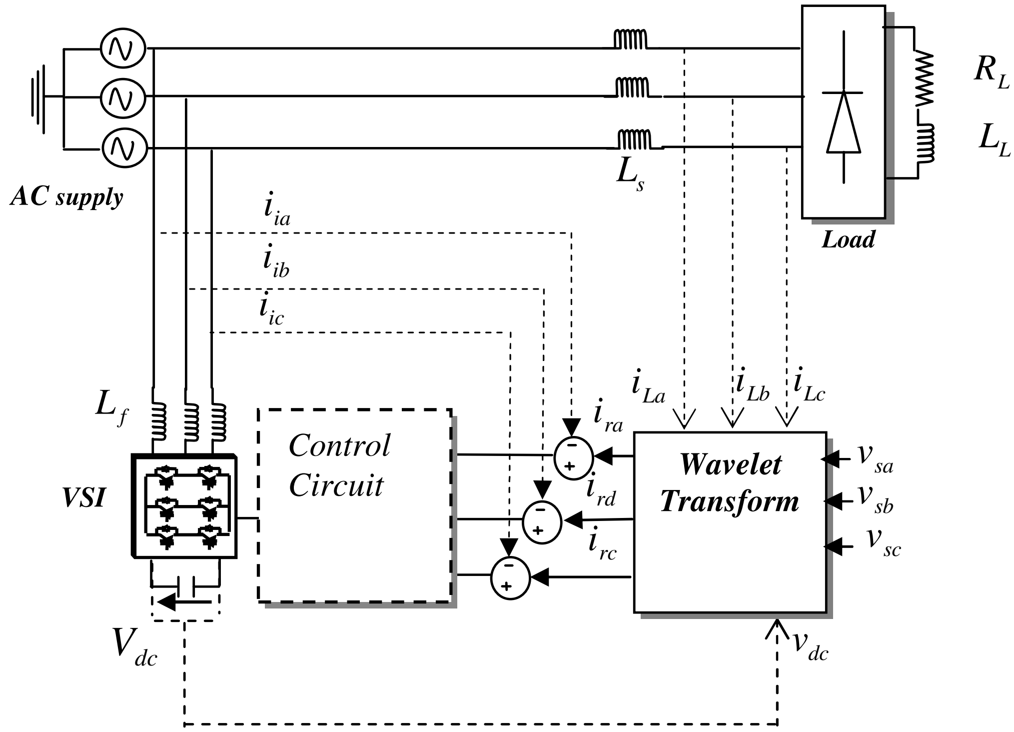

Fig. 1 *Schematic diagram of shunt APF*

2. WAVELET TRANSFORMATION COEFFICIENTS

The continuous Wavelet Transform [10] (CWT) for a signal f is defined by

$$W_f(a,b) = \langle f, \Psi_{a,b} \rangle = \int f(x)\overline{\Psi}_{a,b}(x)dx \tag{1}$$

where a and b are respectively the scaling and translation parameters and the base atom $\Psi(x)$ is a zero average function, centred around zero with a finite energy.

The family of vector is obtained by translations and dilatations of the base atom

$$\Psi_{a,b}(x) = \frac{1}{\sqrt{a}}\Psi(\frac{x-b}{a}) \tag{2}$$

by choosing fixed values $a = a_0^m$ and $b = nb_0 a_0^m$, $m, n = 0, \pm 1, \pm 2, \cdots$, we get the Discrete Wavelet Transform (DWT).

$$(T_f)_{m,n} = \langle \Psi_{m,n}, f \rangle = \int f(x)\overline{\Psi}_{a,b}(x)dx$$

$$(T_f)_{m,n} = a_0^{-m/2} \int \overline{\Psi}(a_0^{-m}x - nb_0) f(x)dx \tag{3}$$

The analysing wavelet is characterized by a number of matematical properties summarized by :

Compact support : $\int \Psi(t)^2$

Zero average $\int_{-\infty}^{+\infty} \Psi(t)dt = 0$ (condition of admissibility) (4)

Zero moments (regularity) $\int_{-\infty}^{+\infty} \Psi(x)\, x^p dx = \hat{\Psi}^{(p)}(0) = 0$ for $p = 0, 1, \cdots$ where p represents the number of zero moment of the wavelet.

In multiresolution analysis [12] $f(x)$ is decomposed on different scales as follows :

$$f(x) = \sum_{j=0}^{j=L} \sum_k d_j^k \Psi_{j,k} + \sum_k C_k^L \Phi_{j,k} \tag{5}$$

where $\Psi_{j,k}$ are the discrete analysis wavelets and $\Phi_{j,k}$ are the discrete scaling functions. The wavelet coefficients d_j^k represent the detailed signals at scale 2^j, and the scaling coefficients C_k^L are the approximated signal at scale 2^L. The calculation of these coefficients consist of convolution carried out between the signal and a pair of quadrature Mirror filters (QMF's), which are downsampled by a factor of two for each scale [11]. A QMF pair consists of a lowpass filter (H) and the highpass filter (G) which split the signal's bandwidth in half. The frequency responses of H and G, and their impulse responses are related by

$$g_n = (-1)^{1-n} h_{1-n} \tag{6}$$

The impulse responses of the decomposition and synthesis QMF pairs denoted $(\tilde{H}, \tilde{G})$ and (H, G) respectively are related by

$$g_n = \tilde{g}_{-n} \tag{7}$$

$$h_n = \tilde{h}_{-n} \tag{8}$$

From which the coefficients for $G, \tilde{H}$ and $\tilde{G}$ can be derived using equations (5),(6) and (7).

The coefficients can be recombined to synthesize the signal $f(x)$ by means of the inverse wavelet transform, which is implemented by up-sampling, by a factor of two, and filtering with the synthesis QMF pair for each scale. Figure 2 illustrates the operations involved in the wavelet decomposition and synthesis of a signal.

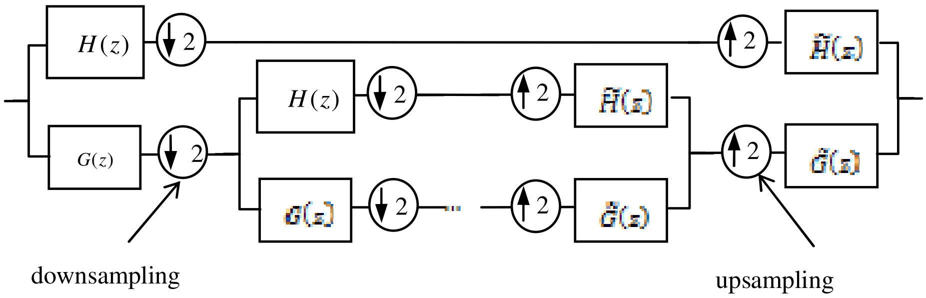

Fig. 2 Implementation of the filters bank for the Discret Wavelet Transform

Figure 3 shows the resulting spectral characteristics of the filter bank for 3-level decomposition.

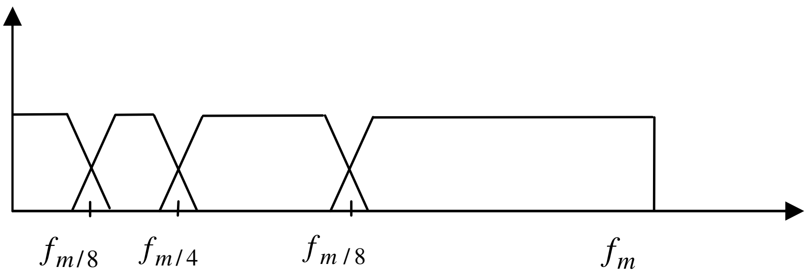

Fig. 3 Spectral characteristics for 3-level decomposition

In this paper the noise extraction to the load courant is realised using discret wavelet transform:

We employ the DWT to the load current signal for produce the noisy wavelet coefficient to the level which we can properly distinguish the fundamental signal (50 Hz). The biorthogonal wavelet, bior3.7 is used.

we select the appropriate threshold at each level to best remove the fundamental signal (suppress 50 Hz).

The inverse wavelet transform for the thresholded wavelet coefficients is effected, to obtain noised signal (harmonic signal).

The same procedure to the noised signal using wavelet Daubechies db8 is realised, to reduce the fundamental signal level still present.

In this work, the Wavelet Transform (WT) picks up the load currents and removes the harmonic component of the load current, in order to create a reference current Ir, a block diagram of the system is illustrated in figure 1. The reference current is composed of the harmonic components of the load current which the active filter must provide. This reference current is fed through a controller and then the switching signal is generated for the active filter switches, such that the active filter will indeed produce the signal required by the load. Finally, the AC supply will only need to provide the fundamental part for the load.

3. DC-LINK CONTROL

The average voltage across the capacitor must be maintained at a constant value. The causes of its variation are primarily losses in switches (conduction and switching) in the decoupling inductors L_f and injection currents during fundamental transient. In steady state, the source must provide an active power equal to the power required by the load. When an active power imbalance occurs in the system, the storage capacity required to provide the difference in power between the network and load, it follows then voltage varying across the capacitor feeding SAPF, where regulation is necessary to stabilize the voltage across the capacitor. The active power P_f (figure 4) necessary to restore the capacitor voltage at a constant value is given by the expression:

$$P_f = P_{lo} - P_s \tag{9}$$

P_f : Instantaneous power injected by the active filter.

P_{lo} : Active power consumed by the load.

P_s : Active power delivered by the source.

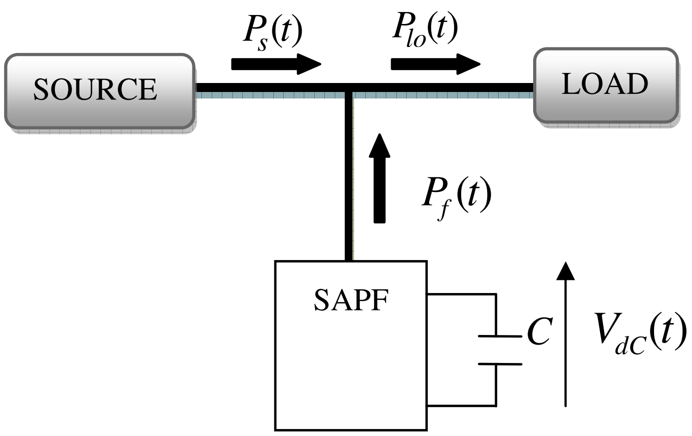

Fig. 4 power Exchange between network, load and filter

By neglecting the losses in the switches and decoupling inductors the relationship between active power absorbed by the capacitor and the voltage across, this latter is given by:

$$P_c = \frac{d\left(\frac{1}{2} C_{dc} \, v_{dC}^2\right)}{dt} \tag{10}$$

Note that the relation (10) is nonlinear. For small changes in voltage V_{dC} around its reference V_{ref} , it can be linearized through the following relations:

$$P_c = C_{dc} v_{ref} \frac{d(v_{dc})}{dt} \tag{11}$$

By applying the Laplace transforms:

$$v_{dc} = \frac{1}{v_{ref} C_{dc} S} P_c(S) \tag{12}$$

From the relation (12) and taking into account the proportional controller (K_c), the DC voltage control loop can be represented by the diagram in Figure 5. The proper choice of the parameter K_c results in a minimum response time.

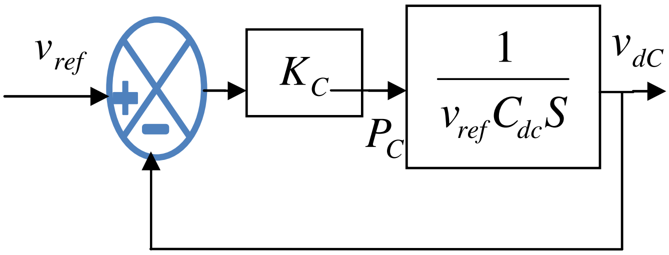

Fig. *5* Control loop of the DC voltage

4. SIMULATION RESULTS

The performance of the proposed detection-control method was examined through simulations. The system model was implanted in Matlab/Simulink environment as it is shown in Figure 6.

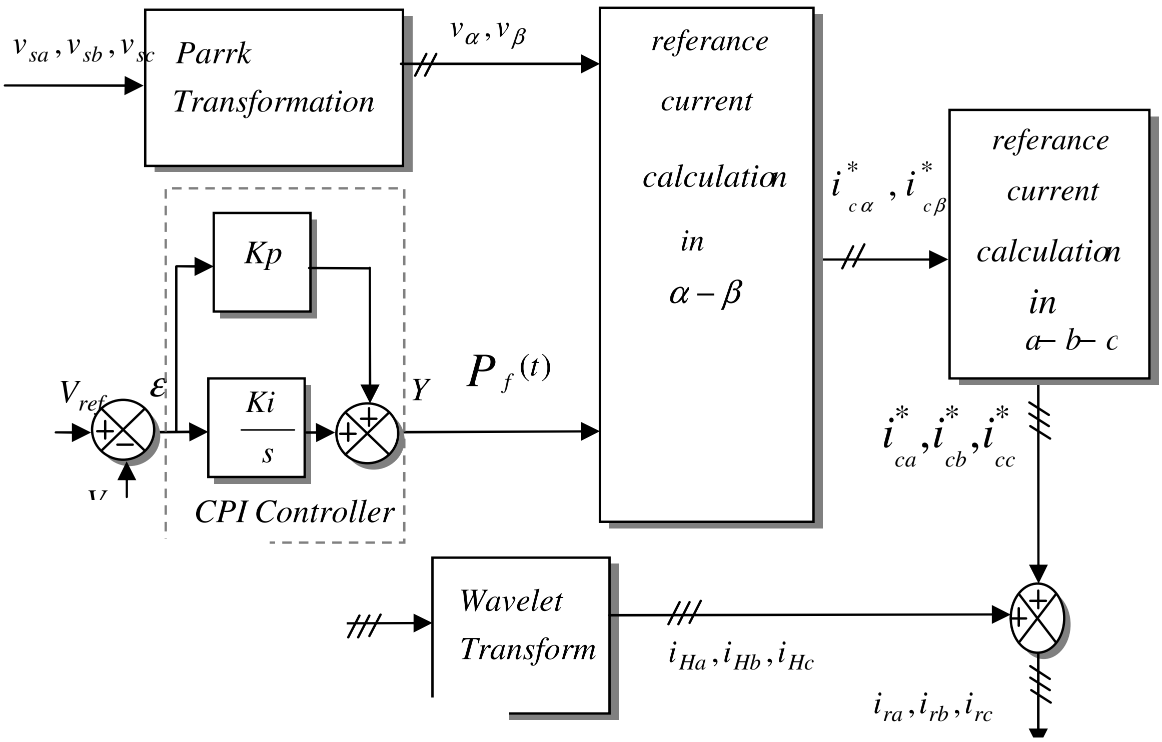

Fig. 6 Block diagram for the Wavelet transform method

The SAPF was designed to compensate harmonics caused by nonlinear loads. The system model parameters are shown in Table 1.

Table.1 system parameters

Parameters	
Supply phase voltage U	220 V
Supply frequency fs	50 Hz
Filter inductor Lf	0.7 mH
Dc link capacitor Cf	0.768474 mF
Vdc	857 V
Smoothing inductor Lsmooth	70 µH

A three-phase diode rectifier with an RL load was used as a harmonic producing load. The initial load (resistance was 3.33 Ω and the inductance 0.06 H. or Load apparent power SL=81VA).

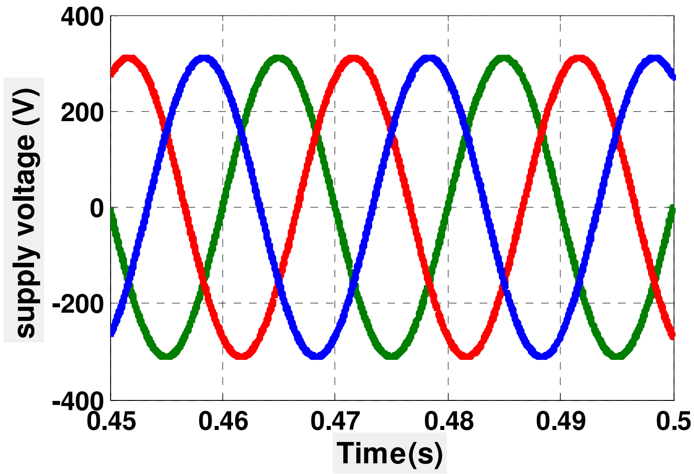

Fig. 7 Simulated of supply voltage waveform.

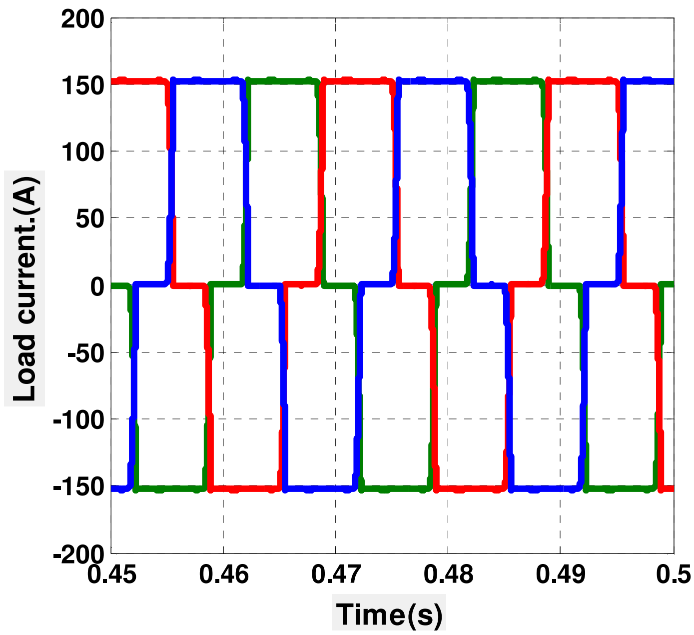

Fig. 8 Simulated of load current

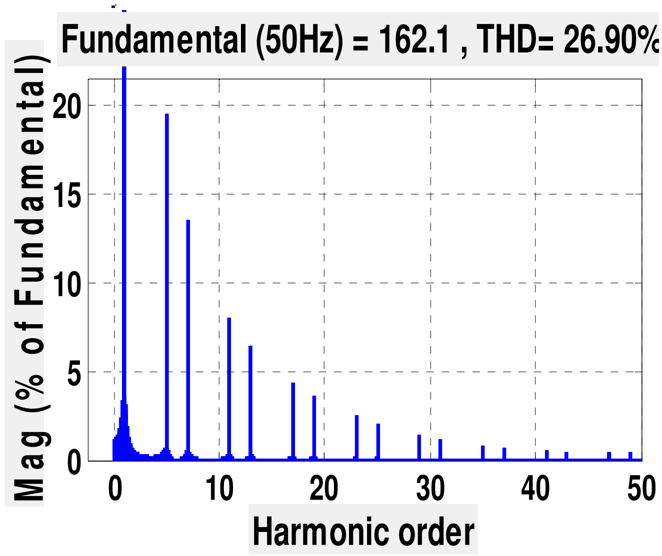

Fig. 9 Harmonic spectrum of load current (Phase -a-)

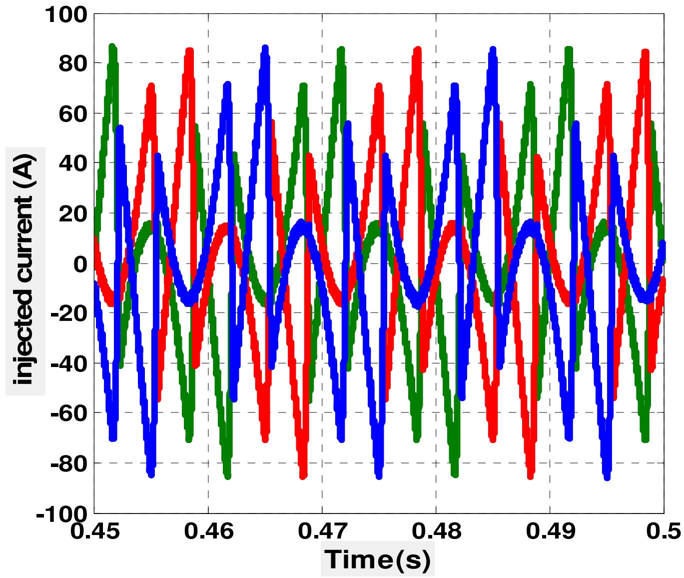

Fig. 10 Simulated of injected current waveforms with (WT) method

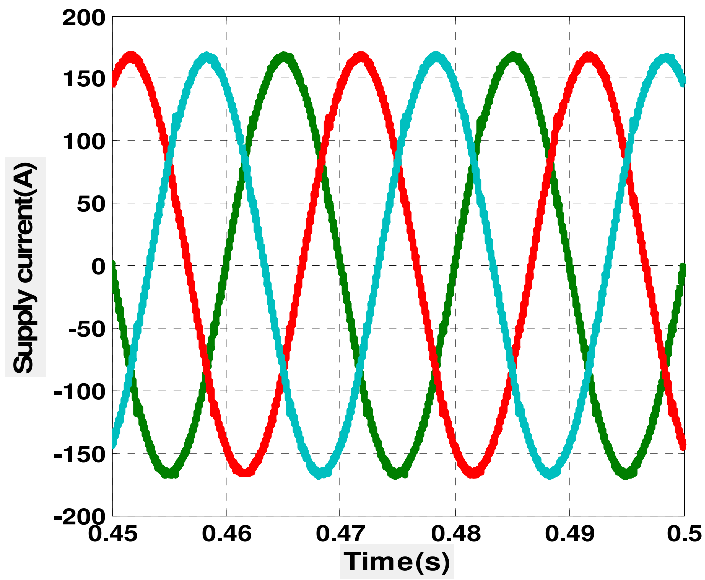

Fig. 11: Simulated of supply current waveforms

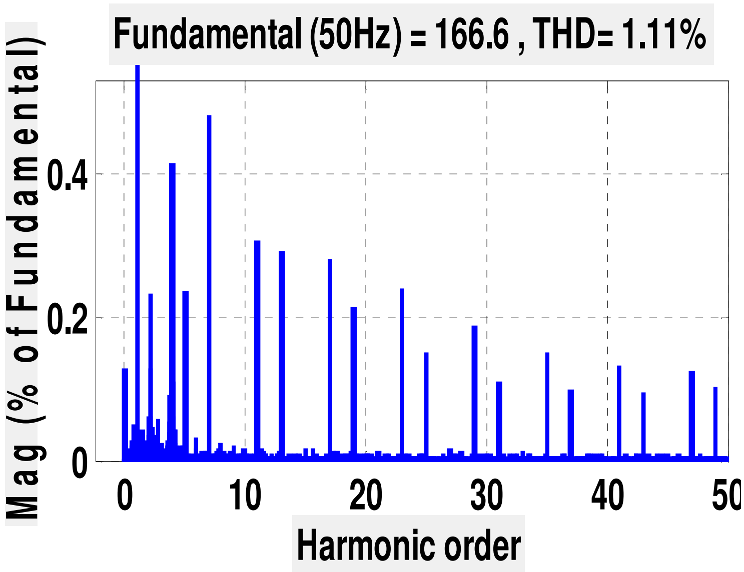

Fig. 12 Harmonic spectrum of supply current (Phase -a-)

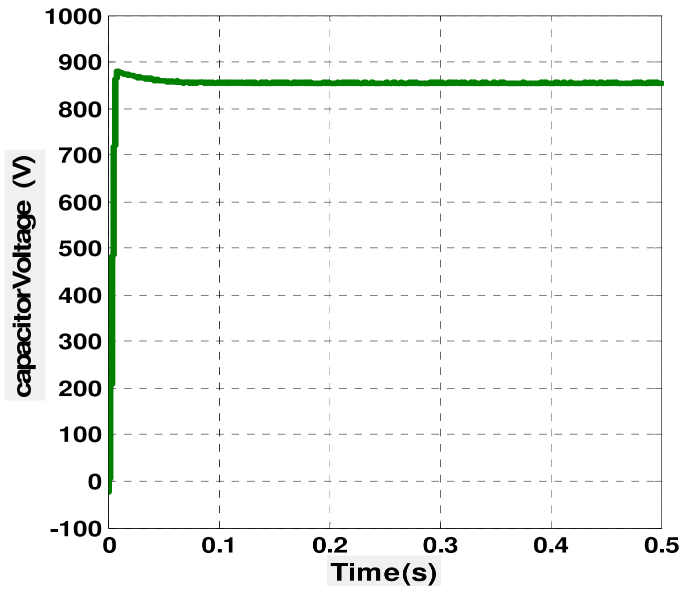

Fig. 13 DC link voltage regulation

In simulations the new identification method was used. Because of the (DWT) capacities to sense the load currents (Figure 8 where figure 9 illustrates his harmonic spectrum) and extracts the harmonic component (Figure 10); this approach improves the (SAPF) performance. The filtering result can be seen in Figure 11 and 12. The deformations have now been reduced and the harmonic distortion calculated up to 2.5 kHz (THD 2.5kHz) has been weakened. Although the filtering performance especially with the low order harmonics has been improved, this can be seen in Figure12, where the THD calculated up to 2.5 kHz is 1.11%, remains less than the Standardization of Harmonic Level, according to IEEE and to IEC. Figure 13 represents the controlled voltage on the borders of the condenser; the regulation of the DC-bus has remained unchanged and stable.

5. CONCLUSION

Nonlinear loads are responsible for the undesired harmonic currents in the network, the most appropriate strategy depends on the correction objective. This paper makes a significant contribution to the identification and control strategies in order to improve the SAPF performance. The novel approach which based on Wavelet Transform techniques has been proposed. The performance of the proposed WT was verified through simulation studies with Matlab. The complete SAPF structure has been implanted to compensate harmonics caused by nonlinear loads. The achieved results can assert that all the identifying objectives of the harmonic currents can be satisfied by the approach based on Wavelet Transform. However, the Wavelet Transform merit is that it contains integrated (PI) controller, added to regulate the capacitor dc voltage of the (SAPF) as the classical technique (p-q theory).

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