A SINGLE PHASE SHUT ACTIVE POWER FILTER WITH FUZZY LOGIC BASED FOR HARMONICS MINIMIZATION UNDER RANDOM LOAD VARIATION

DOI:10.52113/3/eng/mjet/2013-02-02/01-16

Dr. Adel M. Dakhil
Misan University- College of Engineering- Department of Electrical Engineering
Dr.adelmanaa@yahoo.com

Abstract

In this work a simulation of single phase shunt Active Power Filter (APF) to minimize source current distortion is produced by feeding a nonlinear loads. The simulation results for single phase shunt APF with conventional PI controller and fuzzy PI controller were carried out. These two controller forced the single phase shunt APF to inject equal but opposite current in order to shape the source current to a sinusoidal form in phase with supply voltage. Conventional PI controller meets the required performance for ideal APF, but with unbalance load; this controller is failed to do same job hence the gain values of PI controller are set for a certain load condition. This situation lead to search with fuzzy controller in which the proportional and integral gains adjust dynamically as load condition change. The obtained simulation results for the fuzzy controller show good steady state and transient performance for the plant.

Keywords: Active Power Filter (APF),Conventional PI Controller, Fuzzy PI Controller, Harmonics Minimization, Random Load Variation

مرشح قدرة فعال متوازي أحادي الطور مسيطر بمتحكم مضبب لتقليل التوافقيات تحت تغير حمل عشوائي

د.عادل مانع داخل
جامعة ميسان / كلية الهندسة

الخلاصة

تم في هذا العمل محاكاة لمرشح فعال متوازي (APF)لتقليل توافقيات تيار المصدر الناتجة من تغذية أحمال غير خطية. استخرجت نتائج المحاكاة لمرشح أحادي الطور الفعال المتوازي (APF)مع متحكمين تناسبي تكاملي اعتيادي و الأخر مضبب ، هذان المتحكمان أجبرا مرشح القدرة أحادي الطور الفعال المتوازي(APF) لحقن تيار مساوي بالمقدار و متعاكس بالاتجاه لإعادة تشكيل تيار المصدر بشكل جيبي و متوافق بالطور مع فولتية المصدر. المتحكم التناسبي التكاملي

***Received at 26/9/2012** *** Accepted at 7/5/2013**

الاعتيادي وفر الخصائص المطلوبة من مرشح القدرة الفعال المثالي، لكن للأحمال غير المتزنة ؛ هذا المتحكم فشل لعمل ذلك حيث ان قيم الكسب التناسبية والتكاملية للمتحكم الاعتيادي قد وضعت لشروط حمل معينة. هذا الوضع أدى الى البحث عن متحكم تناسبي تكاملي مضبب والذي فيه قيم الكسب التناسبية و التكاملية للمتحكم تضاف بشكل أني كلما تغيرت شروط الحمل. نتائج المحاكاة المستخلصة للمتحكم المضبب بينت خصائص جيدة للحالة الثابتة والانتقالية للمنظومة.

الكلمات المفتاحية :مرشح قدرة فعال، متحكم تناسبي تكاملي اعتيادي، متحكم تناسبي تكاملي مضبب، تقليل التوافقيات، تغير حمل عشوائي

1.Introduction

An active power filter is an inverter, placed between the power supply and the receiver, which absorbs the whole part of disturbances generated by the said receiver [1,2]. Various types of active power filters have been produced[3,4,5] and are classified based on the type of the inverter. Different configuration used, control methodologies, the economic and technical consideration and selection method for specific applications [6,7]. One of the various topologies of the APF developed so far, shunt active APF based on the current controlled voltage source type PWM inverter has been proved to be very effective even when load is highly non-linear. The Current Source Inverter CSI as an APF acts as a non-sinusoidal current source. It is reliable, but has higher losses and requires higher parallel AC power capacitance. At higher voltages ratings with multilevel schemes this type of inverter can not be used to improve performance. Voltage Source Inverter (VSI) as an APF has a self-supporting DC voltage bus with large DC capacitance. The advantages of VSI is lighter, cheaper, and expandable to multilevel schemes [8,9], Fig.(1) presents the basic compensation principle of the shunt APF.

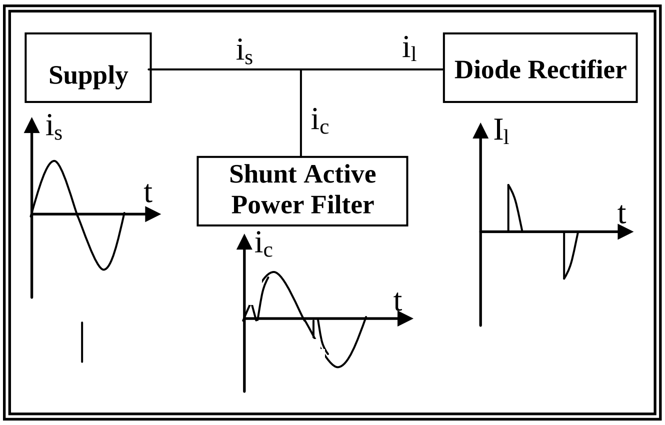

Fig.(1) Compensation Principle of APF [2]

The shunt APF is intended to generate exactly the same harmonics contained in the polluting current ic but with opposite phase. Shunt active power filter is shown in Fig.(2)

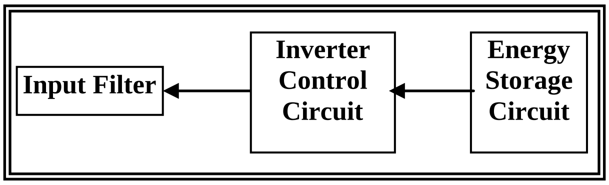

Fig.(2) APF block diagram [2]

The whole power circuit with shunt active power filter is shown in Fig.(3) it comprises a voltage source, passive RC filter, single phase full bridge converter with an energy storage capacitor at the DC side and connected in parallel with the linear or nonlinear load through a filter inductor at the AC side.

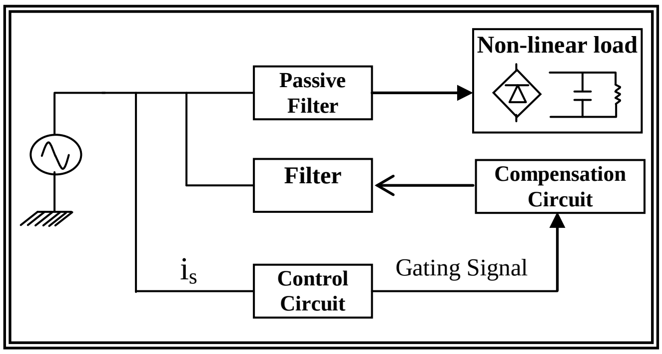

Fig.(3) Power circuit with shunt active power filter [1]

Types of linear and nonlinear load are shown in Fig.(4). The single phase full bridge composed by the two switches pairs, these two pairs must guarantee that the current through the inductor Lf contains the harmonic components demanded by the non-linear loads attached to the system and a fundamental component that compensates the reactive power drained by the loads connected to the AC grid. The DC voltage source must be greater than the AC peak voltages to guarantee the reactive power flow throughout the cycle.

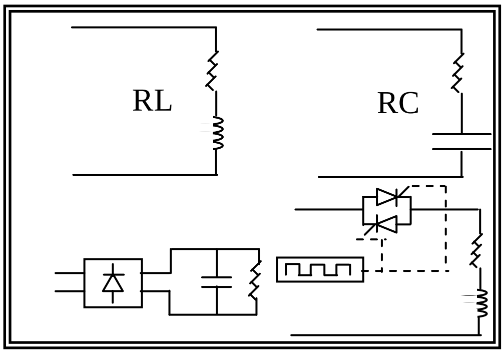

Fig.(4) Different types of nonlinear

In this paper, a simulink studies for single phase shunt APF were carried out using SIMULINK under MATLAB software to compensate harmonics and reactive power requirement of different types of non-linear loads. The response of the single phase shunt APF are tested using first conventional PI controller, the input of the PI controller is the capacitor voltage error. Second test is done with fuzzy controller. The modified method is used to have full compensation under different types of load conditions.

2.Fuzzy Controller

Fuzzy logic serves to represent uncertain knowledge of the system, whereas fuzzy control allows taking a decision even if we can't estimate inputs/ outputs only from uncertain predicates[10]. Fig.(5) shows the synoptic scheme of fuzzy controller which possesses two input: the error (e), and the change of error Δe.

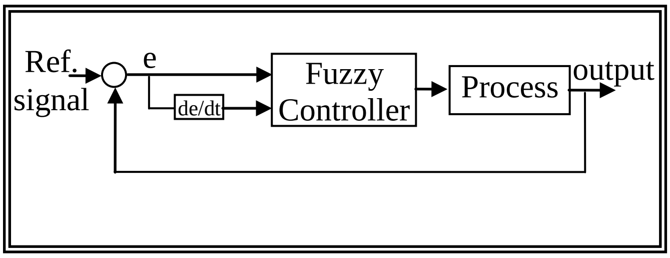

Fig.(5) Fuzzy controller scheme diagram [12]

Fig.(6) illustrates stages of fuzzy control in the considered base of rules and definitions: fuzzification, inference mechanism, and defuzzification.

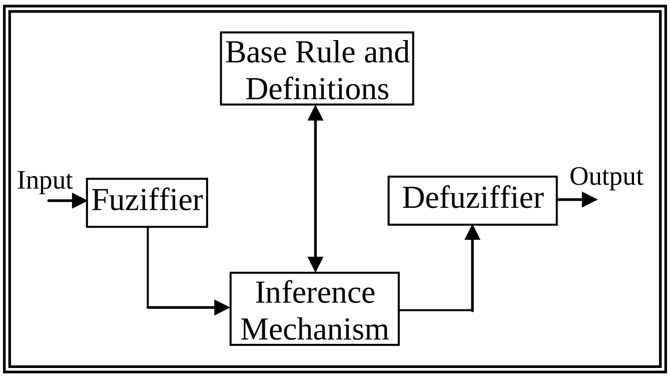

Fig.(6) Fuzzy controller elements

Computational efficiency; memory requirement and computational time are the few important aspects of evolutionary computational methods. The number and type of Membership Function (MF) decides the computational efficiency of a Fuzzy Logic Controller FLC. The shape of fuzzy set affects how well a fuzzy system of if-then rules approximate a function. Triangles have been the most popular shape for approximating non-linear function[11]. The membership functions are chosen to be triangular MF because of their striking simplicity, solid theoretical basis and ease of computation, since they are symmetrical and have zero value at some point away from their center in general, the rule base of mamdani controller is given by [12]

If e is MN and de MP then u is z

Where MN, MP, and Z is linguistic values.

This style of fuzzy conditional statement is often called a " Mamdani " type rule.[2]

3. Conventional and Fuzzy Control for Single Phase Shunt APF

The harmonics present in the source current are compensated by developing a suitable switching pattern for the active filter. The conventional PI controller is first used in the simulink model. For a particular operating condition in the continuous mode the PI controller setting are found to be satisfactory. This setting of the controller can not correct the source current for discontinuous mode of the nonlinear loads. For this reason a fuzzy PI controller is used for various nonlinear load types to reduce the distortion in line current. By using this type of controller the shape of source current is achieved with small amount of distortion and minimization in THD value. For this type of fuzzy controller, there are five triangular membership functions for the inputs (error in capacitor voltage and change of error), and five triangular membership functions for the controller output. Defuzzification stage is done by using center of gravity method. The inference e engine has 25 rules, the whole rule table is listed in table (1).

Table (1) Fuzzy rule table for PI controller

de \ e	VN	MN	Z	MP	VP
VN	**VN**	**VN**	**MN**	**MN**	**Z**
MN	**VN**	**VN**	**MN**	**Z**	**MP**
Z	**MN**	**MN**	**Z**	**MP**	**MP**
MP	**MN**	**Z**	**MP**	**MP**	**VP**
VP	**Z**	**MP**	**VP**	**VP**	**VP**

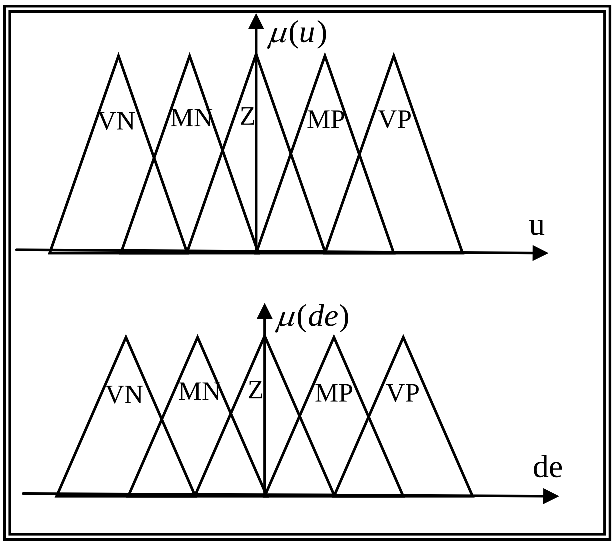

Fig.(7) Input and output membership functions

4.Computer Simulation

First the single phase active power filter with conventional PI controller is implemented by using matlab simulink, after this stage, fuzzy logic controller is designed for the computer simulation. The fuzzy logic controller is designed based on the expert experience. The implemented simulink model for single phase active filter with fuzzy controller is shown in Fig.(8) the input of the fuzzy controller is the error and change of error of capacitor voltage. The simulink model is first test without any filter.

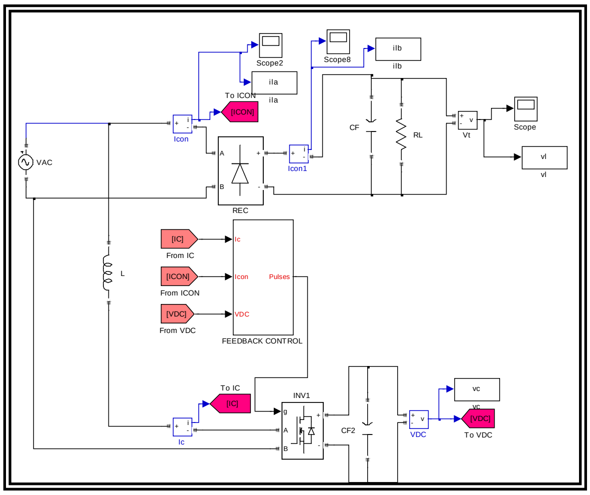

Fig.(8) Simulink model for the single phase shunt APF

Fig.(9) shows the source voltage, the associated source current supplied by the grid to DC loads connected through uncontrolled rectifier with capacitive filter is shown in Fig.(10), the load current drained by DC loads is shown in Fig(11)

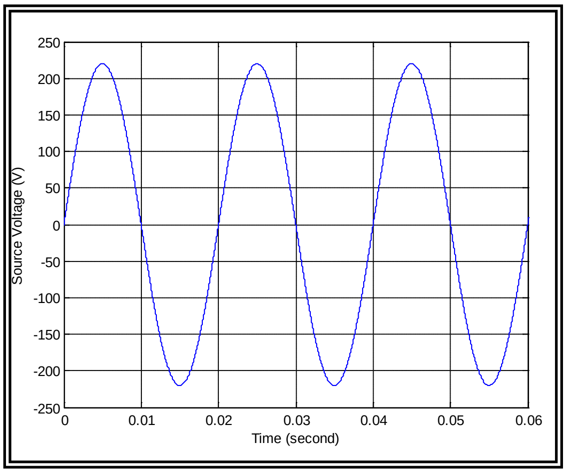

Fig.(9) Source voltage applied to uncontrolled rectifier with capacitive load

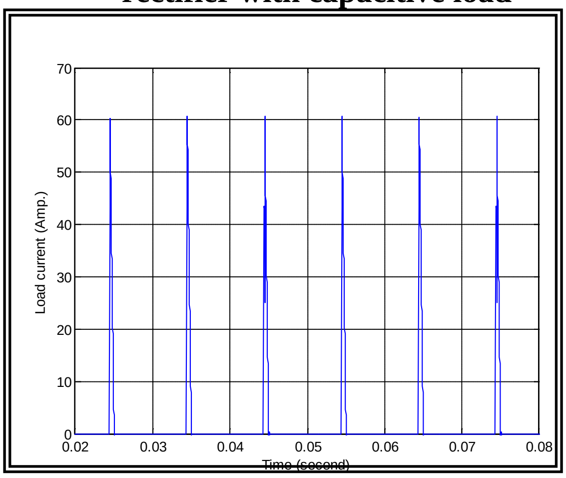

Fig.(10) Source current drained by uncontrolled rectifier with capacitive load

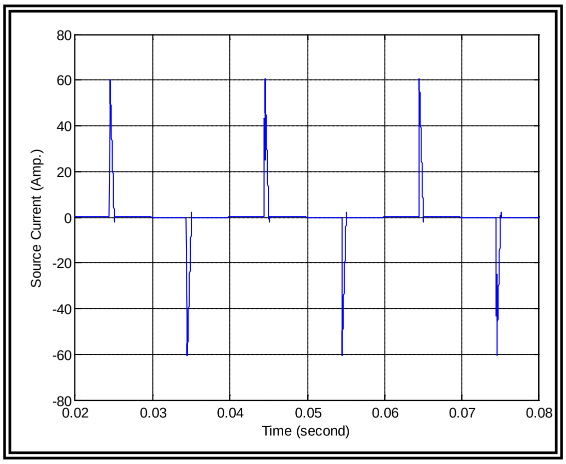

Fig.(11) Source current drained by uncontrolled rectifier with capacitive load

The second test done by applying active power filter with conventional PI-controller. Fig.(12) shows the source voltage, the corresponding source current is shown in Fig.(13), by comparing Fig.(11) which shows the source current drained by load without compensation, with that of Fig.(13), it is clear that the active filter performed the compensation of the nonlinear load connected to the mains.

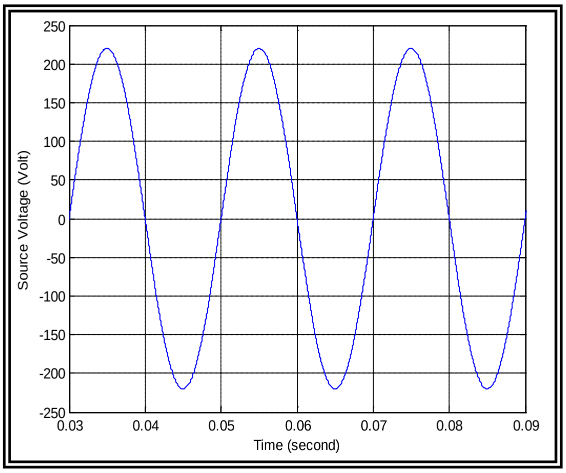

Fig.(12) Source voltage applied to uncontrolled rectifier with capacitive load with APF using conventional PI

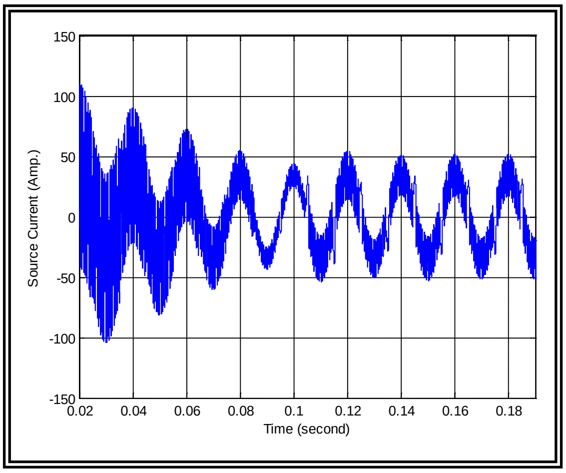

Fig.(13) Source current drained by uncontrolled rectifier with capacitive load with APF using conventional PI

Fig.(14) and Fig.(15) show the load current and load voltage respectively for this type of test. The controller is seen in this discussion satisfied the aim of the use of APF

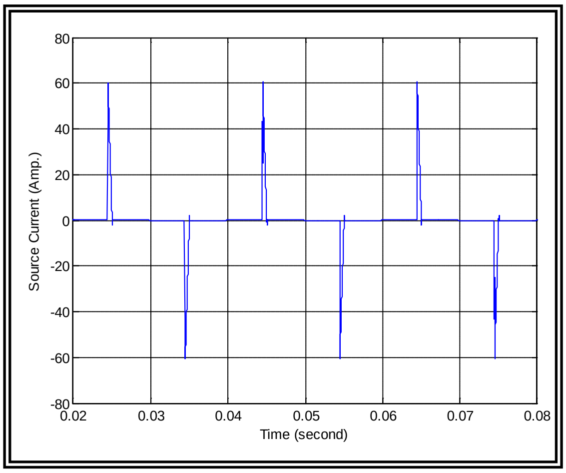

Fig.(14) Source current drained by uncontrolled rectifier with capacitive load

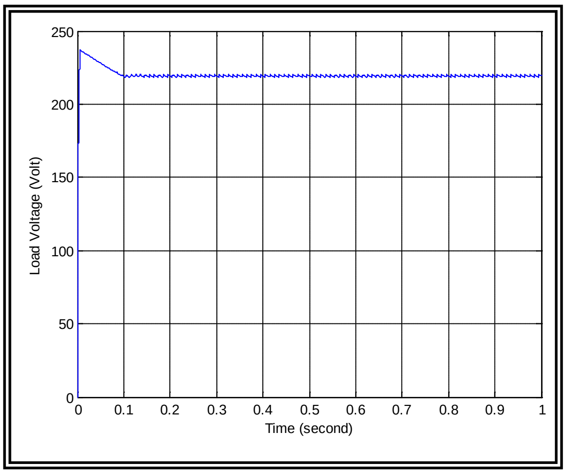

Fig.(15) Load Voltage for the first load condition

The fixed gain values of the proportional and integral controller which introduced the full compensation for source current for the previous loads, now tested with another loads, this controller is failed to do same job. Fig.(16) shows the source current for this load test, the load current before and after the bridge rectifier is shown in Fig.(17) and Fig.(18) respectively.

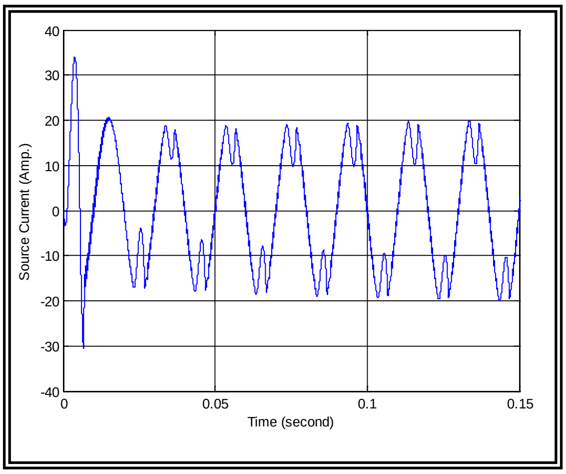

Fig.(16) Source current drained by uncontrolled rectifier with capacitive load with APF using conventional PI in second load test condition

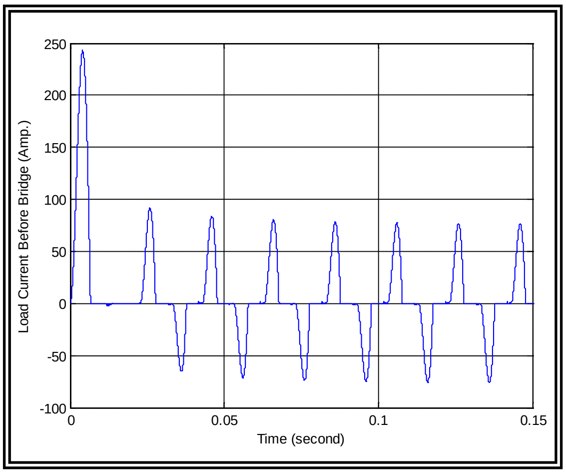

Fig.(17) Load current before bridge using conventional PI in second load test condition

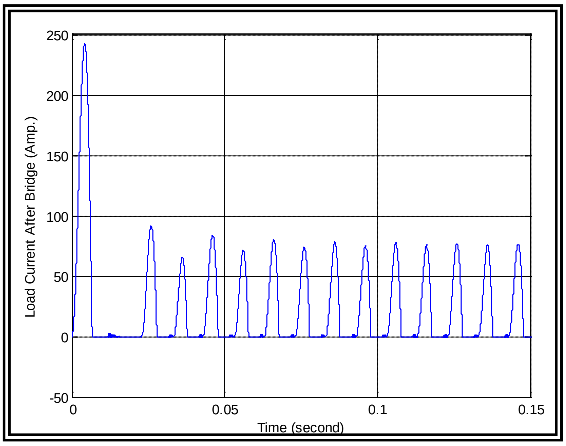

Fig.(18) Load current after bridge using conventional PI in second load test condition

Fig.(19) shows the compensated current corresponding to this test, while Fig.(20) shows the load voltage. The load current shown in Fig.(16) have a much distortion component when compared with that of Fig.(13) due to the fixed values of controller gains.

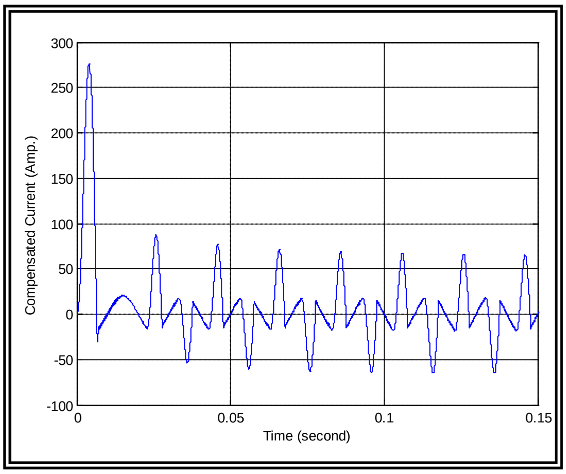

Fig.(19) Compensated current supplied by APF with conventional PI controller in second load test condition

The third test is done to the APF with fuzzy controller. Fig.(21) shows the source current, while the compensated current is shown in Fig.(22). Fig.(23) and Fig.(24) show the load current before and after the bridge rectifier. The load voltage is listed in Fig.(25).

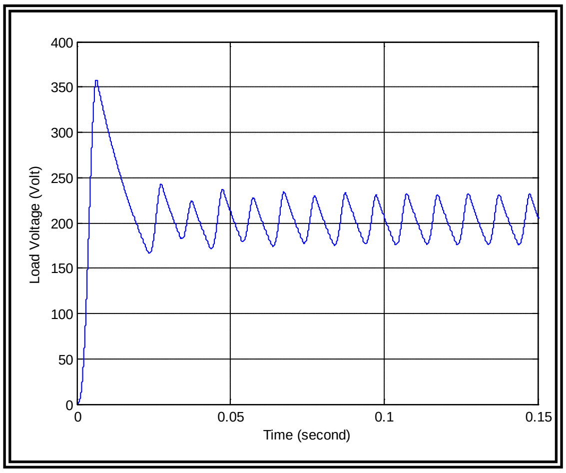

Fig.(20) Load voltage for the second load

This controller seems to be reasonable to full compensation under different load conditions. further more, in the conventional PI controller, the time taken by line current to reach the steady state value is 0.25 second; while the fuzzy one takes 0.09 second. For the continuous and discontinuous operating mode the fuzzy controller works satisfactory at various operating conditions of the nonlinear load. From above discussion the presented fuzzy controller has better dynamics behavior than the conventional one.

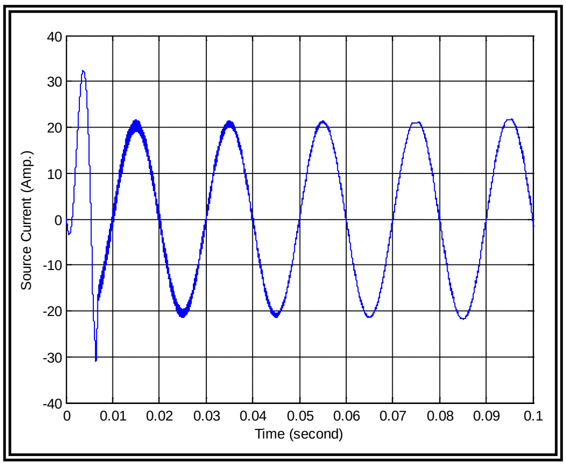

Fig.(21) Source current drained by uncontrolled rectifier with capacitive load with APF using fuzzy PI

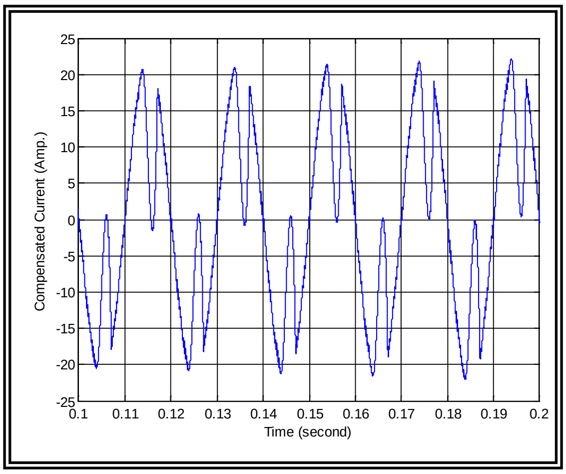

Fig.(22) Compensated current supplied by APF with fuzzy PI controller

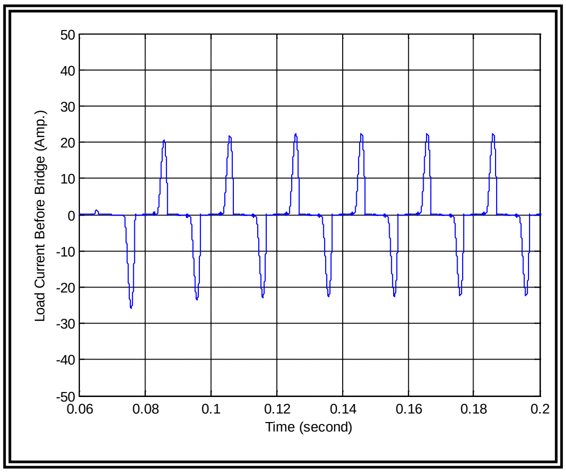

Fig.(23) load current before bridge using fuzzy PI

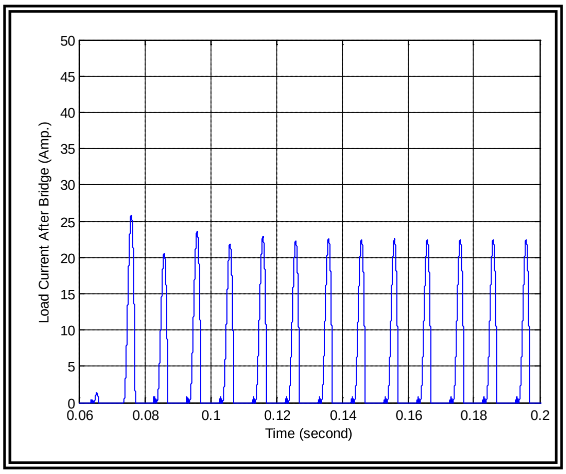

Fig.(24) load current after bridge using fuzzy PI

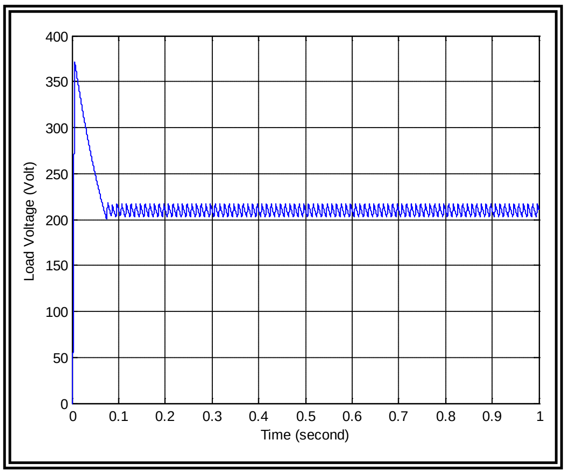

Fig.(25) Load voltage

5.Conclusions

Single phase active power filter with conventional PI-controller and fuzzy controller were verified by simulation using Mathlab package. The reference control system is an optimized conventional PI controller, characterized by a simple design procedure and a simple structure. The accuracy shown in simulation is very good, since the parameters of the PI controller were individually optimized for each considered load. Special tuning of the PI controller for each possible load would represent a computationally complex solution that would eliminate the major advantage of a PI controller, its simplicity. The constant parameter of PI controller for certain load will lead to performance of the PI controller for any other loads would have been significantly worse. In this work, the using of the fuzzy control under different loads was declared to be effectiveness solution to compensate the current harmonics. This controller is used to fully compensate current harmonics and reactive power under linear and nonlinear loads power factor was corrected to unity power factor total harmonics distortion of source current below 0.18% in 0.7 second with fuzzy controller compared to 2.7% in 0.7 second with conventional controller

References

[1] J.C. Das, 2004 ,"Passive Filter: Potentialities and Limitations ", IEEE Transaction Industries Application, Vol.40, No. 1, p.p.232-241,.

[2] H. Benalla and H. Djeyloud, Riyadh,2005 , ' shunt active filter controlled by fuzzy logic " Journal of King Soud University, Vol.18, Engineering Science (2) , P.P. 231-247.

[3] L. Gyugyi and E.C. Strycula , 1976, " Active Power Filters , IEEE Industrial Applications , Society Annual Meeting, Atlanta, Georgia, lU.S.A., p.p.529-535.

[4] F.Z. Peng, H. Akagi, and A. Nabae, , 26 November – 6 December 1990 , " A New Approach to Harmonics Compensation in Power Systems-A Combined System of Shunt Passive and Series Active Filters", IEEE, Transaction Industrial Application , p.p.983-989.

[5] M. El-Habrouk, M.K. Darwish , and P. Mehta , 5 September 2005, " Active Power Filters: A Review " , IEE, Proceeding , Electrical Power Application 147, p.p.403-413.

[6] F.Z. Peng, , July , August 2001 , " Harmonics Sources and Filtering Approaches", IEEE, Industrial Application , p.p.18-25.

[7] D. Chen, and S. Xie (DRPT2004), Hong Kong , April 2004, " Review of Control Strategies Applied to Active power Filters, Proceeding in IEEE International Conference on Electric Utility Deregulation, Restriction and power Technologies", p.p.666-670,.

[8] A.M. Masoud , S.J. Finney, and B.W. Williams , 2004, "Practical Issues of Three Phase Three Wire, Voltages Source Inverter-Based Shunt Active Filters", Proceeding 11th International Conference on Harmonics and Quality Power, p.p.436-441.

[9] G. K. Singh, A.K. Singh, and R. Mitra , 2007, " A Simple Fuzzy Logic Based Robust Active Power Filter For Harmonics Minimization Under Random Load Variation " Science Direct , Electric Power Systems , Vol.77, p.p. 1101-1111.

[10] Hamadi, A. , Al-Haddad K. , Rahmmani S. , and Kanaan, H. , 2004, "Comparison of Fuzzy Logic and Proportional Integral of Voltage Source Active Filter Compensation Current Harmonics and Power Factor ", IEEE International Conference Industrial Technology , No.2, p.p. 645-650.

[11] S. Fan and Y. Wang (DRPT2004), Hong Kong , April 2004, " Fuzzy Model Predictive Control for Active Power Filter", Proceeding IEEE International Conference on Electric Utility Deregulation Restructuring and Power Technologies p.p.295-300,.

[12] Roland S. Burns2001 , "Advanced Control Engineering" ,Butterworth-Heinemann, First Puplished, p.p.325-347,.

[13] Ahmed A. Helal, Naha E. Zakzouk, and Yasser G. Desouky, , 2009, " Fuzzy Logic Controlled Shunt Active Power Filter For Three-Phase Four-Wire Systems with Balanced and Unbalanced Loads " , World Academy of Science, Engineering And Technology 34, p.p. 621-626.