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FUZZY BASED SHUNT ACTIVE POWER FILTER FOR POWER QUALITY ENRICHMENT

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ABSTRACT

Power Quality issues worsen the equipments that are used at the distribution level. Since power quality issues were classified in to short term interruptions and long term interruptions. This work focuses on the assessment and enrichment of short term power quality issues. A Shunt Active Power Filter is introduced along with a Fuzzy Logic Controller (FLC) is to mitigate Total Harmonic Distortion (THD) whose effectiveness is proved by comparing with a Conventional (PI) controller. The simulation result shows that SAPF with fuzzy logic controller with Gaussian membership function dominated a better performance than the conventional (PI) controller.

Keywords: Power Quality, Total Harmonic Distortion, Fuzzy Logic Controller, Shunt Active Power Filter, Proportional Integral (PI) Controller.

I. INTRODUCTION

In a modern power system, due to applications of power electronic components in the degree of waveform gets distorted. The nonlinear loads may cause poor power factors, lead to voltage notch, or result in a high degree of harmonics. Such cases have brought the power quality as a growing concern. Harmonics is one of the short term power quality issues which are caused by non linear loads. However non linear loads produce harmonic currents and inject them into the supply system. It reduces the overall efficiency of the system. Elimination of these harmonic currents includes can be done using filters.

Traditionally, passive filters were used to eliminate current harmonics and increase the power factor. However, the uses of passive filter have many demerits. Shunt active power filters are operated as an ideal current source which can supply a active and adaptable solution for eliminating the harmonic currents and compensating the reactive power by injection of compensation currents [1], [2].

The advances in power semiconductor devices have created a development in Active Power Filters (APF) for harmonic embarrassment. Various topologies of active filters have been proposed for harmonic mitigation. The shunt APF based on Voltage Source Inverter (VSI) structure is an attractive solution to harmonic current problems. The shunt active filter is a pulse width modulated (PWM) voltage source inverter (VSI) that is connected in parallel with the load. It has the capability to inject harmonic current into the AC system with the same amplitude but opposite phase than that of the load [3, 4].

The vectorial theory dual formulation of instantaneous reactive power is introduced to compensate the reactive power and the load current harmonics and to balance asymmetrical loads [5]. The instantaneous power theory (p-q) is introduced to minimize unbalanced and non sinusoidal condition in a three phase four wire system [6]. The space vector approach to the – theory, provides a solution for voltage harmonic distortion [7].

Though voltage source shunt active power filters gave an enhanced performance current source shunt active power filters offers an allowable choice in harmonic mitigation [8]. The performance of Shunt Active Filter for mitigating current harmonics under balanced and unbalanced sinusoidal source voltage conditions for normal load and increased load were analyzed to develop the PI and Fuzzy logic controller (FLC) with triangular membership function [9]. The improvement of power quality by compensating current harmonics which is essential by a nonlinear load is controlled by a fuzzy logic controlled, three-phase shunt active filter [10].

The performances of the three levels active power filters is improved by using of fuzzy logic control algorithm for harmonic current and inverter dc voltage control [11]. A new approach for not direct control of shunt active power filter using fuzzy PI control is attempted with different membership functions of the fuzzy logic controller [12]. The three-phase reference currents for shunt active power filters are extracted by using of the instantaneous active and reactive power (p–q) and current (Id–Iq) control strategies [13].

This work focuses on reduction of the voltage and current harmonics present in the nonlinear load. By introducing a fuzzy logic controlled Shunt Active Power Filter (SAPF) and conventional (PI) controlled shunt active power filter on instantaneous p-q control strategy. Simulation of the both controllers is carried out by using MATLAB. Simulation results and performance of the both controllers are compared.

II. SHUNT ACTIVE POWER FILTER

A three phase AC source is connected with a nonlinear load along with the shunt active power filter as shown in fig.1.The observations were made across the load and at the point of common coupling.

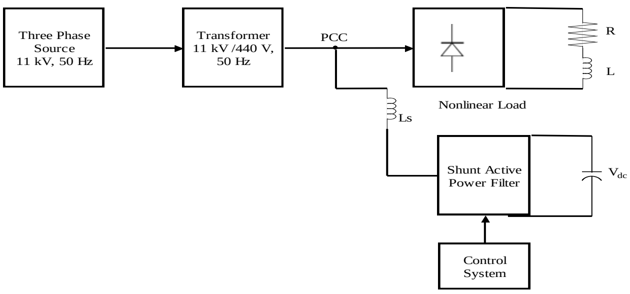


Fig.1. Basic Concept of Shunt Active Power Filter

The active filter which is used to minimize the harmonic level requires a control system that need reference currents whose values are generated using the following theory.

III. INSTANTANEOUS POWER THEORY (P-Q THEORY)

Instantaneous reactive power is a unique value of arbitrary voltage or current with all possible distorted waveforms. The instantaneous voltages and currents in three phase circuit can be mathematically expressed as instantaneous space vectors. The a,b,c plane in three phase system are 2 π /3 or (120°) apart. The instantaneous voltages are V_a, V_b, V_c along a,b.c axes and similarly the currents. The three phase space vectors is converted into α and β using Clarke transformation and expressed as in equation (1) & (2).

$$\begin{bmatrix} V_0 \\ V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{}} \\ 1 & - \\ 0 & \frac{\sqrt{}}{2} \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} \end{bmatrix} \quad (2)$$

The Generalized instantaneous power, p(t) can be expressed as in eqn.(3).

$$P = \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} . \begin{bmatrix} i_{la} & i_{lb} & i_{lc} \end{bmatrix} = v_a i_{la} + v_b i \quad (3)$$

The p–q formulation of instantaneous real (p(t)), and reactive power vector, (q(t)) in terms of the α-β-0 components as

$$P = v_{\alpha\beta 0} . i_{\alpha\beta 0} = v_\alpha i_\alpha + 1 \quad (4)$$

$$q = v_{\alpha\beta 0} \times i_{\alpha\beta 0} = \begin{bmatrix} q_\alpha \\ q_\beta \\ q_0 \end{bmatrix} = \quad (5)$$

$$q = \|\vec{q}\| = \quad (6)$$

$$\begin{bmatrix} p \\ q_\alpha \\ q_\beta \\ q_0 \end{bmatrix} = \begin{bmatrix} v_\alpha \\ 0 \\ v_0 \\ -v_\beta \end{bmatrix} \quad (7)$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix} = \frac{1}{v_{\alpha\beta 0}^2} \begin{bmatrix} v_\alpha & 0 & v_0 & - \\ v_\beta & -v_0 & 0 & \\ v_0 & v_\beta & -v_\alpha & \end{bmatrix} \quad (8)$$

Using the above equations and considering the orthogonal nature of vectors $\bar{v}$ and $\bar{q}$ ($\bar{v}.\ \bar{q} = 0$) the reference source current in the α-β-0 frame is

$$\begin{bmatrix} i_{s\alpha} \\ i_{s\beta} \\ i_{s0} \end{bmatrix} = \frac{1}{v_{\alpha\beta 0}^2} \begin{bmatrix} v_\alpha & 0 & v_0 & - \\ v_\beta & -v_0 & 0 & 1 \\ v_0 & v_\beta & -v_\alpha & \end{bmatrix} \quad (9)$$

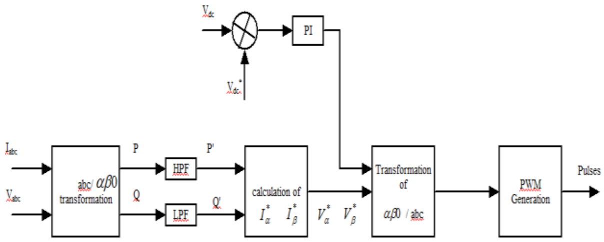


Fig.2. Control method for shunt current compensation based on p-q theory

The objective of the p–q strategy is to obtain the source to provide only the stable active power demanded by the load

$$P_s(t)=P_{L0}(t)+P_{L\alpha\beta}(t)$$

In addition, the source have to to deliver no zero-sequence active power $i_{s0ref} = 0$ (so that the zero-sequence component of the voltage at the PCC does not contribute to the source power). The reference source current in the α–β–0 frame is therefore

$$\begin{bmatrix} i_{s\alpha ref} \\ i_{s\beta ref} \\ i_{s0ref} \end{bmatrix} = \frac{1}{v_\alpha^2+v_\beta^2}\begin{bmatrix} v_\alpha & 0 & v_0 & -v_\beta \\ v_\beta & -v_0 & 0 & v_\alpha \\ 0 & v_\beta & -v_\alpha & 0 \end{bmatrix}\begin{bmatrix} \overline{P_{L\alpha\beta}} + \overline{P_L} \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad (10)$$

IV. FILTER DESIGN OF SHUNT ACTIVE

A shunt active power filter consists of a active device (IGBT) along with a control system, an energy storage system and passive components.

4.1 Filter Design Using Pi Controller

The filter is designed using a PI controller whose structure is framed as shown in fig.(3)

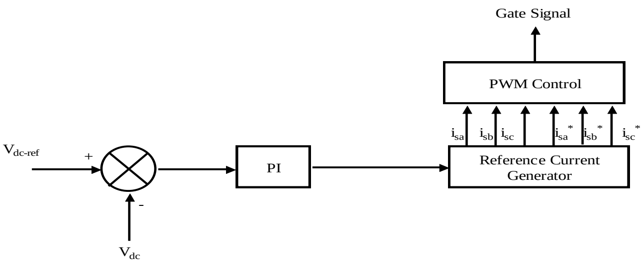


Fig. 3 Conventional PI Controller.

In Fig.3 the entire reference current generation conventional p–q method using PI controller has been illustrated. In order to maintain DC link voltage constant, a PI branch is added to control the active power component. The PI controls this small amount of active current and then the current controller regulates this current to maintain the DC link capacitor voltage. To achieve this, the DC link voltage is detected and compared with the reference voltage setting by control circuit and then the variation is fed to the PI. The difference in voltage, were fed to the PI controller. K_p and K_i values are 0.8 & 1 respectively. The output of the PI is an active current that is the corresponding power flow desired to sustain the DC link voltage. It is used as a part of the reference current for the current controller, which controls the active device to provide the compensation in current and voltage.

4.2 Filter Design Using Fuzzy Logic

The Fuzzy Logic is a mathematical tool for commerce with uncertainty. It is important to analyze the uncertainty that may occur in power system. The fuzzy logic tool provides a platform to analyze such uncertainties which arises frequently. The entire structure of the fuzzy logic controller is depicted as in fig. (4)

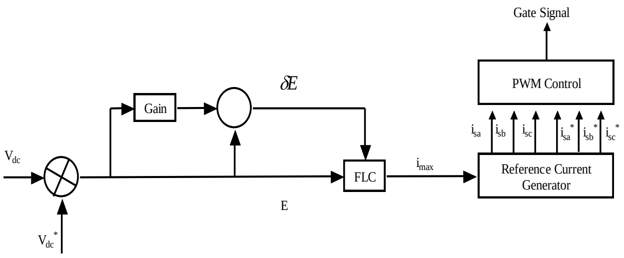


Fig.4.Fuzzy Logic Controller

4.2.1 Fuzzy Logic Controller

The operations performed are fuzzification, interference mechanism and defuzzification. The interference mechanism uses a set of linguistic rules to convert the input conditions into a fuzzified output. Finally defuzzification is used to alter the fuzzy outputs into required crisp signals shown in fig 5.

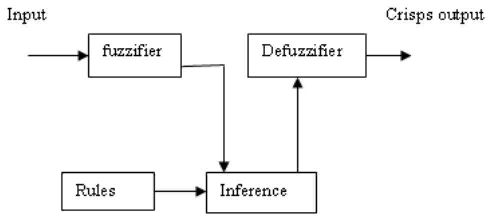
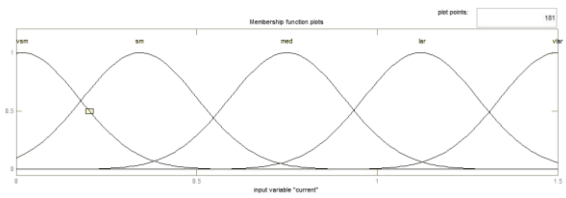
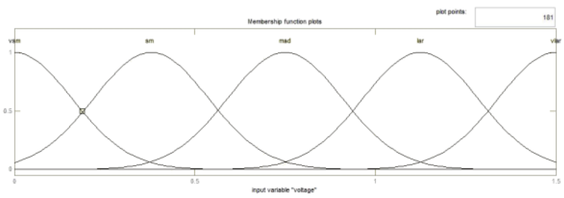


Fig.5. Internal structure of fuzzy logic controller

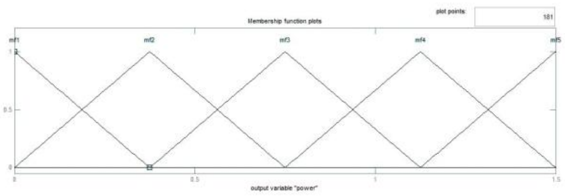
A fuzzy logic based PWM control technique is used to generate the gating signals. Fuzzy logic is characterized by (1) five fuzzy sets (VSM, SM, ZE, LAR, VL) for both input and output variables. (2) A gauss and triangular membership functions are used to the input and output variables. (3) Implication using Mamdani-type min-operator and Aggregation using Mamdani-type max-operator. (4) Defuzzification using the method of centroid.



(a) Error Signal



(b) Change of error Signal



(c) **Output Signal**

Fig.6. Membership functions for input of error, change of error and output variables

The FLC has the two input signals such as error(E) and change in error (δE) and one output signal are shown in fig.(6). Both input and output signals were assigned in the five membership functions. Input signals are represented in the gauss member functions and output signal is represented by triangular member function. Five labels with two input variables have the 25 input label pairs. The rule table relates with 25 input pairs to the relevant output label as shown in table.1.

Table.1. Rules for Fuzzy Logic Controller

δE / E	VSM	SM	ZE	LAR	VL
VSM	VSM	VSM	VSM	SM	ZE
SM	VSM	VSM	SM	ZE	LAR
ZE	VSM	SM	ZE	LAR	VL
LAR	SM	ZE	LAR	VL	VL
VL	ZE	LAR	VL	VL	VL

The fuzzy logic controller rules can be viewed as shown in Fig.7.

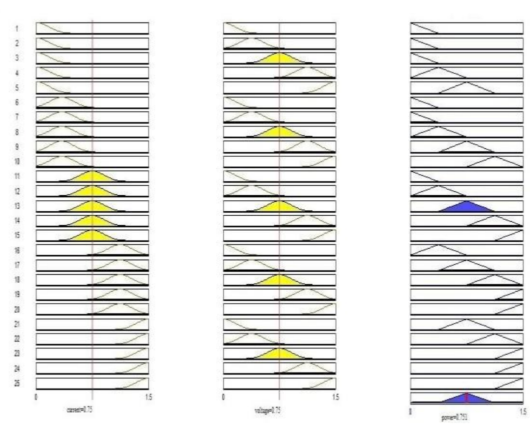


Fig.7. fuzzy rule viewer

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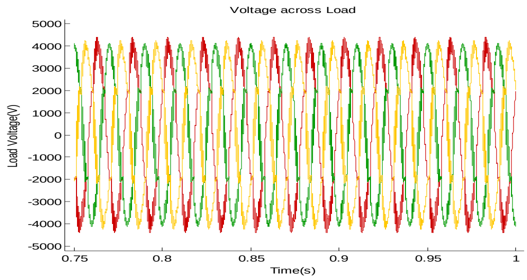
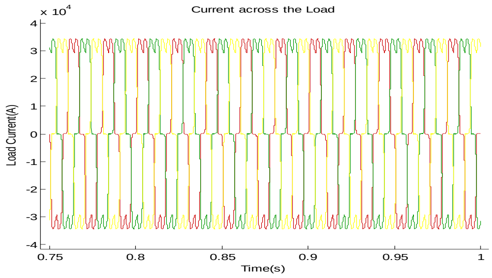
V. SIMULATION RESULTS

The proposed systems were analyzed in three different cases.

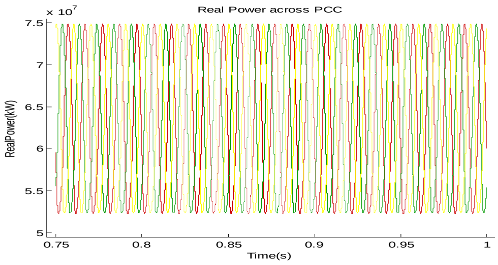
1. CASE 1: Proposed System with Shunt Active Power Filter

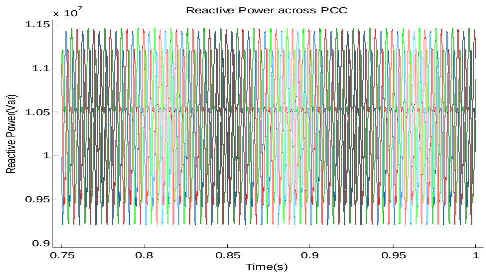
In this scenario the system was simulated without any filter. The simulation results shows the presents of harmonics due to the nonlinear load which is connected with the system. The voltage, current, and power were shown in fig.8 (a-d) respectively. Harmonic Spectrum of the proposed system without active power filter is shown in fig.9 for both current and voltage present in the load.





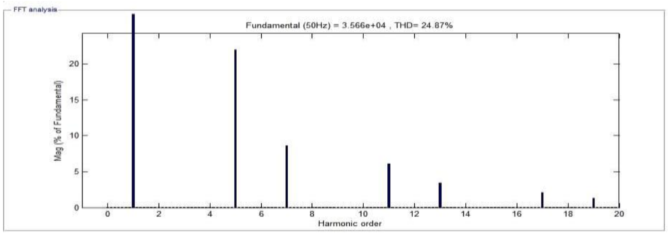
(a) Voltage across the load **(b)Current across the load**



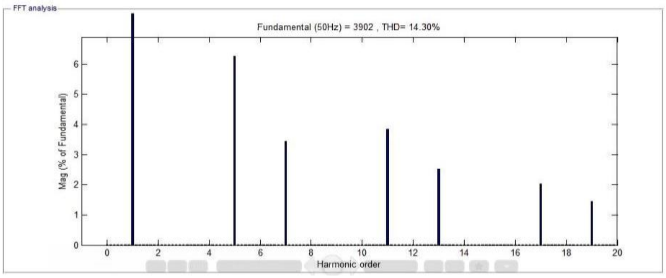


(c)Real Power across PCC **(d)Reactive power across PCC**

Fig.8. Output and Power waveforms for without filter.



(a) Current



(b) Voltages

Fig.9. Harmonic spectrum in the phase a for without filter.

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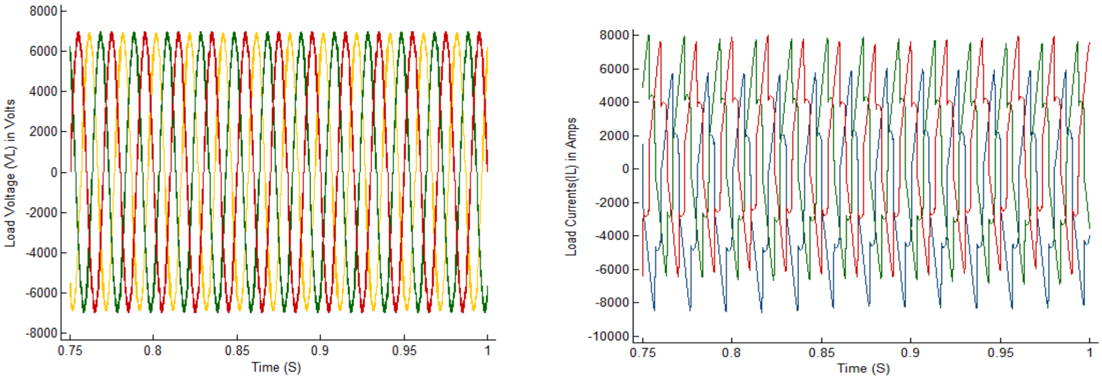
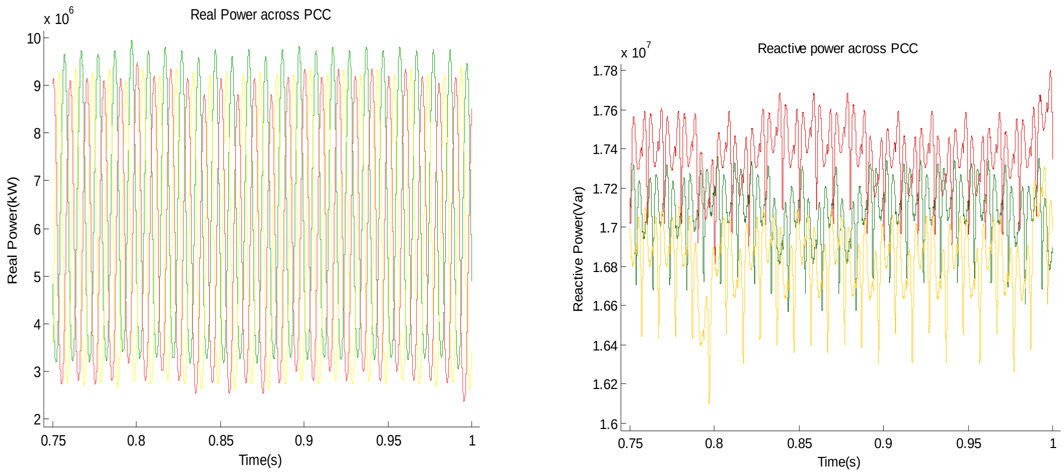
2. CASE 2: Proposed System with PI controlled Shunt Active Power Filter

In this case the system was simulated using conventional PI controlled shunt active power filter. The voltage, current, and power were shown in fig. 10(a-d) respectively. Total harmonic distortion was evaluated using fast Fourier transform. This simulation results of voltage and currents for phase a only were as shown in fig.11.

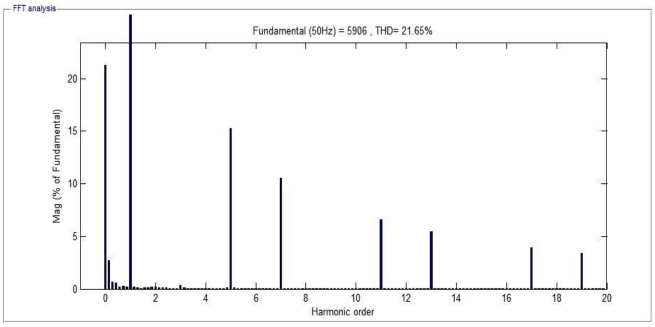


(a) Voltage across the load **(b) Current across the load**



(c) Real power across PCC **(d) Reactive power across PCC**

Fig.10.Load output and power waveforms for PI controlled SAPF



(a) Current

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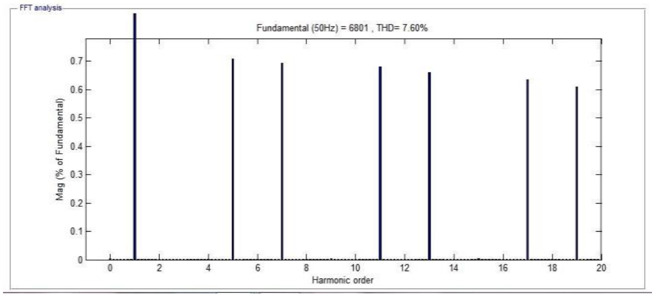
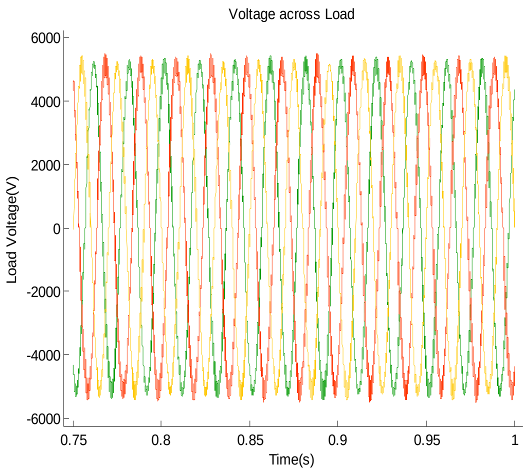


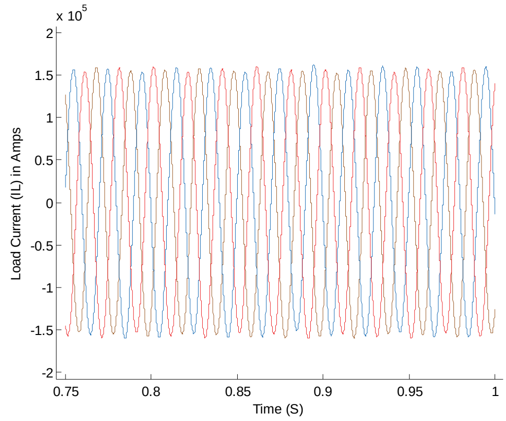
(b) Voltage

Fig.11. Harmonic spectrum in the phase a for SAPF with PI controller

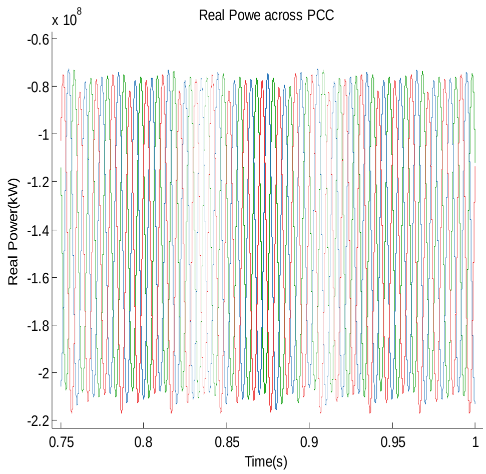
3. CASE 3: Proposed System with Fuzzy Logic Controlled Shunt Active Power Filter

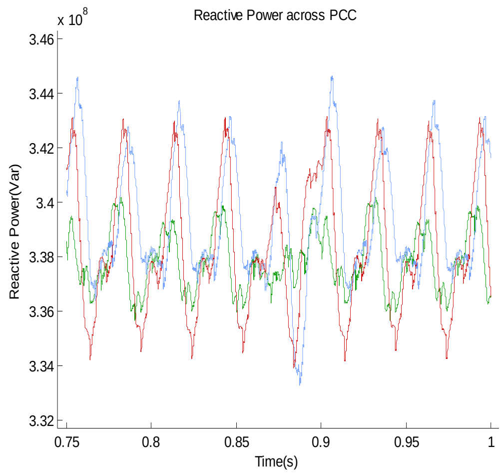
In this scenario the system was simulated fuzzy logic controlled shunt active power filter. The voltage, current, and power were shown in fig. 12(a-d) respectively. Total harmonic distortion was evaluated using fast Fourier transform. This simulation results of voltage and currents for phase a only were as shown in fig.13.





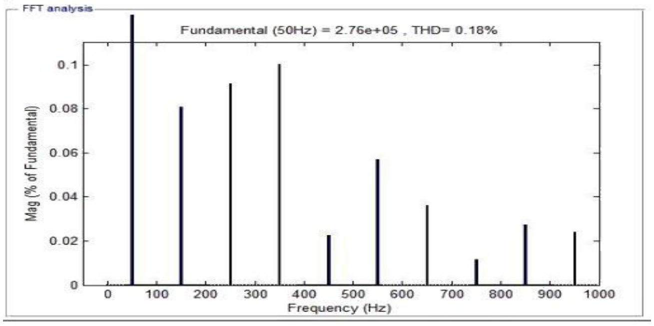
(a) Voltage across the load **(b) Current across the load**



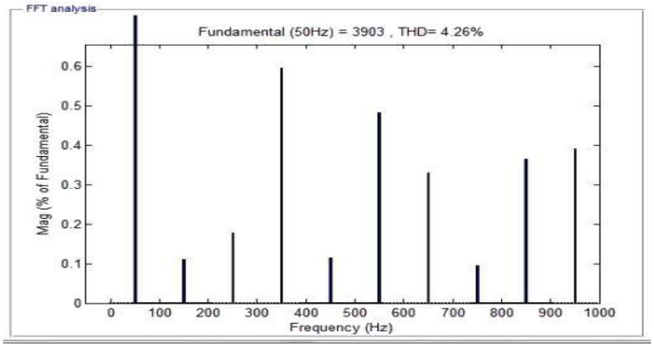


(b) Real Power across PCC **(c) Reactive power across PCC**

Fig.12. Load output and power waveforms for fuzzy logic controlled SAPF



(a) Current



(b) Voltage

Fig.13. Harmonic spectrum of in the phase a for Fuzzy Logic Controlled SAPF

The comparison of total harmonic distortion for voltage and current for without filter, conventional PI controlled with shunt active power filter and fuzzy logic controlled shunt active power filter is shown in Table II. It is observed that the SAPF with fuzzy logic controller have acceptable harmonic limits.

TABLE II.Comparison of THD

Phase Voltages & Currents	*THD (%)*					
	Proposed System Without Filter		*Proposed System with PI Controlled SAPF*		*Proposed System with Fuzzy Logic Controlled SAPF*	
	Voltage	*Current*	*Voltage*	*Current*	*Voltage*	*Current*
Phase A	*14.30*	*24.87*	*7.57*	*20.73*	*4.26*	*0.18*
Phase B	*15.95*	*24.85*	*6.69*	*20.81*	*4.46*	*0.16*
Phase C	*16.80*	*24.86*	*6.52*	*20.67*	*5.32*	*0.16*

VI. CONCLUSION

In this work two controllers were introduced for a shunt active power filter .instantaneous p-q theory has been used to improve the performance under unbalanced sinusoidal conditions. PI controlled shunt active power filter is considered for the validation of fuzzy logic controlled shunt active power filter. The function and modeling were made using simulation package. The total harmonic distortions were measured at the point of common coupling and the load .simulation results presents that the fuzzy logic controlled shunt active power filter provides a better performance in improving the power quality .

REFERENCES

[1] Akagi H, (2005) "Active harmonic filters ", Proceedings of the IEEE, vol. 93, no.12.

[2] Udom. Khruathep, Suittichai Premrudeepreechacharn,Yuttana Kumsuwan, "Implementation of shunt active power filter using source voltage and source current detection," *IEEE*, pp. 2364-2351, 2008.

[3] Abdelaziz Zouidi; Farhat Fnaiech, Kamal Al-Haddad, "Voltage source inverter based three-phase shunt active power filter: Topology, Modeling and control strategies," *IEEE, ISIE 2006*, pp. 785-790, 2006.

[4] Zainal Salam, Tan Perng Cheng and Awang Jusoh, " Harmonics Mitigation using Active Power Filter : A Technological Review" Elekrika, Vol.8, No.2, 2006, 17-26.

[5] P.Salmeron and S.P. Litran, (2010) "Improvement of the Electric Power Quality Using Series Active and Shunt Passive Filters", IEEE Transactions on Power Delivery, vol.25, no.2, pp 1058-1067.

[6] R.S. Herrera and P. Salmeron, (2007) "Instantaneous Reactive Power Thoery: A Coparative Evaluation of Different Formulations", IEEE Transactions on Power Delivery, vol.22, no.1, pp 595-604.

[7] Gabrio Superti Furga and Grazia Todeschini, (2008) "Discussion on Instantaneous p-q Strategies for Control of Active Filters", IEEE Transactions on Power Electronics, vol. 23, no 4, pp 1945-1955.

[8] Mikko Routimo, Mika Salo and Heikki Tuusa, (2007) "Comparison of Voltage-Source and Current-Source Shunt Active Power Filters", IEEE Transactions on Power Electronics, vol. 22, no. 2, pp 636-643.

[9] D.A.Mistry,Bhupelly Dheeraj,Ravit Gautam, M.S. Meena, S.Mikkili, "Power Quality Improvement Using PI and Fuzzy Logic Controllers Based Shunt Active Filter", World Academy of Science, Engineering and Technology International Journal of Electrical, Computer, Electronics and Communication Engineering Vol:8, No:4, 2014.

[10] Shilpy Agrawal, Vijay Bhuria, "Shunt Active Power Filter for Harmonic Mitigation by using Fuzzy Logic Controller", International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) Volume 2, Issue 6, June 2013.

[11] S. Saad∗, L. Zellouma, "Fuzzy logic controller for three-level shunt active filter compensating harmonics and reactive power", Electric Power Systems Research 79 (2009) 1337–1341.

[12] T Narasa Reddy, M V Subramanyam, "Fuzzy Logic Controlled Shunt Active Power Filter for Mitigation of Harmonics with Different Membership Functions", International Conference on Advances in Computing, Control, and Telecommunication Technologies, 2009.

[13] Suresh Mikkili ⇑, A.K. Panda, "Real-time implementation of PI and fuzzy logic controllers based shunt active filter control strategies for power quality improvement", Electrical Power and Energy Systems 43 (2012) 1114–1126

[14] S.N.Sivanandam, S. Sumathi and S.N. Deepa, "Introduction to Fuzzy Logic using MATLAB", Springer-Verlag Berlin Heidelberg, 2007.