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POWER QUALITY IMPROVEMENT BY USING UPQC WITH THE COMPARISON OF CONVENTION AND SOFT COMPUTING METHOD

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ABSTRACT:*Presence of Harmonics, voltage & frequency variations deteriorates the performance of the system. Quality of Power supplied is affected by various factors of the power system. Most of the Power Quality problems are introduce in to the system by the Power Electronics equipment because of its fast switching and non-linear characteristics. In the market competition Power Quality issues become very large because of using more sensitive equipment. This sensitive equipment will introduce more problems due to the built in compensation and sometimes lack of enforced regulations. Thus, Power quality improvement is become more important factor as a point of view for reliable & continuous Power System operation. Power quality may be improved by using filters and compensators. For improvement of Power Quality active power filters are used. Among which a new Synchronous-Reference Frame based control method to compensate power-quality problems through a three-phase four-wire Unified Power QualityConditioner under unbalanced and distorted load conditions. One modern and very promising solution that deals with both current and voltage imperfections is the Unified Power Quality Conditioner. Here, one of the most effective custom power devices, UPQC is studied and analysed. And also the control strategy to control this device is presented. The proposed control strategy is simulated in MATLAB SIMULINK & the results are presented.*

Keyword: Harmonics, THD, Active Filters, Shunt Active Filter, UPQC, Synchronous-Reference Frame (SRF),Fuzzy Logic Controller (FLC), etc…..

I. INTRODUCTION

Most of the power quality problems are introduce by the Power Electronics devices because of its fast switching & non-linear characteristics. Because of increase in non-linearity causes different undesirable features like low system efficiency and poor power factor. It also causes disturbance to other consumers and interference in nearby communication networks. Hence, it is very important to overcome these undesirable features. Any Power Quality problem manifested in voltage and/or current deviations result into failure or disoperation of customer equipment. Both electric utility and end users of electric power are becoming increasingly concerned about the quality of electric power.

II. BASIC CONFIGURATION OF UPQC

Fig.1.1 shows system configuration of a three-phase UPQC. The key components of UPQC are as follows:

1. **Series Active Power Filter:** It is a voltage-source inverter connected in series with AC line through a series transformer and acts as a voltage source to mitigate voltage distortions. It eliminates supply voltage flickers and imbalances from the load terminal voltage. Control of the series inverter output is performed by using pulse width modulation (PWM). Among the various PWM technique, the hysteresis band PWM is frequently used because of its ease of implementation. Besides fast response, the method does not need any knowledge of system parameters.
2. **Shunt Active Power Filter:** It is a voltage-source inverter connected in shunt with the same AC line which acts to cancel current distortions, compensate reactive current of the load and improve the power factor of the system. It also performs the DC-link voltage regulation, resulting in a significant reduction of the DC capacitor rating. The output current of shunt converter is adjusted using a dynamic hysteresis band by controlling the status of the semiconductor switches such that output current follows the reference signal & remains in a pre-determined hysteresis band.

3. **DC capacitor:** The voltage across this capacitor provides the self-supporting DC voltage for proper operation of both the inverters. With proper control, the DC link voltage acts as a source of active as well as reactive power and thus eliminates the need of external DC source like battery. Two voltage source inverters are connected with this DC capacitor.
4. **Low-pass filter:** Itis used to attenuate high-frequency components of the voltages at the output of the series converter that are generated by high-frequency switching of VSI.
5. **High-pass filter** is installed at the output of shunt converter to absorb ripples produced due to current switching.
6. **Series Injection Transformer:** The harmonic compensated voltage generated by the Series active filter for maintaining the pure sinusoidal voltage is injected into the line through this transformer. Turns ratio is also important aspect for control of current flowing through the series inverter.

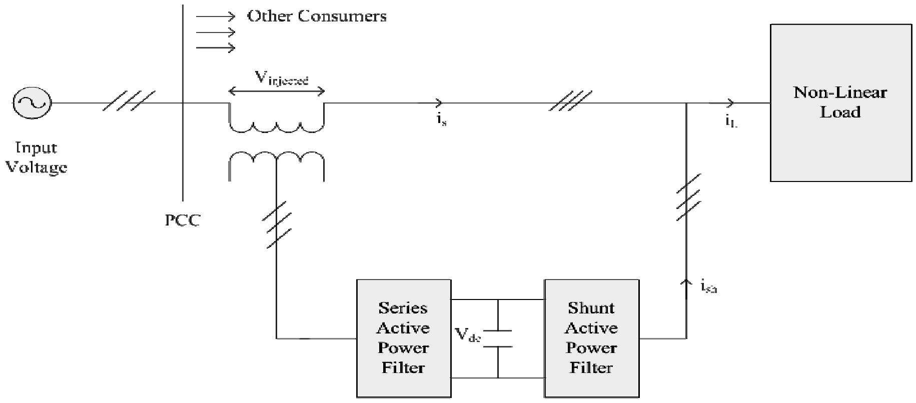

Fig.1. 1Basic Configuration of UPQC

The power circuit of active power filter consists of energy storage unit, passive filter and DC to AC inverter. DC link voltage should be higher than maximum peak of the supply voltage. DC link voltage can be controlled using proportional-integral-derivative (PID) controller, PI controller and fuzzy logic.

Series active filter connected in series with a transformer, acts as controlled voltage supply and can compensate all voltage related problems, such as voltage harmonics, voltage sag, voltage swell, flicker, etc. On the other hand, Shunt active filter is connected across the load, acts as controlled current source and compensate reactive power, current unbalance and harmonics.

III. CONTROL STRATEGY FOR UPQC

1. Control Strategy for Shunt Active Filter

Instantaneous three-phase currents and voltages are transformed to α-ß co-ordinates as shown in equation.

$$I_\alpha = \frac{2}{3} I_a - \frac{1}{3}(I_b - I_c)$$

$$I_\beta = \frac{2}{\sqrt{3}}(I_b - I_c)$$

$$V_\alpha = \frac{2}{3} V_a - \frac{1}{3}(V_b - V_c)$$

$$V_\beta = \frac{2}{\sqrt{3}}(V_b - V_c)$$

The source side instantaneous real and imaginary power components are calculated by using source currents and phase voltages as given in equation:

$$\begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix}$$

$I^*_{S\alpha}$and$I^*_{S\beta}$ are the reference currents of shunt APF in α-β co-ordinates given by :

$$\begin{bmatrix} I^*_{S\alpha} \\ I^*_{S\beta} \end{bmatrix} = \frac{1}{{V_\alpha}^2 + {V_\beta}^2} \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} \bar{p} + P_0 + P_{loss} \\ 0 \end{bmatrix}$$

Two-axis stationary reference frame is converted to three phase reference frame.

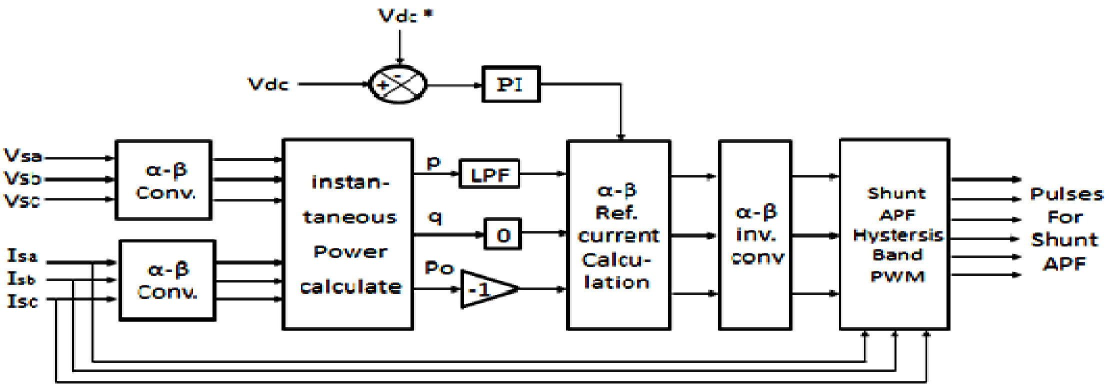

Fig.1. 2 Control Strategy of Shunt Active Filter

$I_a^* = I_{s\alpha}^*$

$I_b^* = \frac{-I_{s\alpha}^* + \sqrt{3}I_\beta^*}{2}$

$I_c^* = \frac{-I_{s\alpha}^* - \sqrt{3}I_{s\beta}^*}{2}$

These reference source current signals are then compared with sensed three-phase source currents, and the errors are processed by hysteresis band PWM controller to generate the required switching signals for the shunt APF switches.

2. Control Strategy for Series Active Filter

These produced three-phase load reference voltages are compared with load line voltages and errors are then processed by sinusoidal PWM controller to generate the required switching signals for series APF IGBT switches as shown in Fig. 1.3

A series filter is used for compensation of voltage harmonics, sag, swell and reactive power in a three phase system even with unbalanced source condition. Series filter uses different control algorithms new control strategy is proposed for the series active filter. The sensed source and actual filter voltage is given as the input of the controller and the source voltage is given to a second order low pass filter in order to extract the fundamental component with a phase shift of 90°.A Phase shifter circuit is used in order to eliminate the phase shift. Peak value of the fundamental component of the source voltage is calculated using a peak detector circuit. The phase shifted and the peak detector output is given to a divider circuit and a unit amplitude sine wave is obtained. The output of the divider circuit is multiplied with a constant value which is the required voltage at bus bar. The multiplier output and the source voltage is given to a subtraction and reference filter voltage is obtained. The filter voltage is compared with the actual voltage and the pulses for the filter are obtained. Hysteresis controller is used to generate the pulses for the series filter.

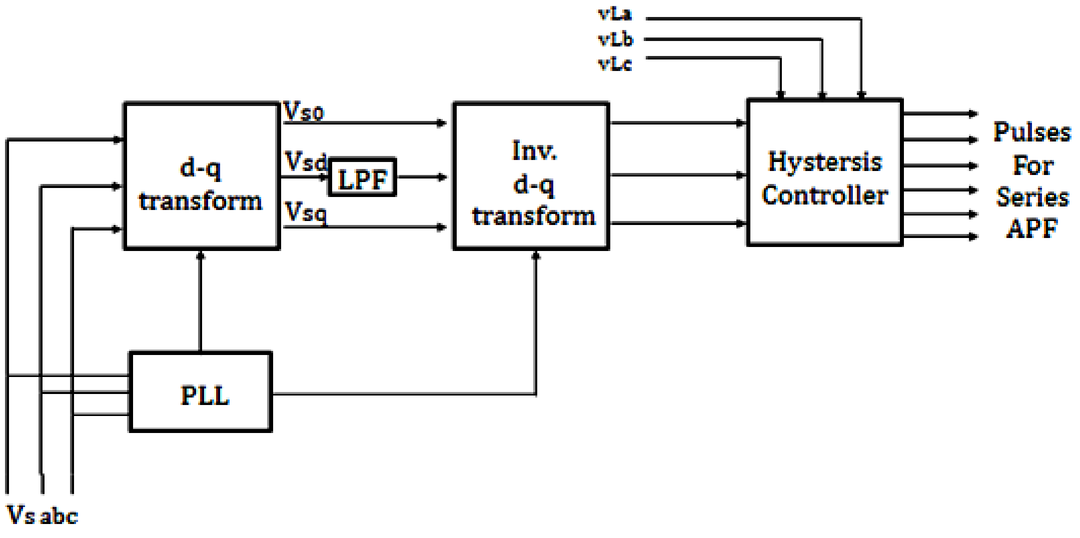

Fig.1. 3 Control Strategy for Series Active Filter

IV. Introduction to FLC

1. Fuzzy logic controller (FLC)

Fuzzy logic expressed operational laws in linguistics terms instead of mathematical equations. Many systems are too complex to model accurately, even with complex mathematical equations; therefore traditional methods become infeasible in these systems.

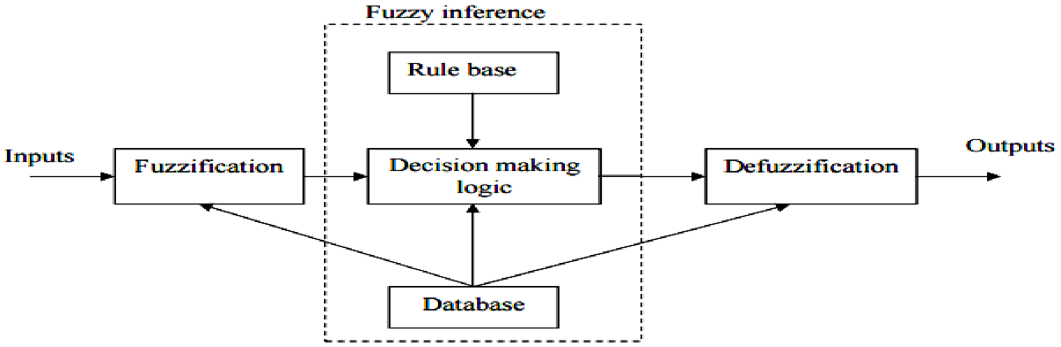

Fig.1. 4Structure of Fuzzy logic controller

However fuzzy logics linguistic terms provide a feasible method for defining the operational characteristics of such system. Fuzzy logic controller can be considered as a special class of symbolic controller. The configuration of fuzzy logic controller block diagram is shown in Fig.1.4.

2. Steps for Fuzzy Logic controller

The general design procedure for fuzzy control can be given as follow:

- First, analyse whether the problem has sufficient elements to warrant a fuzzy logic application; otherwise, apply a conventional method.
- Get all the information (design and operation characteristics of the plant) from the operator of the plant to be controlled.
- If model is available, develop a simulation model and study the performance characteristics.
- Identify the function elements where fuzzy logic can be applied.
- Identify the input and output variables of each fuzzy system.
- Formulate the fuzzy sets and select the corresponding membership function shape of each.
- Formulate the rule table.
- Test the model, evaluate the results, tune the rules and membership functions, and retest until satisfactory results are obtained.

V. SIMULATON MODEL OF UPQC CONNECTED WITH NON LINEAR LOAD

1. Simulation of UPQC with PI controller

The model used in Simulink to study with UPQC is shown below:

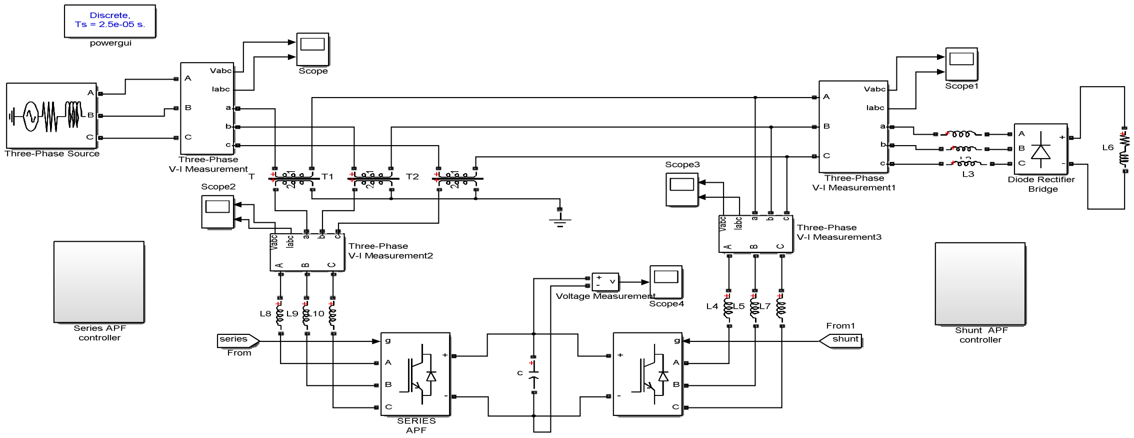

Fig.1. 5 Simulink model of UPQC with Non-linear load

2. Subsystem of Shunt Active Power Filter Controller

Fig 1.6 depicts SIMULINK model of with shunt active filter, which shows the implementation details of shunt active filter which consist the four blocks such as bridge, PQ & I-compensation, PI-controller and DC capacitor. PI-controller is connected with dc capacitor which regulates the dc voltage.

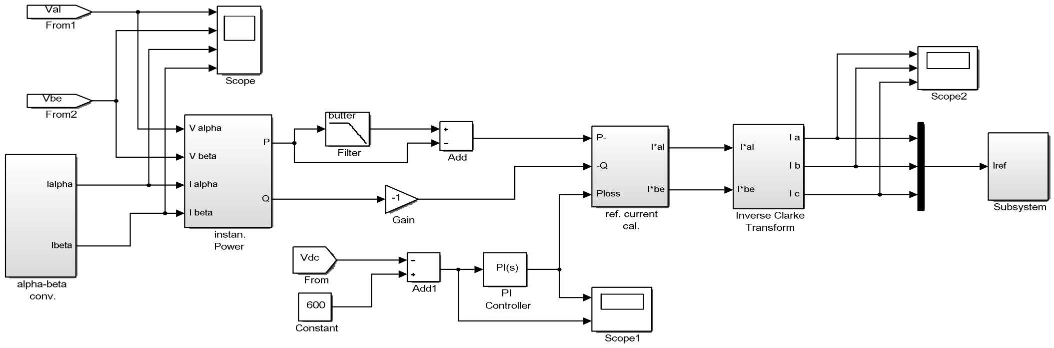

Fig.1. 6 Subsystem of Shunt Active Filter

3. Subsystem of Series Active Filter

Fig 1.7 depicts SIMULINK model of with series active filter, which shows the implementation details of series active filter which consist the four blocks such as d-q transformation, inverse d-q transformation, inverse Clarke transformation and pulse generation block.

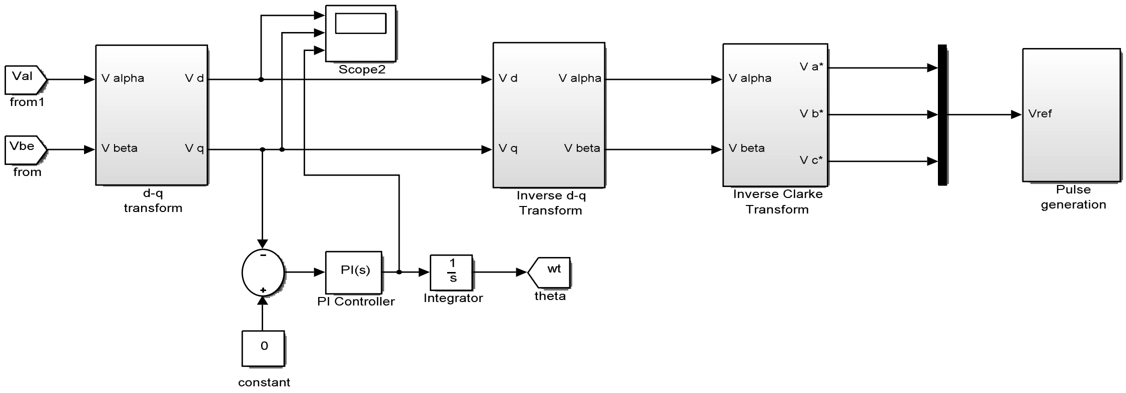

Fig.1. 7 Simulink model of Series Active Filter

4. Subsystem of Shunt Active Power Filter Controller with FLC

Fig 1.8 shows the Simulink model of Shunt Active Power Controller with Fuzzy Logic Controller (FLC).

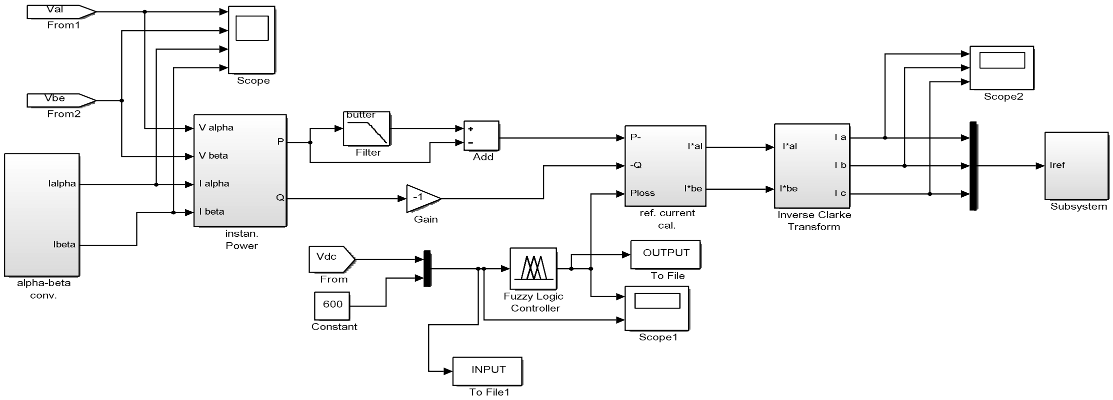

Fig.1. 8 Simulink model of Shunt Active Power Filter Controller with FLC

VII. RESULTS AND DISCUSSION

I. Waveform of UPQC with PI Controller

- **Source Voltage**

Fig 1.9 Shows the waveform of source voltage when the UPQC is connected between Source and Non-linear load by using PI controller.

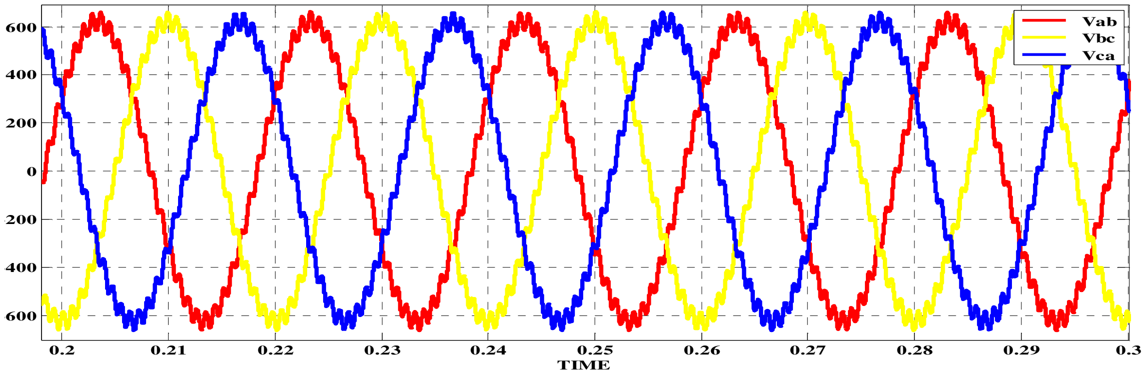

Fig.1. 9 Waveform of Source Voltage using PI Controller in UPQC

- **Load Voltage**

Fig 1.10 Shows the waveform of load voltage when the UPQC is connected between Source and Non-linear load by using PI controller.

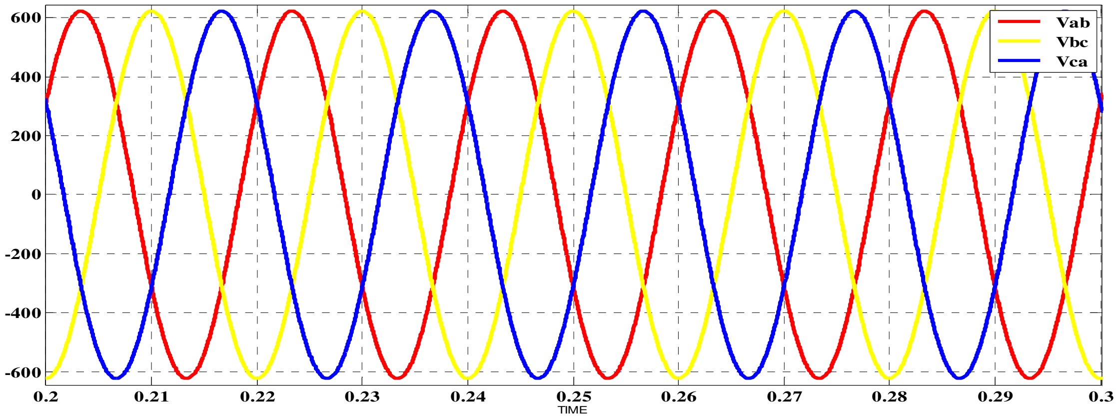

Fig.1. 10 Waveform of Load Voltage using PI Controller in UPQC

- **Source Current**

Fig 1.11 shows the waveform of source current when the UPQC is connected between Source and Non-linear load by using PI controller.

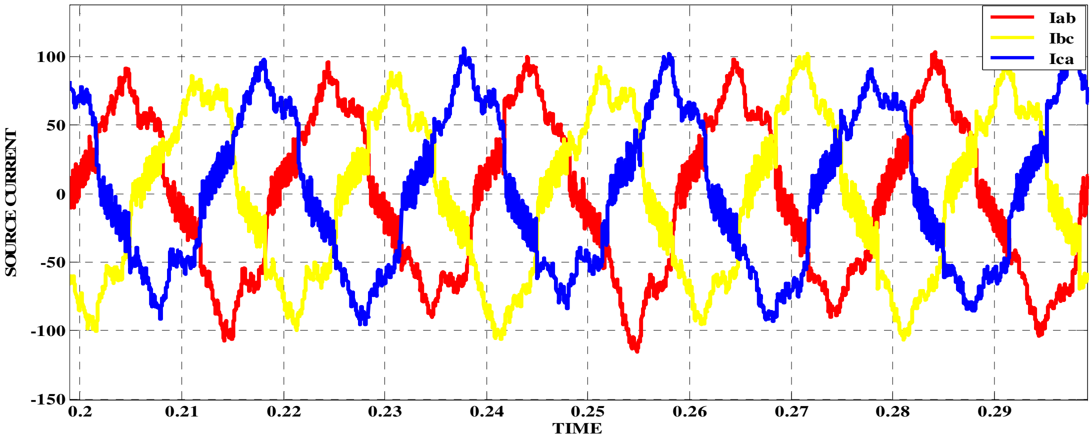

Fig.1. 11 Waveform of Source Current using PI controller in UPQC

- **Load Current**

Fig 1.12 shows the waveform of load current when the UPQC is connected between Source and Non-linear load.

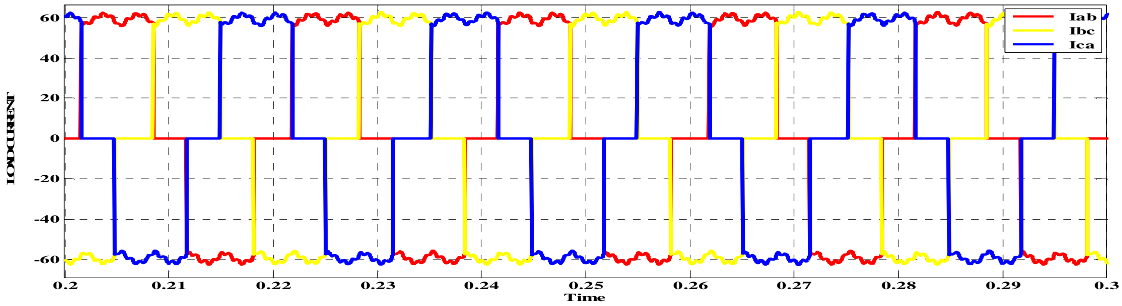

Fig.1. 12 Waveform of Load Current using PI controller in UPQC

II. Waveform of UPQC with FLC Controller

- **Source Voltage**

Fig 1.13 Shows the waveform of source voltage when the UPQC is connected between Source and Non-linear load by using Fuzzy Logic Controller.

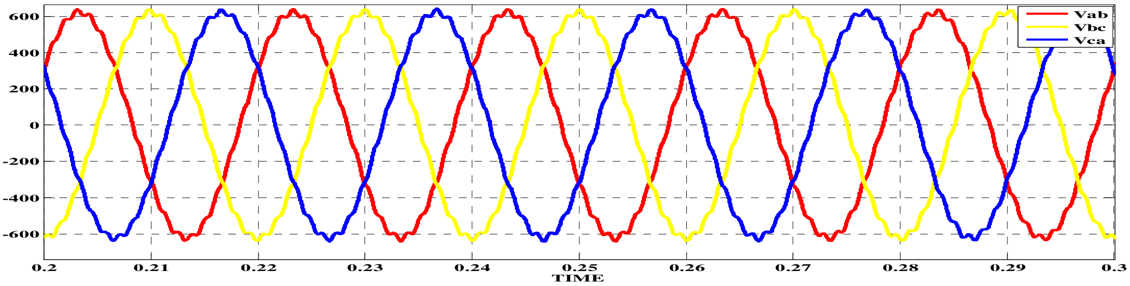

Fig.1. 13 Waveform of Source Voltage using FLC in UPQC

- **Load Voltage**

Fig 1.14 Shows the waveform of load voltage when the UPQC is connected between Source and Non-linear load by using Fuzzy Logic Controller.

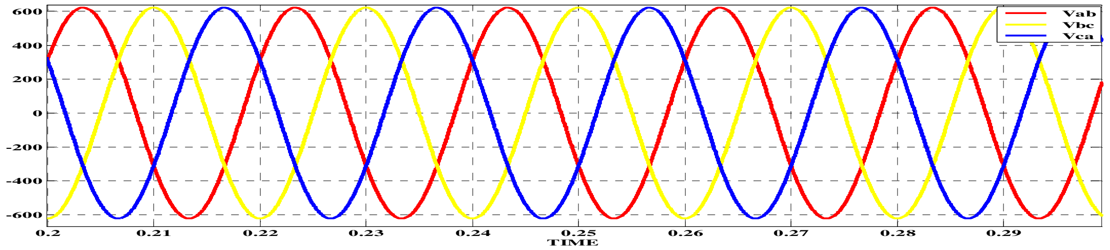

Fig.1. 14 Waveform of Load Voltage using FLC in UPQC

- **Source Current**

Fig 1.15 shows the waveform of source current when the UPQC is connected between Source and Non-linear load by using Fuzzy Logic Controller.

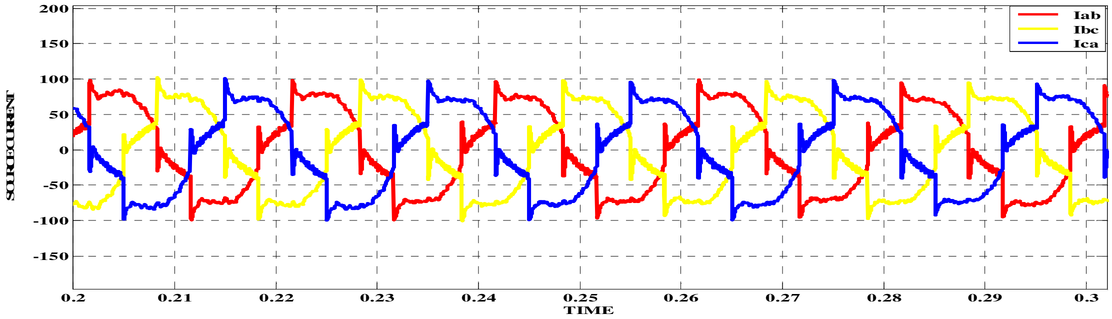

Fig.1. 15 Waveform of Source Current using FLC in UPQC

- **Load Current**

Fig 1.16 shows the waveform of load current when the UPQC is connected between Source and Non-linear load by using Fuzzy Logic Controller.

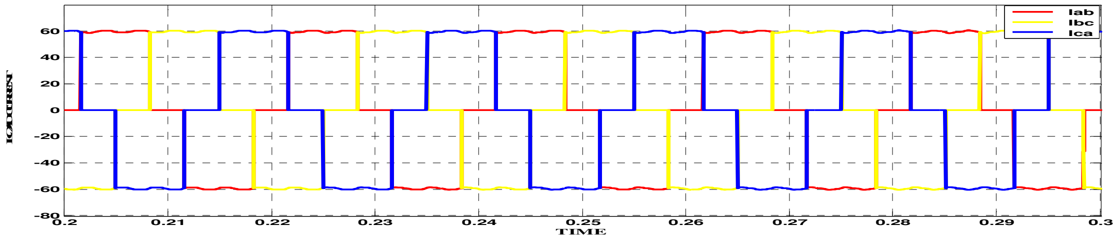

Fig.1. 16 Waveform of Load Current using FLC in UPQC

III. THD Analysis of Source Voltage

- **UPQC with PI controller**

The THD analysis of load voltage using PI controller in UPQC is connected with nonlinear load shown in Fig. 1.17.

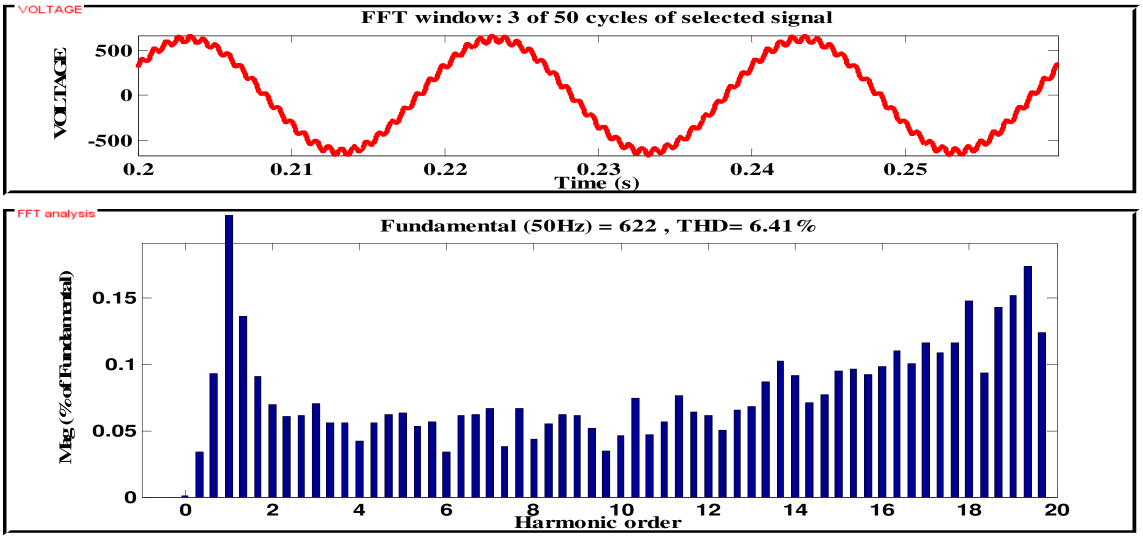

Fig.1. 17 THD Analysis Source Voltage using PI controller in UPQC

- **UPQC with Fuzzy Logic Controller**

The THD analysis of load voltage using Fuzzy Logic Controller in UPQC is connected with nonlinear load shown in Fig.1.18.

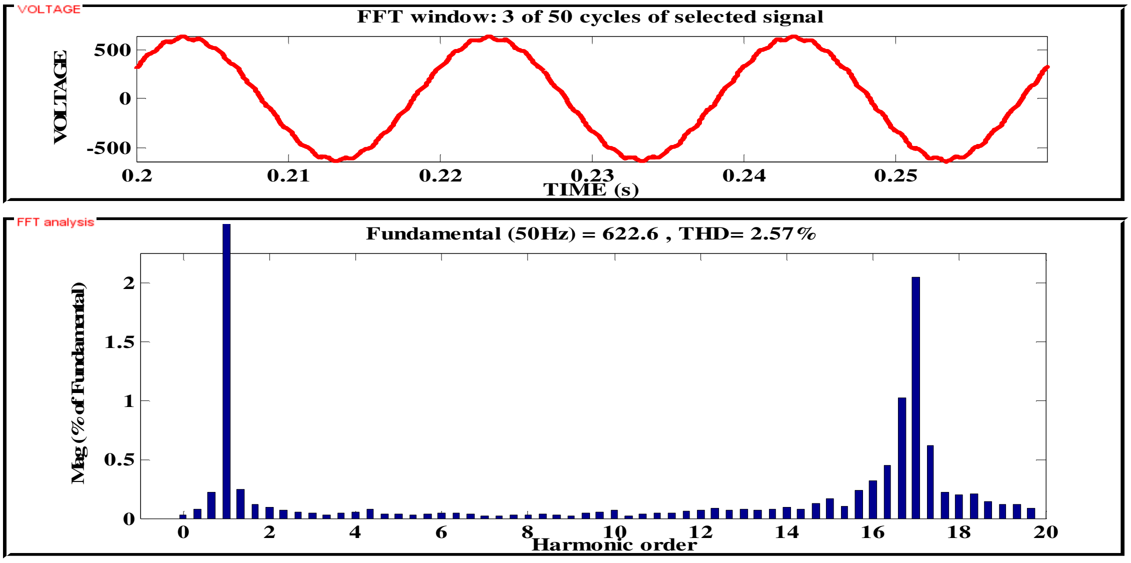

Fig.1. 18 THD Analysis Source Voltage using FLC in UPQC

IV. Comparative THD Analysis with UPQC at Different Load Condition

The comparative analysis of THD with various types of load is given in Table 1.1

Table 1.1 THD Analysis of Different load

Sr. NO	Different Load	THD Analysis	
		PI Controller	FLC Controller
1	Non-Linear	6.41%	2.57%
2	RL Series	6.21%	2.58%
3	RC Series	6.75%	2.70%
4	RLC Series	7.37%	3.27%

From the above results, it can be observed that the Fuzzy Logic Controller based UPQC have better Total Harmonic Distortion (THD) result than PI Controller based UPQC. According to **IEEE STD 519-2014,** the Total Harmonic Distortion (THD) limit of voltage is 8% if the bus voltage is under 1KV. (V ≤ 1 KV than THD limit is 8 %.)

Thus, the overall Power Quality is improving by the use of Fuzzy Logic Controller based UPQC.

VIII. CONCLUSION

In this paper, a Unified Power Quality Conditioner (UPQC) has been investigated for power quality enhancement. UPQC is an advanced hybrid filter that consists of a series active filter (APF) for compensating voltage disturbances and shunt active power filter (APF) for eliminating current distortions. UPQC system Configuration is discussed in detail. The modelling of series APF, shunt APF and the UPQC has been carried out. A simple Control technique, extraction of unit vector template has been used to model the control scheme for series APF. This scheme utilizes phase locked loop (PLL) and a hysteresis band controller to generate the reference signals for series APF. The instantaneous reactive power theory has been used to model the control scheme for shunt APF. The series and shunt APF models are combined to configure the UPQC model. Using hysteresis band controller the model has been developed in MATLAB/SIMULINK Environment. It is found from the simulation results that UPQC improves power quality of Power system by compensating harmonic of load voltage and it also makes load voltage sinusoidal at required voltage level by compensating with series APF. The THD of the load voltage is below the harmonics limit imposed by IEEE standard 519-2014.The THD of the load voltage is also compared with conventional controller (PI) based UPQC and Fuzzy Logic Controller based UPQC at different load (i.e. Non-linear, RL-Series, RC-Series, RLC-Series) condition.

IX. FUTURE WORK

The UPQC model as developed can be modified to be more effective in eliminating power quality related problems in power system. The various paths in which the presented work can be extended are listed below:

- A laboratory prototype can be made for the developed model.
- The control strategy used here can be modified for three-phase four-wire system under unbalance load.
- The model has been developed for right shunt UPQC configuration. The model can be modified for left shunt UPQC.
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