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A SHUNT ACTIVE POWER FILTER CONTROLLED BY FUZZY LOGIC CONTROLLER FOR CURRENT HARMONIC COMPENSATION AND POWER FACTOR IMPROVEMENT

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ABSTRACT

This paper describes work that is being done in the design of a three phase shunt active filter for electrical power quality purposes. This type of filter is able to compensate the harmonic current caused by the non-linear loads.

The main objective of this work is the study and the comparison of two types of control algorithms applied on this shunt active filter. These two types of control are the notch filter and the synchronous reference algorithms, they used to generate the references current of the compensator, the last one algorithm is based on two types of voltage controller, the classical controller PI (proportional-integral) and the fuzzy logic controller ,they used for the DC voltage regulation. The hysteresis band method is employed to derive the switching signals of the compensator.

A series of simulation by MATLAB/SIMULINK environment are presented and discussedin this paper to show the performance and the effectiveness of these control strategies.

Keywords: *Shunt active filter, Voltage regulation, hysteresis control, Fuzzy logic controller, PI controller*

1.INTRODUCTION

The growing use of electronic equipment produces a large amount of harmonics in the powerdistribution systems because of non-sinusoidal currents consumed by non-linear loads. Some of theexamples for non-linear loads are diode-rectifiers, thyristor converters , adjustable speed drives, furnaces, computer power supplies, uninterruptiblepower supplies, etc. Even though these devices are economical, flexible and energy efficient, they may degrade power quality by creating harmonic currents and consuming excessive reactive power [1].

The problems associated with harmonically polluted power systems are well known. Among often-cited problems caused by harmonic distortion are poor use of the a.c. source and distribution wiring volt/amp capacity, nuisance tripping of computers and computer-controlled industrial processes and medical equipment, excessive heating in transformers and equipment failure due to over voltages caused by the resonance between the impedance of the equipment and the whole transmission system [2].

To avoid these undesirable effects, traditional solutions using passive LC filters have been used, but they are ineffective due to their inability to adapt to network characteristic variation. Therefore, recent progress in switching devices has resulted in the formulation of several active filter topologies, not only for current or voltage compensation but also for voltage dips, flicker, imbalance or other kinds of disturbances [3].

The shunt APF based on Voltage Source Inverter (VSI) structure is an attractive solution to harmonic current problems. It is connected in parallel with the non-linear load. It has the capability to inject

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harmonic current into the AC system with the same amplitude butopposite phase than that of the non-linear load [4]. The mainscurrents, obtained after compensation, are thensinusoidal and in phase with the supply voltages [3] as shown in fig.1.

The performance of an active filter depends mainly on the technique used to compute the reference current and the control method used to inject the desired compensation current into the line [4].

Several methods were proposed for the identification

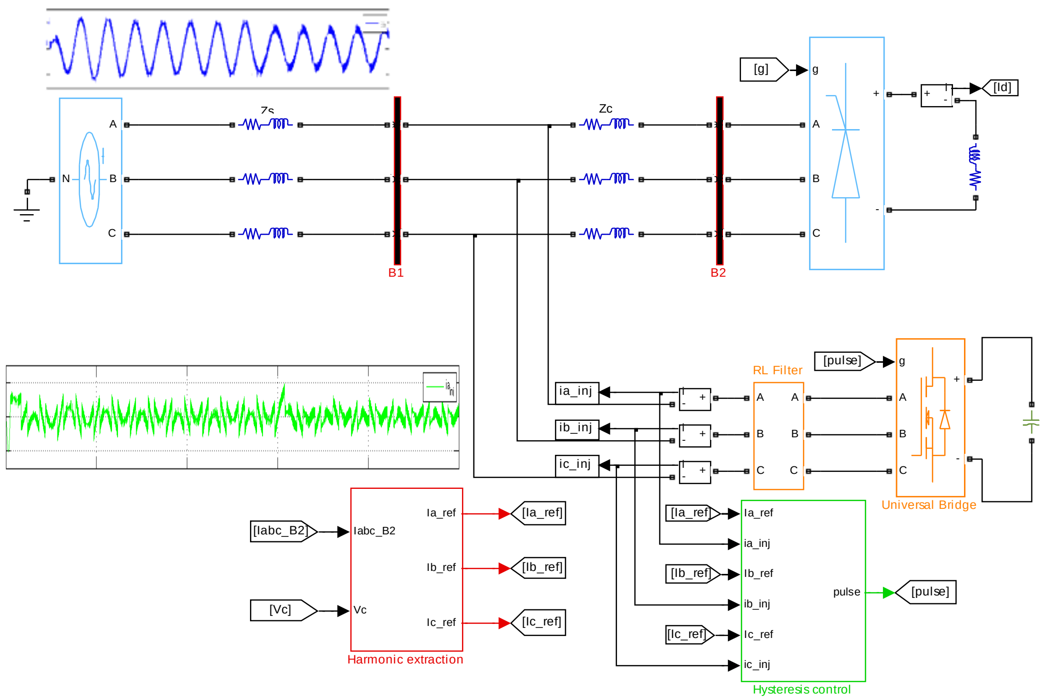

Fig.1 shunt active power filter model

of the APF harmonic current references. Mainly, we quote the methods based on the FFT (Fast Fourier Transformation) in the frequency domain, and the methods based on instantaneous power calculation in the time domain [5].In this paper the time domain methods are used because they require less calculations and are widely followed for computing the reference current [4].Two domain methods are used to detect the harmonic current references, the notch filter and the synchronous reference theory. The last one is followed in this work.

For the APF's pulse generation we have used the hysteresis band control because it's the most popular for active power filter applications.

Another important task in the active filter 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 diodes and MOSFETs of the inverter in APF, which tend to reduce the value of voltage across the DC capacitor [4].In this paper we have used two types of DC bus controller, a classical PI controller and Fuzzy logic controller they are integrated in the synchronous reference algorithm.

Finally we made a series of simulation in MATLAB/SIMULINK environment to show the effectivenessof the active power filter based on Fuzzy logic controller in the elimination of harmonic currents.

2. SHUNT APF CURRENT DETERMINATION

There are several methods used to determinate the harmonic current references. In this study, we apply

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two methods, the notch filter and the synchronous reference theory.

2.1. NOTCH FILTER METHOD

In this type of control the load current is filtred by a cut band filter which is sometimes called filter “notch”. These cut band filters eliminate the fundamental component while letting the harmonic components [6]. They therefore, the same cut frequency.

In our study we have found that we can use a simple cut band filter but it does not have good insulation properties as the figure.2 and 3 shows it. For that reason we have applied the method of notch filter which consists of two identical band-pass filters in series, as shown in figure. 4.

Fig.2 simple cut band filter method

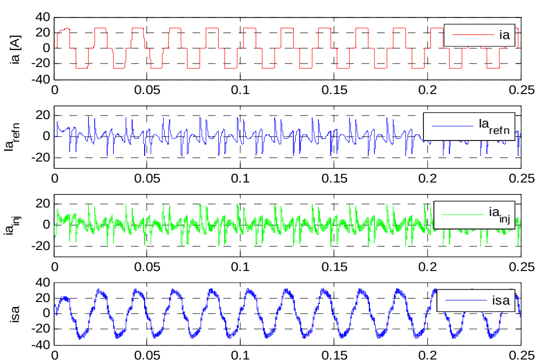


Fig.3 Harmonic compensation based on simple cut Band filter

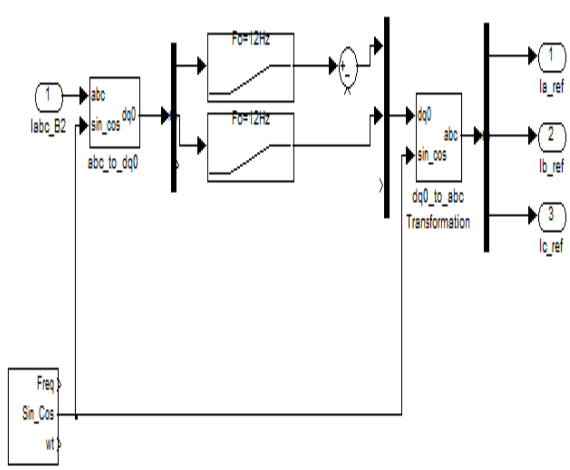
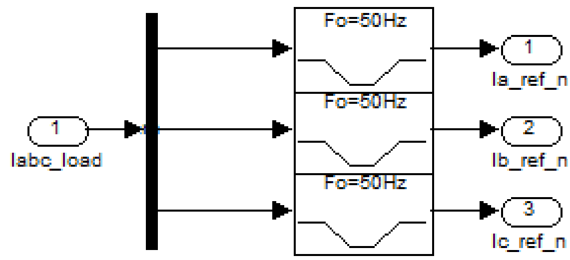


Fig.4 the band-pass filter algorithm



2.2.SYNCHRONOUS REFERENCE METHOD

This method involves transforming the coordinateda-b-c of the current in coordinated d - q and the assistance of the transforms of Park by setting the frequency thereof in synchrony with the network [6].

$$\begin{bmatrix} id \\ iq \end{bmatrix} = 2/3 \begin{bmatrix} \sin(\omega t) & \sin(\omega t - 2\pi/3) & \sin\left(\omega t + \frac{2\pi}{3}\right) \\ \cos(\omega t) & \cos(\omega t - 2\pi/3) & \cos\left(\omega t + \frac{2\pi}{3}\right) \end{bmatrix} \begin{bmatrix} ia \\ ib \\ ic \end{bmatrix}$$

The park transformation transforms the fundamental current component to continuous component while the harmonic current components undergo a shift in the frequency spectrum, the continuous component can be eliminated by adding a high pass filter (HPF). Harmonic currents references can be obtained by performing the inverse transform of parks synchronized with network frequency [6] as shown in figure.5.

$$\begin{bmatrix} ia^* \\ ib^* \\ ic^* \end{bmatrix} = \begin{bmatrix} \sin(\omega t) & \cos(\omega t) \\ \sin\left(\omega t - \frac{2\pi}{3}\right) & \cos\left(\omega t - \frac{2\pi}{3}\right) \\ \sin\left(\omega t + \frac{2\pi}{3}\right) & \cos\left(\omega t + \frac{2\pi}{3}\right) \end{bmatrix} \begin{bmatrix} id \\ iq \end{bmatrix}$$

The transfer function of this band pass filter is given by:

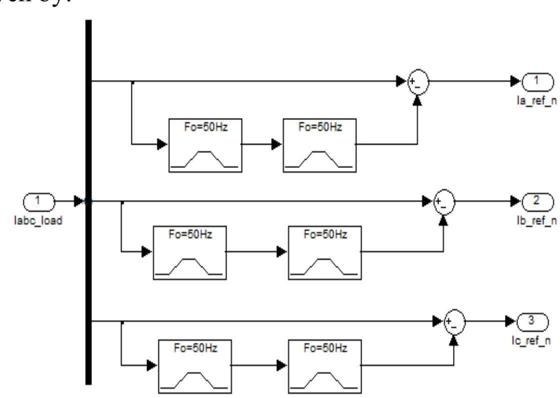


Fig.5. synchronous reference algorithm

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$$T_F = \frac{K.B.F}{P^2 + B.P + \omega_C^2}$$

Where:

K is the gain , P is laplace operator,B is an angular frequency equal to $2\pi f_b$, f_b is the width of the busy band and ω_c is the cutoff frequency.

3. DC VOLTAGE CONTROL

The capacitor that powers the active filter acts avoltage source.This tension must be maitained constant.So as not to degrade the performance of filtring, and not to exced the limit voltage of semi-conductors.The main cause of the variation of the voltage is the change in the pollutant load , which creates an exchange of active power with the network.

The regulation of this voltage is necessary to keep its value constant , and to limit this voltage fluctuations[7].The aim of the regulator is to adjust Vc to its reference Vc* and to attenuate harmonic frequencies resulting from power fluctuation.

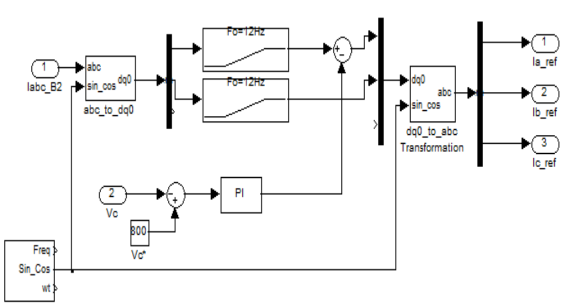
To realise these objectives, a proportional integral(PI) and Fuzzy logic controllerswill beconsedered

and compared[8].

3.1. PI CONTROLLER

The figure 6 shows the PI controlSchemeused in this paper , when theDC capacitor voltageVc is sensed and compared with the reference valueVc*. The input of PI controller is the value of error,e= Vc*- Vc , and its output after a limit is consideredas themagnitude of peak reference current Imax.The coefficients of PIcontroller ,KP and KI, are fixed in our model to give a good performance dynamic for this active powerfilter.

Fig.6DC voltage controlusingPI controller



3.2. FUZZY LOGIC CONTROLLER

Among the various power filter controller, the mostpromising is the fuzzy logic control. A fuzzy controllerconsists of stages: fuzzification, knowledgebase,inference mechanisms and defuzzification. Theknowledge bases designed in order to obtain a gooddynamic response under uncertainty in processparameters and external disturbances[8].

In this study the fuzzy logic controller is used to control the DC capacitor voltage.The capacitor voltage deviation and its derivative are considered as the inputs variables of the FLC and the control voltage dvc present the output as shown in figure.7.

The input and output variables are converted into linguistic variables. We have shosen seven Fuzzy subsets, NL(Negative Large), NM(Negative Medium),
NS (Negative Small), ZE (Zero), PS (PositiveSmall), PM(Positive Medium) and PL (Positive large).

In this paper, we have applied min-max inference method to get implied fuzzy set of the turning rules and the "centroid" method was used todeffuzzify the implied fuzzy control variables. The membership functions used for the input and outputvariables are shown in figure.8 and figure.9, the Fuzzyrule base is given in the tabe.1 [4].

Fig.7DC voltage controlusingFuzzy logic controller

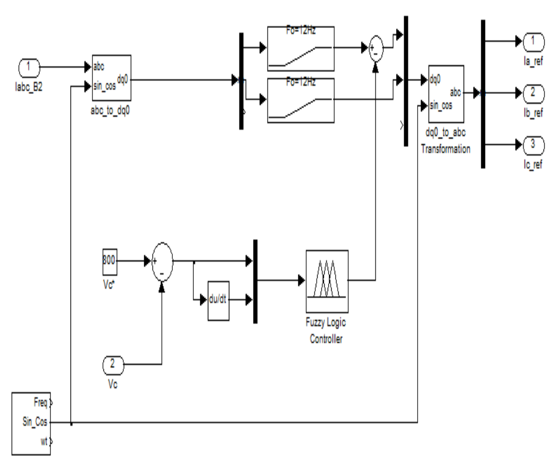


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Fig.8 Membership functions for input variables (e, de)

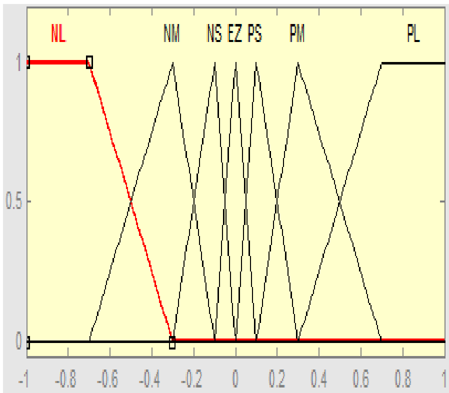

Fig.9 Membership functions for output variable (dvc)

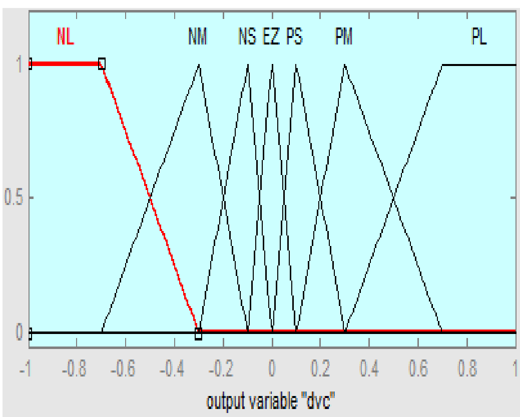

Table.1Fuzzy control rule

e / de	NL	NM	NS	ZE	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	ZE
NM	NL	NL	NL	NM	NS	ZE	PS
NS	NL	NL	NM	NS	ZE	PS	PM
ZE	NL	NM	NS	ZE	PS	PM	PL
PS	NM	NS	ZE	PS	PM	PL	PL
PM	NS	ZE	PS	PM	PL	PL	PL
PL	NL	NM	NS	ZE	PS	PM	PL

4.CURRENT CONTROL

In this paper we have used the hysterisis current control ,it's very commonly used because of its simplicity of implementation and its robustness.This
strategy provides satisfactory control of current without requiring extensive knowledge of control system model or its parameters[9].Figure 10 presents the principle of command that this is mainly to maitain each of the currents generated by the APF's in a band surrounding the reference currents.

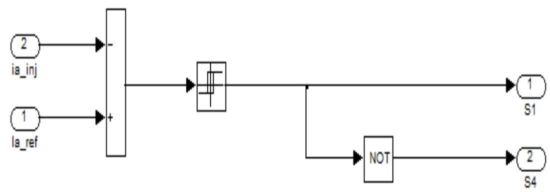

Fig.10 simulation shame for the hysterisis current control

Each violation of this band gives an order of commutation [6] as the figure11 shows.

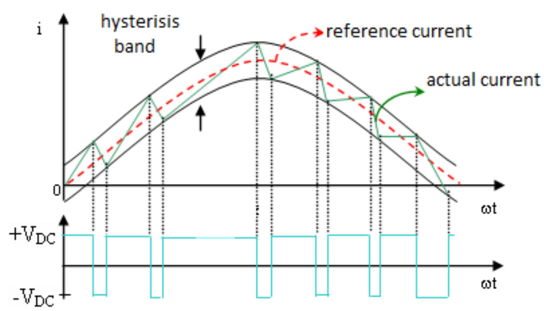

Fig.11 pulse generation by hysteresis band control

5. SIMULATION RESULTS AND DISCUSSION

A seriesofsimulationhavebeen done in

MATLAB/SIMULINK to validate ourTheoretical study. simulation parameters used in this paper are summarized in table.2.

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Table.2 simulation parameters

network	Vs rms=320V,f=50HZ Rs=0.5mΩ,Ls=15µH
Non linear load	Rc=1.2 mΩ,Lc=50µH Rd=25 Ω,Ld=50mH α=45 º
Shunt active filter	C=485µF,Rf=1.5 mΩ Lf=1200µH
Hysteresis control	ΔI=2A
Iref calculation: -2nd order HPF	fc=12HZ, σ=0.7
-2nd order band-pass filter	fc=12HZ, σ=0.707
PI controller	KP=2,Ki=1.5
Reference voltage	Vc*=800V

Figure 12 and 13 shows the waveform of the source current of phase a (ica) and its harmonic spectrum with a harmonic distortion rate equal to 28,20%.the figure 14 shows the phase shift between current and voltage source, this phase shift make a degradation of power factor that we want to take a value very close to unity. After the application of the shunt active Filter we obtain the results shown in Figures 15 and 16 where the harmonicCurrents of reference is derived by a Band-pass filter, without performing regulation of the DC capacitor voltage.

The figure 17 proves that current and voltage source are approximately in phase each other, and in figure 18 we show that the THD has decreased to a value of 2.46%.

and when we have applying the shunt active filter controlled by a proportional integral controller (PI) ,where the harmonic current references are deducted by thesynchronous reference method, we obtain the results presented in figure 19 and 20 ,we can notice here thatthe current source takes a form very close to a sinusoid and theharmonic currents injected by the shunt active filter followed their references , we can see also that the DC capacitor voltage is well regulated and maintained at a constant value of 800V with a very limited fluctuation. The figure 21 shows the harmonic spectrum where the THD is degraded to satisfactory value of 2.11% compared to 2.46% without introducing the PI corrector which justify the effectiveness of the PI controller and we can see in figure 22 the correction of the power factor where the source current and voltage are in phase each to other.

Now and when we introducing the Fuzzy logic controller, we notice that the THD has degraded to a very acceptable value equal to 1.82% as the figure 25 shows, and we can see in figure 24 that the DC capacitor voltage is well regulated and maintained at a constant value of 800V ,especially in the second 5ms , compared to that obtained by the PI controller (figure 20), which justify the effectiveness of the Fuzzy logic controller. We can also see in figure 23 that the harmonic currents injected by the shunt active filter followed their references.

Concerning the power factor correction and reactive power compensation, we see in figure 26 similar results compared to those obtained by PI controller.

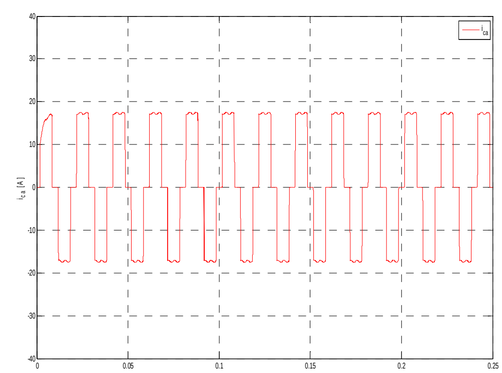

Fig.12 supply current (phase a) absorbed by the non-linear load

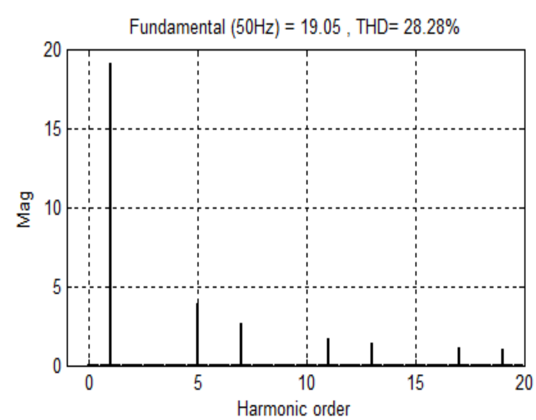

Fig.13 harmonic spectrum of ica current

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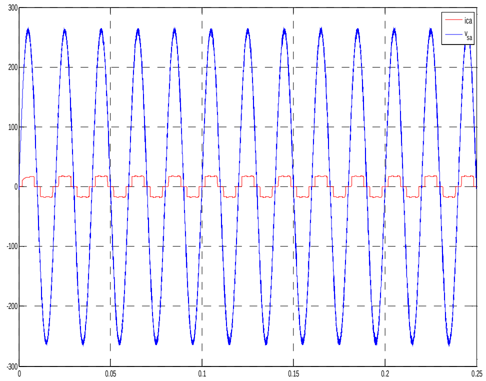

Fig.14 power factor degradation

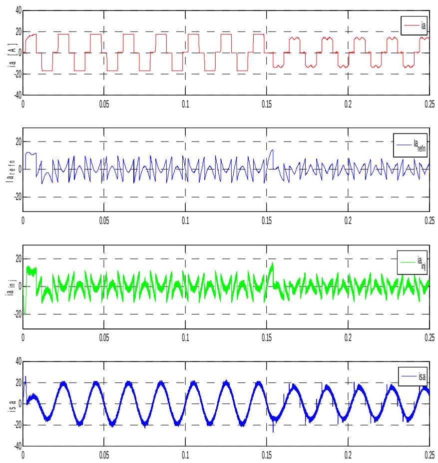

Fig.15Harmonic compensation usingthe band-pass filter algorithm

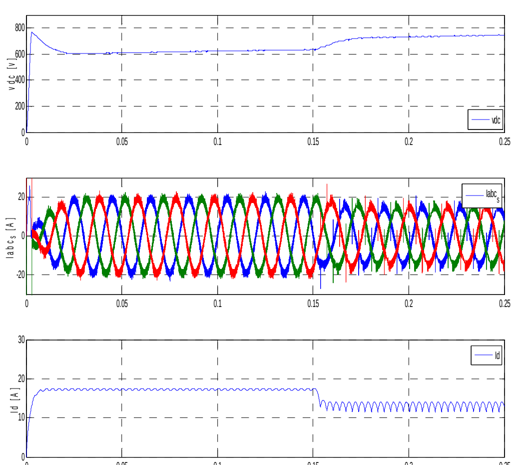

Fig.16 wave forms of the DC capacitor voltage , the three phase supply currents and the load current of the non-linear load without introducing DC voltage controller

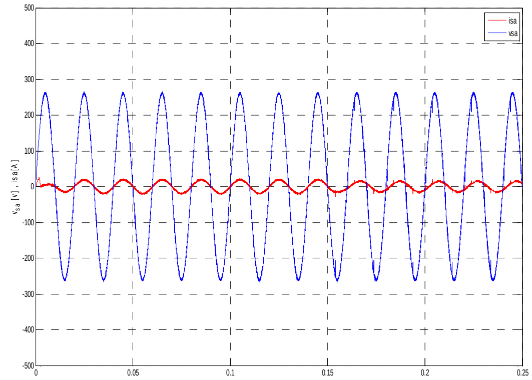

Fig.17 Source voltage and Current After compensation

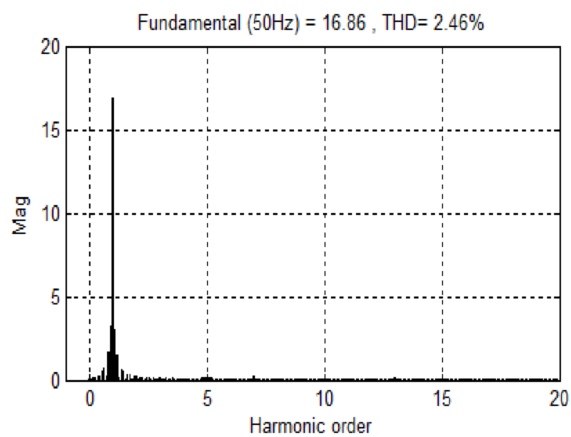

Fig.18Harmonic spectrum of the compensated current isa

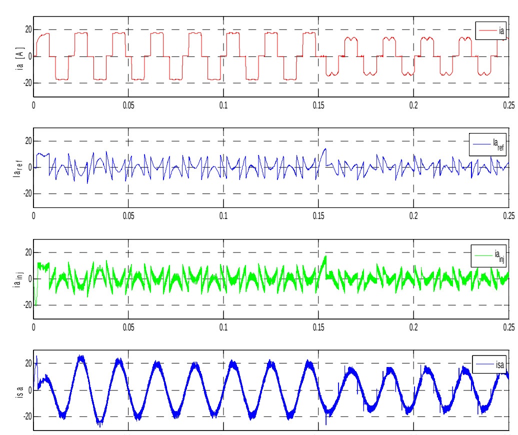

Fig.19Harmonic compensation usingthe synchronous reference method and the PI controller

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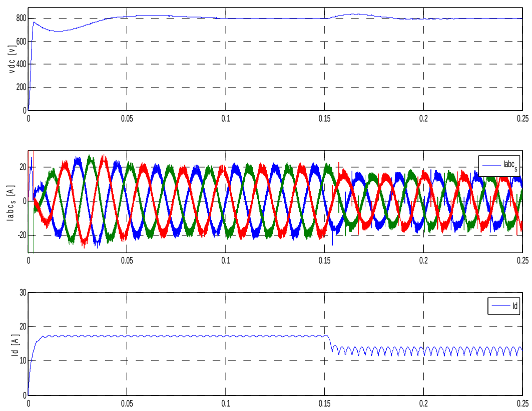

Fig.20 wave forms of the DC capacitor voltage , the three phase supply currents and the load current of the non-linear load using the PI controller

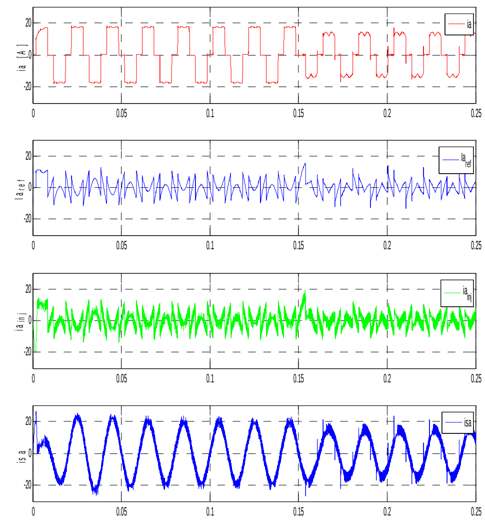

Fig.23Harmonic compensation usingthe synchronous reference method and the fuzzy logic controller

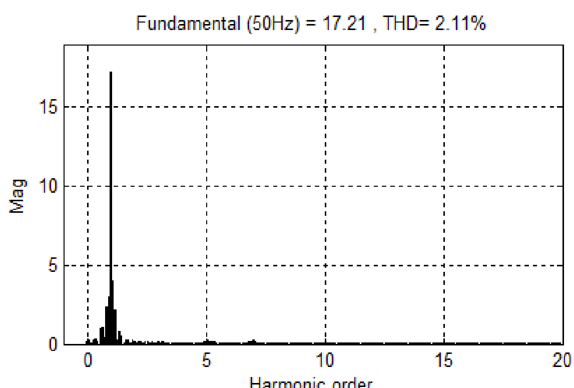

Fig.21Harmonic spectrum of the compensated current isa

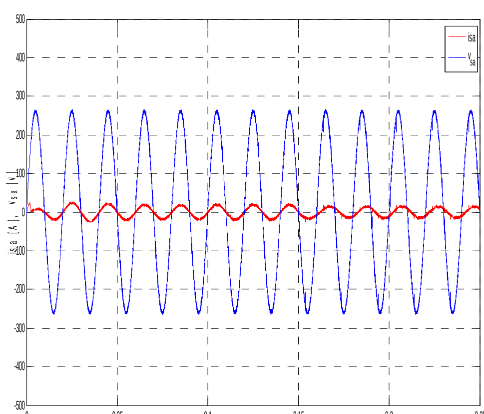

Fig.22the source current and voltage in phase each to other

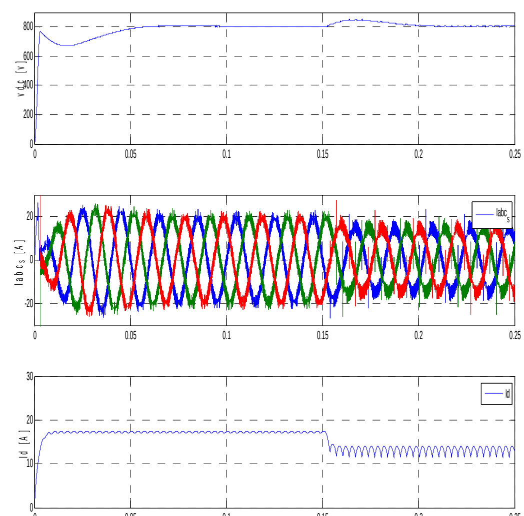

Fig.24 wave forms of the DC capacitor voltage , the three phase supply currents and the load current of the non-linear load using Fuzzy logic controller

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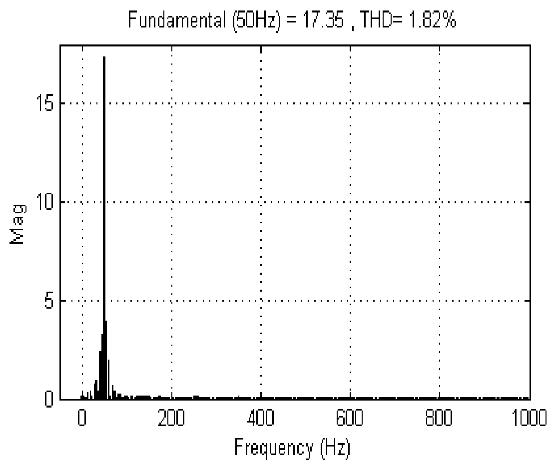

Fig.25Harmonic spectrum of the compensated current isa

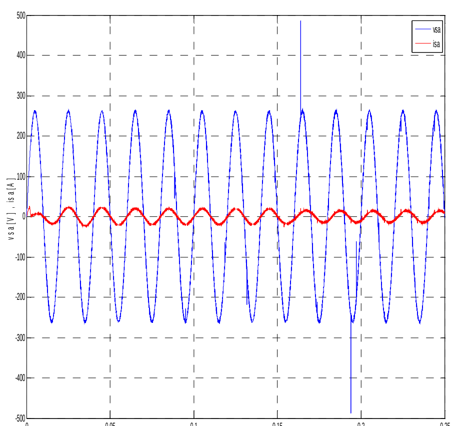

Fig.26power factor correction

6. CONCLUSION

In this paper we have seen the effectiveness of the shunt active filter controlled by a Fuzzy logic controller with variation of load at t=0.15ms.

Two control algorithms have been used to generate harmonic currents of reference, the synchronous reference method and the notch filter method, for this last one we have found that the use of two band-pass filters placed in series gives acceptable results. For the generation of control signals we have used the order by hysteresis.

The results obtained of THD complies with the standard IEEE std 519-1992 , where the value of THD is 1.82% with voltage regulation by Fuzzy logic controller compared to 2.11% with the PI controller and we can see that the power factor is well corrected.

REFERENCES

[1] T.Mahalekshmi,"current harmonic compensation and power factor improvement by hybrid shunt active power filter" international journal of computer applications (0975 – 8887) volume 4 – no.3, july 2010.

[2] M. Palandöken. M. Aksoy. M. Tümay, "A Fuzzy-Controlled Single-Phase Active Power Filter Operating With Fixed Switching Frequency For Reactive Power And Current Harmonics Compensation" Electrical engineering (2003) 86: 9–16doi 10.1007/s00202-003-0183-5.springer-verlag 2003.

[3] B. Mazari And F. Mekri, "Fuzzy Hysteresis Control And Parameter Optimization Of A Shunt Active Power Filter" JOURNAL OF INFORMATION SCIENCE AND ENGINEERING 21, 1139-1156 (2005)

[4] P Rathika, Dr D Devaraj," Artificial Intelligent Controller based Three-Phase Shunt Active Filter for Harmonic Reduction and Reactive Power Compensation" proceedings of the International Multiconference of engineers and computer scinentists 2010 Vol 2,IMECS 2010,March 17-19,2010,Hong Kong.

[5] H. Benalla and H. Djeghloud,"A Novel Time-Domain Reference-Computation Algorithm for Shunt Active Power Filters" ACSE Journal, Volume (6), Issue (2), June, 2006.

[6] Steeve Beaulieu, " Real-Time Modelling And Simulation Ofan Active Power Filter" lasted International Conference on Power and Energy Systems PES 2007, Clearwater, Florida, U.S.A.

[7] T. Benmiloud ,A. Omari," Régulation de la tension d'alimentation du filtre actif parallèle par PI adaptatif " 4th International Conference on Computer Integrated Manufacturing CIP'2007 03-04 November 2007.

[8] B.Mazari, F.Mekri, S.Fasla," Fuzzy Logic Control Of The Energy Storage Capacitor Of A

Journal of Theoretical and Applied Information Technology
15th October 2011. Vol. 32 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Three Phase Active Power Filter In Unbalanced Network "

[9] Mohamed Muftah Abdusalam, "Structures et stratégies de commande des filtres actifs parallèle et hybride avec validations expérimentales " thèse de doctorat , Laboratoire GREEN (Groupe de Recherche en Electrotechnique et Electronique de Nancy) Faculté des Sciences & Techniques – 54500 Vandoeuvre-lès-Nancy .

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