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PI AND FUZZY LOGIC CONTROLLER BASED UPQC FOR P-Q IMPROVEMENT DISTRIBUTION SYSTEM

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ABSTRACT:

The Unified Power Quality Conditioner (UPQC) is a versatile device which could function as both series filter and shunt filter. The main concern is to introduce a new concept of UPQC for mitigating different power system problems. The new concept is known as the UPQC-S, in which the series inverter of UPQC is controlled to perform the simultaneous voltage sag/swell compensation and load reactive power sharing with shunt inverter. The reference voltage signal for controlling the series inverter is generated using the UPQC controller based on PAC approach. The Active Power Control approach is integrated with the theory of Power Angle Control approach to perform the two functions simultaneously. The controlling of shunt inverter of UPQC-S is done using fuzzy logic controller.

I. INTRODUCTION

Wide application of power electronic based equipment has resulted in a serious impact on the nature of electric power supply. Smooth uninterrupted sinusoidal voltage at desired magnitude and frequency should always be provided to the consumers. On the other hand consumers should draw sinusoidal current [1]. Efforts are being made by many researchers for the effective improvement of power quality. UPQC is considered as the most powerful solution to the problems arising due to power quality. It is adequate enough to take care of supply voltage disturbances like voltage sag/swells, voltage flickers, load reactive power as well as voltage and current harmonics. The UPQC can also be named as the universal active power line conditioner, universal power quality conditioning system and also universal active filter. It is a cascade connection of series and shunt active power filter (APF) connected through a common DC link capacitor [2]. The series APF is coupled to the supply line through a series transformer. The series APF prevents the source side voltage disturbances from entering into the load side to make the load voltage at desired magnitude and frequency [2]. Whereas the shunt APF connected in parallel across the load confines the current related problems to the load side to make the current from the source purely sinusoidal [3]. In this manuscript two different control schemes are used for series and shunt APF. The control algorithm is simulated in MATLAB/SIMULINK.

II. UPQC CONTROL STRATEGY

The detailed structure of UPQC is described in Fig.3.1. The UPQC comprises two voltage source inverters connected through a common dc link capacitor. The series inverter coupled to the line in series compensates for the voltage related problems such as voltage sag/swells, voltage flickers and voltage harmonics. The shunt inverter is treated as current source and is connected in shunt with the same AC line to mitigate problems related to current such as current harmonics, load reactive power and control of the dc link capacitor voltage. The DC link capacitor expedites the sharing of active power among the two inverters.

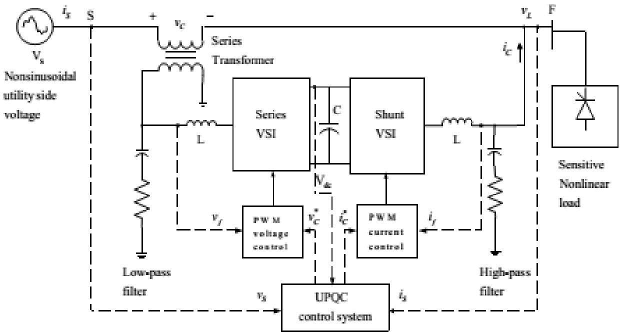

Fig 1 Detailed configuration of UPQC

A) Control of Series APF:

A simple algorithm is used to control the series filter. The concept of unit vector template (UVT) as proposed in [4] is used as control strategy of series APF. The UVT is extracted from the distorted supply. The extraction process is shown in Fig.3.2. The objective is to make the voltage at the load terminal V_{La}, V_{Lb}, V_{Lc} perfectly balanced and sinusoidal with desired amplitude. In order to carry this out the series filter injects voltages opposite to the distortion and/or unbalance present in the source voltage and these voltages cancels each other resulting in a balanced and required magnitude voltage at the load side. The load reference voltage obtained by this control strategy is compared with the load voltage signals and the error is fed to a hysteresis controller which generates the required gating signal for the series inverter. This is shown in Fig.3.2. The hysteresis controller as described in [5] has been used. The hysteresis band controller decides the pattern of switching in the inverters. This operation of the hysteresis controller is dependent on the error signal generated on comparing the load reference voltage and the instantaneous load voltage signals.

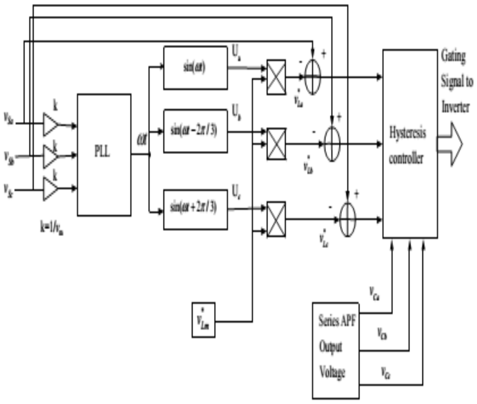

Fig 2 Control block diagram of series APF

B) Shunt Active Power Filter:

Instantaneous reactive power theory, also known as p-q theory [3], is utilized to generate the reference signals for the shunt APF. Fig.3.3 describes the control strategy of the shunt APF. According to this theory the three phase voltages and currents are measured instantaneously and by the use of equation (3.1) and (3.2) are converted to α−β−0coordinates [3].

$$\begin{bmatrix} v_{in\_0} \\ v_{in\_\alpha} \\ v_{in\_\beta} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_{in\_a} \\ v_{in\_b} \\ v_{in\_c} \end{bmatrix} \qquad (1)$$

$$\begin{bmatrix} i_{in\_0} \\ i_{in\_\alpha} \\ i_{in\_\beta} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \sqrt{\frac{1}{2}} & \sqrt{\frac{1}{2}} & \sqrt{\frac{1}{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_{in\_a} \\ v_{in\_b} \\ v_{in\_c} \end{bmatrix} \qquad (2)$$

Equation (3.3) shows the computation of the real power (p_s), imaginary power (q_s) and the zero sequence components drawn by the load. The real power and imaginary power are measured instantaneously. Equation (3.4) shows the presence of oscillating and average components in instantaneous power.

$$\begin{bmatrix} p_0 \\ p_s \\ q_s \end{bmatrix} = \begin{bmatrix} v_{in\_0} & 0 & 0 \\ 0 & v_{in\_\alpha} & v_{in\_\beta} \\ 0 & -v_{in\_\beta} & v_{in\_\alpha} \end{bmatrix} \begin{bmatrix} i_0 \\ i_{in\_\alpha} \\ i_{in\_\beta} \end{bmatrix} \tag{3}$$

$$p_s = \bar{p}_s + \tilde{p}_s \; ; \; q_s = \bar{q}_s + \tilde{q}_s \tag{4}$$

Where $\bar{p}_s$= direct component of real power; $\tilde{p}_s$= fluctuating component of real power; $\bar{q}_s$ = direct component of imaginary power; $\tilde{q}_s$ = fluctuating component of imaginary power.

The total imaginary power (q_s) and the fluctuating component of real power are selected as power references and current references and are utilised through the use of equation (3.5) for compensating harmonic and reactive power. There will be no zero sequence power (p_0) as the load is considered to be balanced.

$$\begin{bmatrix} i^*_{C o\alpha} \\ i^*_{C o\beta} \end{bmatrix} = \frac{1}{v^2_{in\_\alpha} + v^2_{in\_\beta}} \begin{bmatrix} v_{in\_\alpha} & -v_{in\_\beta} \\ v_{in\_\beta} & v_{in\_\alpha} \end{bmatrix} \begin{bmatrix} -\tilde{p}_s + \bar{p}_{loss} \\ -q_s \end{bmatrix} \tag{3.5}$$

The signal $\bar{p}_{loss}$, is obtained from the voltage regulator and is utilized as average real power [6]. It can also be specified as the instantaneous active power which corresponds to the resistive loss and the switching loss of the UPQC [7]. The error obtained on comparing the actual DC-link capacitor voltage with the reference value is processed in proportional-integral controller (PI), engaged by the voltage control loop as it minimizes the steady state error of the voltage across the DC link to zero.

The compensating currents ($i^*_{co\alpha}$, $i^*_{co\beta}$) required to meet the power demand of load are shown in equation (3.5). These currents are represented in α−β coordinates. Equation (3.6) is used to acquire the phase current (i^*_{coa},i^*_{cob},i^*_{coc}) required for compensation. These phase currents are represented in a-b-c axis obtained from the compensating current in the α−β coordinates.

$$\begin{bmatrix} i^*_{Coa} \\ i^*_{Cob} \\ i^*_{Coc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i^*_{Co\alpha} \\ i^*_{Co\beta} \end{bmatrix} \tag{3.6}$$

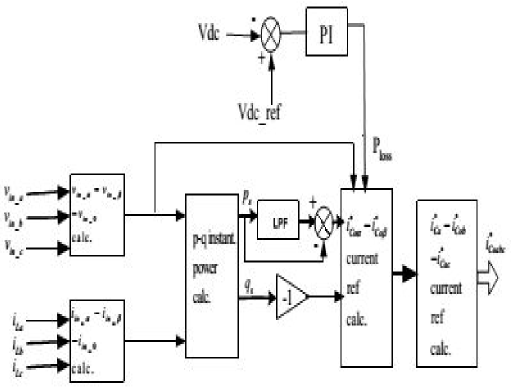

Fig 3 Control block diagram of shunt APF

The control strategy observed in Fig.3 using p-q theory is applicable for ideal 3-phase systems but is inappropriate for non-ideal mains voltage cases. Under non-ideal voltage circumstances, ($v^2_{in\_\alpha}$ $+v^2_{in\_\beta}$) is inconstant and current and voltage harmonics will be introduced in the instantaneous real and imaginary powers. As a result, compensation current equal to current harmonics will not be generated by shunt APF. To overcome these limitations, instantaneous reactive and active powers have to be calculated after mains voltages have been filtered. Voltage harmonic filter is used as shown in Fig.3.4. In this method instantaneous voltage is first transformed to d-q coordinates (Park transformation) as shown in equation (3.7).

$$\begin{bmatrix} v_{in\_d} \\ v_{in\_q} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \sin(\omega t) & \sin(\omega t - \frac{2\pi}{3}) & \sin(\omega t + \frac{2\pi}{3}) \\ \cos(\omega t) & \cos(\omega t - \frac{2\pi}{3}) & \cos(\omega t + \frac{2\pi}{3}) \end{bmatrix} \begin{bmatrix} v_{in\_a} \\ v_{in\_b} \\ v_{in\_c} \end{bmatrix} \tag{3.7}$$

The 5^{th} order low pass filter (LPF) with cut-off frequency at 60 Hz filters the d-q factors of voltages. These filtered components are changed to α−β coordinates as shown in equation (3.8). Thus, using LPF in d-q coordinates, the non-ideal main voltages are transformed to classical sinusoidal shape.

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \begin{bmatrix} \sin(\omega t) & \cos(\omega t) \\ -\cos(\omega t) & \sin(\omega t) \end{bmatrix} \begin{bmatrix} v_{in\_d} \\ v_{in\_q} \end{bmatrix} \qquad (3.8)$$

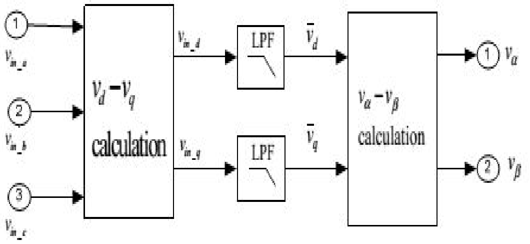

Fig 4 Voltage harmonic filtering block diagram

The reference currents as computed by control algorithm are provided to the power system by controlling the switching action of inverter. The reference currents are compared with the instantaneous line currents. The result is fed to a hysteresis band PWM control which generates the switching pattern of the VSI. The basis of this hysteresis current controller depends on the error signals between the current injected and the reference current of the shunt APF.

III. INTRODUCTION TO FUZZY LOGIC CONTROLLER

A new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to dc-to-dc converter system. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of dc-to-dc converter and performance of proposed controllers. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of dc-to-dc converters. The basic scheme of a fuzzy logic controller is shown in Fig 5 and consists of four principal components such as: a fuzzyfication interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].

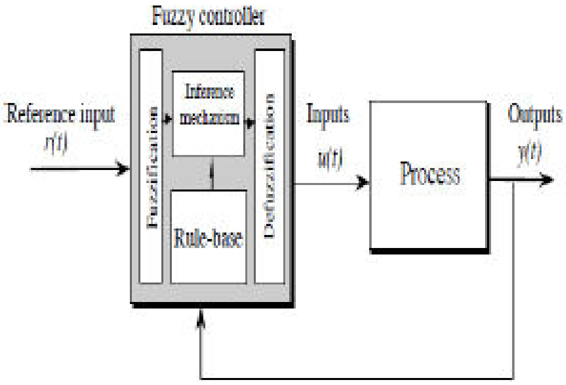

Fig.5. General structure of the fuzzy logic controller on closed-loop system

The fuzzy control systems are based on expert knowledge that converts the human linguistic concepts into an automatic control strategy without any complicated mathematical model

[10]. Simulation is performed in buck converter to verify the proposed fuzzy logic controllers.

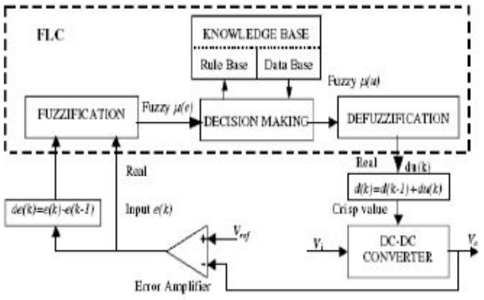

Fig.6. Block diagram of the Fuzzy Logic Controller (FLC) for dc-dc converters

A. *Fuzzy Logic Membership Functions:*

The dc-dc converter is a nonlinear function of the duty cycle because of the small signal model and its control method was applied to the control of boost converters. Fuzzy controllers do not require an exact mathematical model. Instead, they are designed based on general knowledge of the plant. Fuzzy controllers are designed to adapt to varying operating points. Fuzzy Logic Controller is designed to control the output of boost dc-dc converter using Mamdani style fuzzy inference system. Two input variables, error (e) and change of error (de) are used in this fuzzy logic system. The single output variable (u) is duty cycle of PWM output.

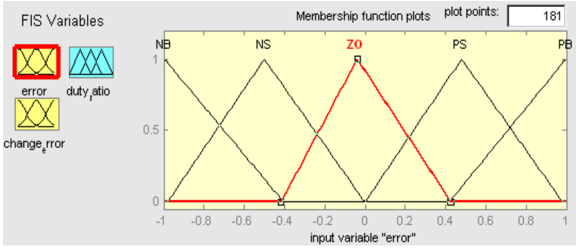

Fig. 7.The Membership Function plots of error

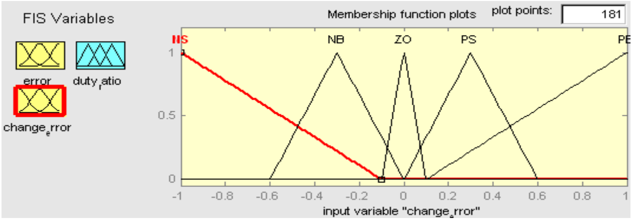

Fig.8. The Membership Function plots of change error

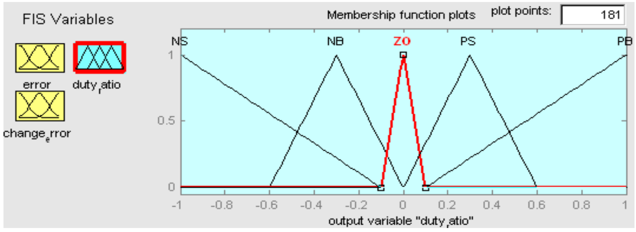

Fig.9. The Membership Function plots of duty ratio

B. *Fuzzy Logic Rules:*

The objective of this dissertation is to control the output voltage of the boost converter. The error and change of error of the output voltage will be the inputs of fuzzy logic controller. These 2 inputs are divided into five groups; NB: Negative Big, NS: Negative Small, ZO: Zero Area, PS: Positive small and PB: Positive Big and its parameter [10]. These fuzzy control rules for error and change of error can be referred in the table that is shown in Table II as per below:

Table I

Table rules for error and change of error

(de) \ (e)	NB	NS	ZO	PS	PB
NB	NB	NB	NB	NS	ZO
NS	NB	NB	NS	ZO	PS
ZO	NB	NS	ZO	PS	PB
PS	NS	ZO	PS	PB	PB
PB	ZO	PS	PB	PB	PB

IV. MATLAB/SIMULINK MODEL

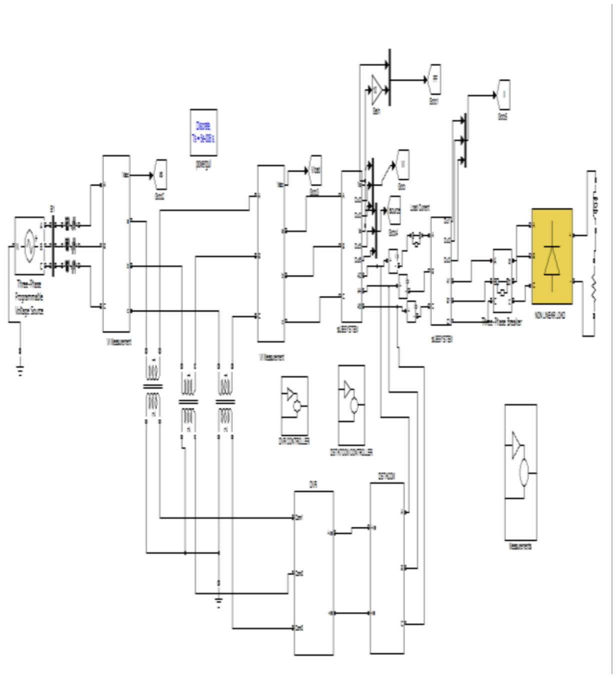

Fig.10 shows the matlab/Simulink model of proposed UPQC system

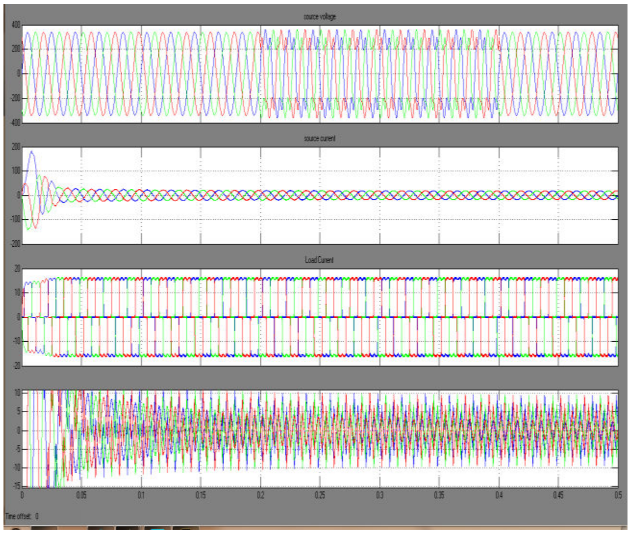

Fig.11 shows the simulated waveforms of proposed system like Source voltage, source current, load current and compensation currents with pi controller

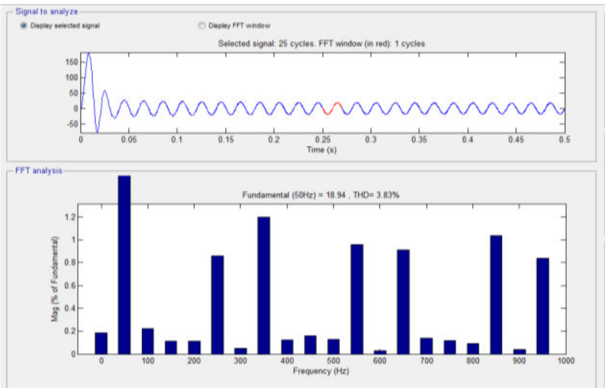

Fig.12 shows the THD analysis of proposed system for source current with Pi controller

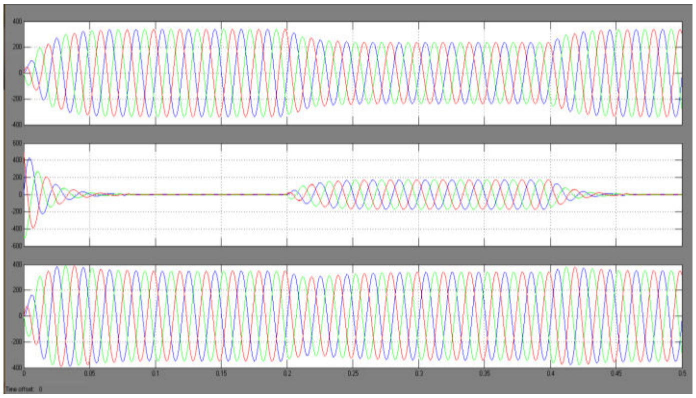

Fig.13 shows the upqc performance under voltage sag condition

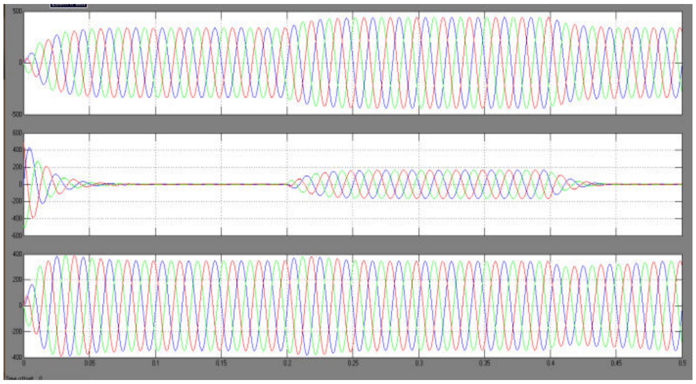

Fig.14 shows the upqc performance under voltage swell condition

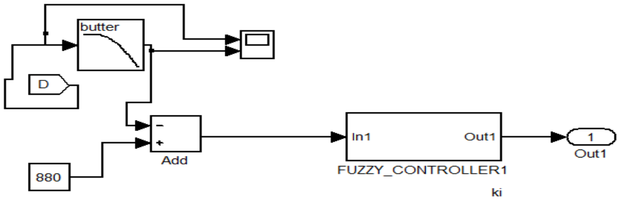

Fig.15 shows the Simulink diagram of fuzzy logic controller

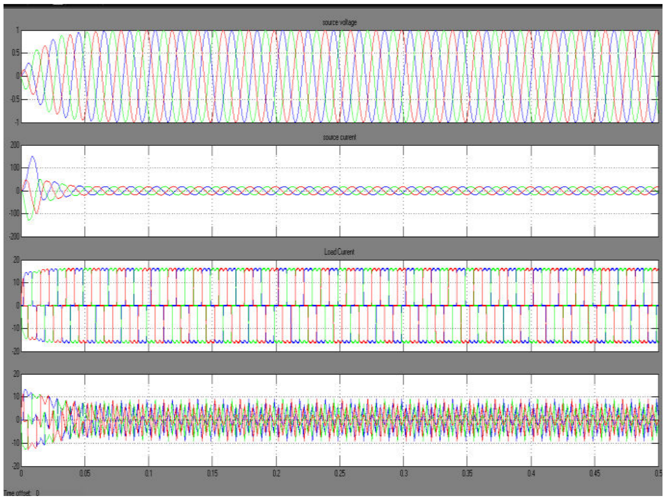

Fig.16 shows the simulated waveforms of proposed system like Source voltage, source current, load current and compensation currents with fuzzy logic controller

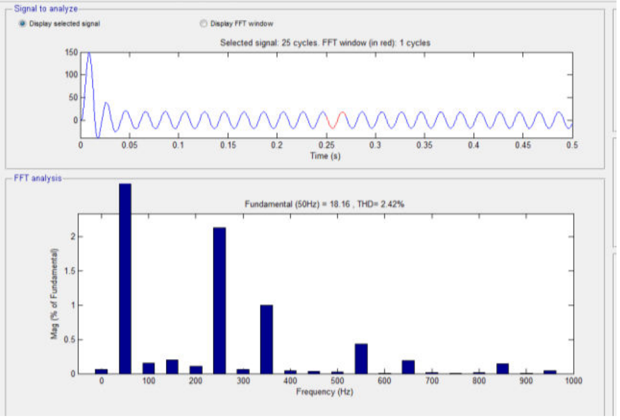

Fig.17 shows the THD analysis of proposed system for source current with fuzzy logic controller

V. CONCLUSION

The project proposed a control scheme for UPQC based on hysteresis voltage and current controller. In this scheme the series APF and the shunt APF of the UPQC are controlled by the combination of UVT and instantaneous p-q theory. The UPQC model was developed and simulated in MATLAB/SIMULINK software. It can be observed from the results obtained through simulation that the supply side voltage sag/swell, harmonic as well as the load side current harmonics are easily taken care of by the use of the proposed control scheme. The proposed concept is uses two types of controllers Pi and Fuzzy logic controllers and performance of the controllers are observed, the comparison shows that fuzzy logic controller is providing better performance than PI controller.

REFERENCES

[1] H. Awad, M. H.J Bollen, “Power Electronics for Power Quality Improvements,” IEEE Symp. On Industrial Electronics, 2003, vol.2, pp.1129-1136.

[2] Aredes M., Heumann K., Watanabe E.H., “An universal active power line conditioner”, IEEE Transactions on Power Delivery, 1998, vol. 13, pp. 545-551.

[3] Metin Kesler and Engin Ozdemir, “A Novel Control Method for Unified Power Quality Conditioner(UPQC) Under Non-Ideal Mains Voltage and Unbalanced Load Conditions,” IEEE Conference on Applied Power Electronics, Feb. 2010, pp. 374-379.

[4] V. Khadkikar, P. Agarwal, A. Chandra, A.O. Bany and T.D.Nguyen , “ASimple New Control Technique For Unified Power Quality Conditioner (UPQC),” IEEE International Conference on Harmonics and Quality of Power, Sept. 2004, pp. 289 – 293.

[5] F. A. Jowder, “Modeling and Simulation of Dynamic Voltage Restorer (DVR) Based on Hysteresis Voltage Control,” The 33rd Annual Conference of the IEEE Industrial Electronics Society (IECON) Nov. 2007, pp. 1726-1731.

[6] Mehmet Ucar and Engin Ozdemir, “Control of a 3-phase 4-leg active power filter under non-ideal mains voltage condition,” Electric Power Systems Research 78 (2008) 58–73.

[7] Shankar, Sai, Ashwani Kumar, and W. Gao. "Operation of unified power quality conditioner under different situations", IEEE Power and Energy Society General Meeting, 2011, pp. 1-10

[8] V.Khadkikar, A.Chandra, A.O. Barry and T.D.Nguyen, “Conceptual Study of Unified Power Quality Conditioner (UPQC),” IEEE International Symposium on Industrial Electronics,vol.2, July 2006,pp. 1088-1093.

[9] Ewald Fuchs, Mohammad A. S. Masoum, “Power Quality in Power Systems and Electrical Machines,” Academic Press, 29-Aug-2011 -Technology & Engineering, pp. 447-448

[10] IEEE standard 519-1992, IEEE recommended practices and requirement for harmonic control in electrical power systems, IEEE, Inc. 1993.