Enhancement of power quality by using UPQC system with comparison of PI and FUZZY control methods under distorted and unbalanced Load conditions

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Abstract

Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage. Sensitive power electronic equipment and nonlinear loads are widely used in industrial, commercial and domestic applications leading to distortion in voltage and current waveforms. As a result, harmonics are generated from power converters or nonlinear loads. This causes the power system to operate at low power factor, low efficiency, increased losses in transmission and distribution lines, failure of electrical equipments, and interference problem with communication system. So, there is a great need to mitigate these harmonic, reactive current components and poor voltage regulation.

Modern solution is the unified power quality conditioner (UPQC), with a combination of shunt active power filter and series active power filter. The performance of the active power filter mainly depends on control strategy, a modified synchronous-reference frame (SRF) and instantaneous PQ (IPQ) theory based control technique to compensate power-quality (PQ) problems through a three-phase unified PQ conditioner (UPQC) under unbalanced and distorted load conditions. This paper emphasis enhancement of power quality by using UPQC with fuzzy logic controller (FLC) and proportional integral (PI) controller the main purpose of the proposed (FLC) is capable of providing good static and dynamic performances compared to PI controller. The performance of the proposed controllers has been evaluated through Matlab/simulink.

Keywords: *Power quality (PQ), Active power filter (APF), Harmonics, Instantaneous PQ (IPQ), Synchronous reference frame (SRF), Unified power quality conditioner (UPQC), PI controller and Fuzzy logic controller (FLC).*

1. Introduction

The power quality has become a challenging issue in our day to day life. The term power quality has become one of the most prolific buzzwords in the power industry since the late 1980s [1]. As the consumer's requirement increases day by day, the quality of the power supply has also to be improved accordingly. Both the electric utilities and end users of electric power are becoming increasingly concerned about the quality of electric power. In recent years, the development of power electronics devices has been led for the implementation of electronic equipment which is suitable for electrical power systems. The non-linear loads produce harmonics and reactive power related problems in the utility systems. The harmonic and reactive power cause poor power factor and distort the supply voltage at the customer service point. The presence of harmonics in power lines results in greater power losses in the distribution system, interference problems in communication systems and, sometimes, in operation failures of electronic equipments, which are more and more sensitive since they include microelectronic control systems, which work with very low energy levels. Because of these problems, the issue of the power quality delivered to the end consumers is, more than ever, an object of great concern. To control power quality problems, many standards are proposed by different agencies, such as the IEEE-519 standard [1-2]. Ideally, voltage and current waveforms are in phase, the power factor of load equals to unity, and the reactive power consumption is zero. This situation enables the most efficient transport of active power, leading to the attainment of the cheapest distribution system. In the past, the solutions to mitigate as fixed compensation, resonance with the source impedance, and difficulty in tuning time dependence of filter parameters, these identified power quality problems were through conventional passive filters. However, their limitations, such have ignited the need for active and hybrid filters [2-3]. Under this circumstance, a new technology called Custom Power Devices (CPDs) emerged in distribution sector that power quality can be significantly improved.

The Unified Power Quality Conditioner (UPQC) is a custom power device that is employed in the distribution system to mitigate the disturbances that affect the performance of sensitive and/or critical load [4-5]. The function of unified power quality conditioner is to compensate supply voltage flicker/imbalance, reactive power, negative sequence current, and harmonics. In other words, the UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. Many control strategies to determine the reference signals of the voltage and the current of three-phase UPQC are reported in the literature. The most common are the p-q-r theory, modified instantaneous PQ (IPQ) theory [10]. Synchronous Reference Frame (SRF) theory [11] is used for the control of three-phase Unified power quality conditioner (UPQC). The performance of UPQC mainly depends upon how quickly and accurately compensation signals are derived. The control strategies used here are based on PI Controller and Fuzzy Controller. Control schemes of UPQC based on PI controller has been widely reported [12]. The PI control based techniques are simple and reasonably effective. Further, the control of UPQC based on the conventional PI control is prone to severe dynamic interaction between active and reactive power flows. In this work, the conventional PI controller has been replaced by a Fuzzy Logic Controller (FLC). Recently, fuzzy logic controller has generated a great deal of Interest in various applications and has been introduced in the power electronics field [13-15]. The FLC has been used in APFs in place of conventional PI controller for improving the dynamic performance. The FLC is basically nonlinear and adaptive in nature. The advantages of fuzzy logic controllers over the conventional PI controller are that they do not need an accurate mathematical model; they can work with imprecise inputs, can handle nonlinearity, and may be more robust than the conventional PI controller.

The performance of the proposed system is demonstrated through simulated waveforms using Sim Power Systems (SPS) Matlab/Simulink environment. The UPQC configuration is discussed in Section 2, the control algorithm for UPQC is illustrated in Section 3 and the comparison of PI and Fuzzy logic controller explained in section 4. The SPS Matlab/Simulink-based simulation results are explained in Section 5. Section 6 concludes the paper.

2. System configuration

The Unified Power Quality Conditioner (UPQC) is one of the best solutions to compensate both current and voltage-related problems simultaneously. UPQC was widely studied by many researchers as an eventual method to improve power quality of electrical distribution system. The UPQC is the most versatile and complex of the FACTS devices, combining the features of the STATCOM (Static Compensator) and the DVR (Dynamic Voltage Restorer). Fig.1 shows a basic system configuration of a general UPQC consist of combined series and shunt active power filters (APFs) for simultaneous compensation of voltage and current disturbances and reactive power [4-5]. They are applicable to power distribution systems, being connected at the point of common coupling (PCC) of loads that generate harmonic currents. The main aim of the series APF compensate the source voltage-based distortions, such as harmonics, dips or over-voltages, which might deteriorate the operation of the local load while the shunt APF attenuates the undesirable load current components (harmonic currents and the fundamental frequency component which contributes to the reactive load power). Moreover, the shunt APF must control the dc-bus voltage in order to ensure the compensation capability of the UPQC [4].

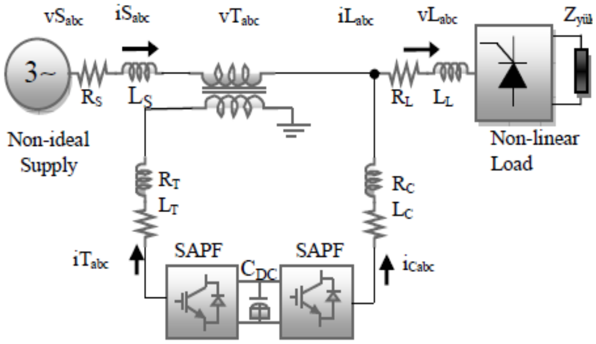


Fig.1 Unified Power Quality Conditioner configuration

The Superiority of UPQC over other devices why? Means each of Custom Power devices has its own benefits and limitations. The UPQC is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage and load current disturbances /imbalance. The most effective type of these devices is considered to be the UPQC. There are numerous reasons why the UPQC is preferred over the others. UPQC is much flexible than any single inverter based device. It can simultaneously correct for the unbalance and distortion in the source voltage and load current where as all other devices either correct current or voltage distortion. Therefore the purpose of two devices is served by UPQC only.

3. The proposed UPQC control algorithm

The UPQC consists of two voltage source inverters Connected back to back with each of them sharing a common dc link. Fig-2 shows the control diagram of UPQC system. One inverter work as a variable voltage source is called series APF, and the other as a variable current source in called shunt APF [6]. The main aim of the series APF is harmonic isolation between load and Supply; it has the capability of voltage flicker/ imbalance compensation as well as voltage regulation and harmonic compensation at the utility-consumer PCC. The shunt APF is used to absorb current harmonics, compensate for reactive power and negative-sequence current, and regulate the dc link voltage between both APFs. The control strategy is at the heart of the any compensating device [7-8].

The proposed UPQC control algorithm block diagram in Matlab/Simulink simulation software is shown in Fig. 3

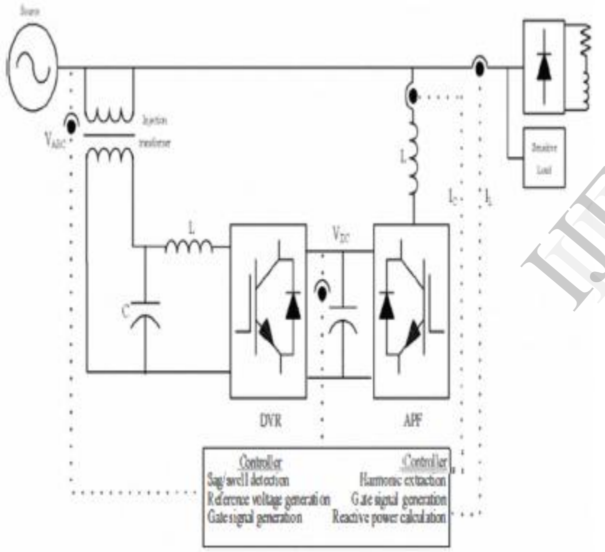


Fig.2 shows the control diagram of UPQC system

3.1 Synchronous Reference Frame Method (SRF) Based Control Technique for Series Active Power Filter (APF)

This method uses the Park transform. The Park components of a three-phase system can be found through the application of a Clarke transform, which causes the source voltages *Vsa*, *Vsb* & *Vsc* to be represented by two coordinates $V\alpha$ and $V\beta$, and later, by rotation of the reference system of an angle θ, into the Park coordinates *Vd* and *Vq*. In cases where exists zero sequence component (homo polar components), it will be represented by a third axis normal to the *d-q* plane [9-10].

The proposed series active power filter control algorithm is shown in Fig.3 In equation (1), supply voltages Vsabc are transformed abc to dq0. In addition, PLL conversion is used for reference voltage calculation.

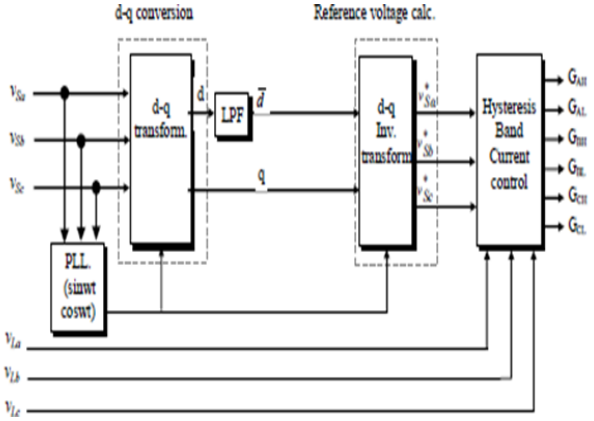


Fig. 3 Series active power filter control block diagram

The series APF control algorithm calculates the reference value to be injected by the series APF transformers, comparing the positive-sequence component with the load side line voltages. In equation (1), supply voltages Vsabc are transformed to d-q-O coordinates

$$\begin{bmatrix} v_0 \\ v_d \\ v_q \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\ \sin(wt) & \sin(wt - 2\frac{\pi}{3}) & \sin(wt + 2\frac{\pi}{3}) \\ \cos(wt) & \cos(wt - 2\frac{\pi}{3}) & \cos(wt + 2\frac{\pi}{3}) \end{bmatrix} \begin{bmatrix} v_{Sa} \\ v_{Sb} \\ v_{Sc} \end{bmatrix} \quad (1)$$

Voltage in d axes (Vd) given in equation (1) is composed from DC and AC components ($\bar{V}_d$ and $\tilde{V}_d$). $\bar{V}_d$ Voltage is calculated by using LPF (low pass filter).

$$V_d = \bar{V}_d + \tilde{V}_d \quad (2)$$

V*Sabc reference voltages are calculated as given in equation (3). The switching signals are assessed reference voltages (V*Sabc) load voltages (VLabc) and via hysteresis band current control.

$$\begin{bmatrix} v^*_{Sa} \\ v^*_{Sb} \\ v^*_{Sc} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \sin(wt) & \cos(wt) & 1 \\ \sin(wt - 2\frac{\pi}{3}) & \cos(wt + 2\frac{\pi}{3}) & 1 \\ \sin(wt + 2\frac{\pi}{3}) & \cos(wt + 2\frac{\pi}{3}) & 1 \end{bmatrix}\begin{bmatrix} \overline{v}_d \\ v_q \\ v_0 \end{bmatrix} \tag{3}$$

The 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 switches.

The Series active power filter control block diagram in Matlab/Simulink simulation software is shown in Fig. 4

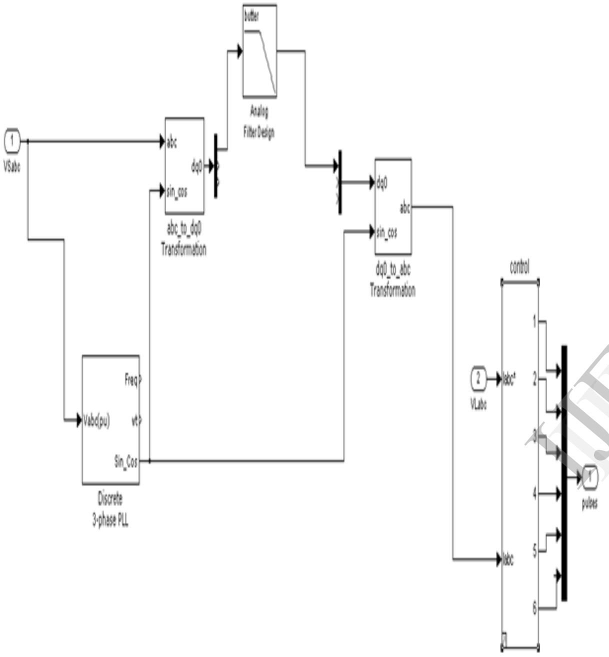


Fig. 4 Simulink diagram of Series Active Filter

3.2 Instantaneous PQ (IPQ) Theory Based Control Technique for Shunt Active Power Filter (APF)

This theory, also known as "instantaneous power theory" was proposed in 1983 by *Akagi et al.* [11] to control active filters. It is based on instantaneous values in three-phase power systems with or without neutral wire, and is valid for steady-state or transitory operation, as well as for generic voltage and current waveforms. The p-q theory consists of an algebraic transformation (Clarke transformation) of the three-phase voltages and currents in the *a-b-c* coordinates to the α-β-*0* coordinates. The proposed shunt active power filter control algorithm is shown in Fig. 5 Instantaneous reactive power (p-q) theory is used to control of shunt active power filter in real time. In this theory, instantaneous three-phase current and voltages are transformed to a-b-0 from a-b-c coordinates as shown in equation (4) and (5).

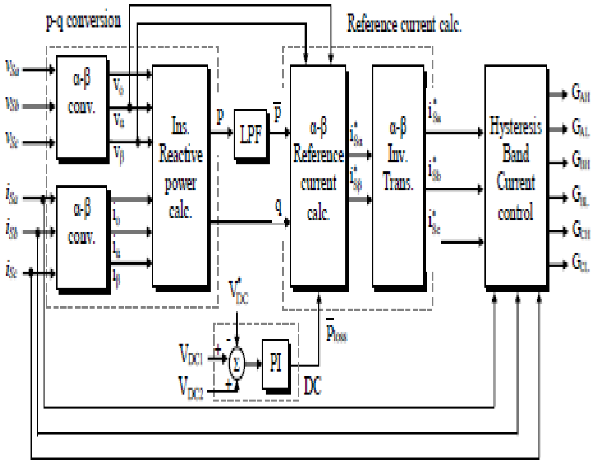


Fig.5 Shunt active power filter control block diagram

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} v_{Sa} \\ v_{Sb} \\ v_{Sc} \end{bmatrix} \tag{4}$$

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} i_{Sa} \\ i_{Sb} \\ i_{Sc} \end{bmatrix} \tag{5}$$

Load side instantaneous real and imaginary power components are calculated by using load currents and phase-neutral voltages as given in equation (6).

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix}\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{6}$$

Instantaneous real and imaginary powers include AC and DC components as shown in (7). DC components of p and q composed from positive sequence components ($\overline{p}$ and $\overline{q}$) of load current. AC components ($\tilde{p}$ and $\tilde{q}$) of p and q include harmonic and negative sequence components of load currents. In order to reduce neutral current, Po was calculated by using DC and AC components of imaginary power and AC component of real power; as given in (8) if both harmonic and reactive power compensation is required

$$p_0 = v_0 * i_0 \quad ; \quad p = \bar{p} + \tilde{p} \tag{7}$$

$$\begin{bmatrix} i^*_{S\alpha} \\ i^*_{S\beta} \end{bmatrix} = \frac{1}{v_\alpha^2 + v_\beta^2} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} -\tilde{p} + p_0 + \bar{p}_{loss} \\ -q \end{bmatrix} \tag{8}$$

I*sα and i*sβ are reference currents of shunt active power filter in a-b coordinates. These currents are transformed to three-phase system as shown below in equation (9).

$$\begin{bmatrix} i^*_{Sa} \\ i^*_{Sb} \\ i^*_{Sc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3/2} \\ -1/2 & -\sqrt{3/2} \end{bmatrix} \begin{bmatrix} i^*_{S\alpha} \\ i^*_{S\beta} \end{bmatrix} \tag{9}$$

The reference currents in three-phase system (i*sa i*sb i*sc) are calculated in order to compensate neutral, harmonic and reactive currents in the load. The switching signals used in shunt active power filter control algorithm are generated by comparing reference currents and actual line currents and using hysteresis band current control algorithm.

4. Comparison of PI and FUZZY controller

In this section the behaviour of the two current controllers will be compared based on the dynamic response.

4.1 PI Controller

When PI based controller is used, the dc link voltage is sensed at regular intervals and is compared with a reference value. The error signal thus derived is processed in a PI controller [12]. A limit is put on the output of the controller to ensure that the shunt active power filter supplies active power of the load through the series active power filter. The STATCOM model in UPQC is connected in shunt with transmission line using step down transformer. The voltage can be regulated to improve the voltage stability of the power system. Thus the main function of the STATCOM is to regulate key bus voltage magnitude by dynamically absorbing or generating power to the ac transmission line.

Simulation Results of UPQC Using PI Controller:-An ideal three-phase sinusoidal supply voltage of 380V, 50Hz is applied to the non-linear load injecting current harmonics into the system. Fig.6 The Shunt active power filter control block diagram by using PI controller in Matlab/Simulink, Shunt inverter is able to reduce the harmonics from entering into the system.

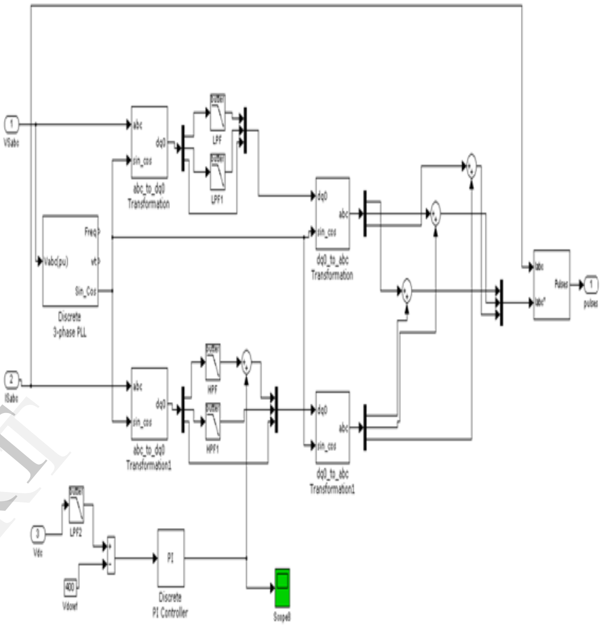


Fig.6 Simulink diagram of Shunt active power filter control block diagram by using PI controller

4.2 By comparing PI and Fuzzy Logic Controller (FLC)

The advantages of fuzzy logic controllers over conventional PI controllers are that they [13],

- ➢ Do not need an accurate mathematical model,
- ➢ Can work with imprecise inputs and
- ➢ Can handle Non-linearity's and are more robust than conventional PI controllers.

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis, from which decisions can be made. The process of fuzzy inference involves membership functions, fuzzy logic operators and if-then rules. Two types of fuzzy inference systems that can be implemented in the Fuzzy Logic Toolbox are,

- ➢ Mamdani type and
- ➢ Sugeno type

The Mamdani type of fuzzy controller used for the control of APF gives better results compared with the PI controller. Further, all the coefficients have to be optimized to get better performance than the conventional PI controller. This increases the complexity of the controller. Hence, this demands large computational time. As a result, it may not be useful for real time applications with small sampling time. On the other hand, the fuzzy controller may have an edge over the Mamdani type fuzzy controller in the following features:

- numbers of fuzzy sets used for input Fuzzification,
- number of rules to be used,
- number of coefficients to be optimized and
- Computation time.

Therefore, a part from the reduction in Total Harmonic Distortion (THD) in fuzzy logic controller has been implemented for a three-phase shunt active filter with the objective

- To reduce THD,
- Reactive power compensation and
- Power factor improvement

The fuzzy controller can provide a wide range of control gain variation and it can use both linear and nonlinear rules in the consequent expression of the fuzzy rule base. In this project, through the simulation results, it is shown that the fuzzy logic controller has improved the dynamic response of the system.

4.3 Basic Fuzzy Algorithm

In a fuzzy controller as shown in Figure 7 the control action is determined from the evaluation of simple linguistic rules. The development of the rules requires a thorough understanding of the process to be controlled but it does not require a mathematical model of the system [14].

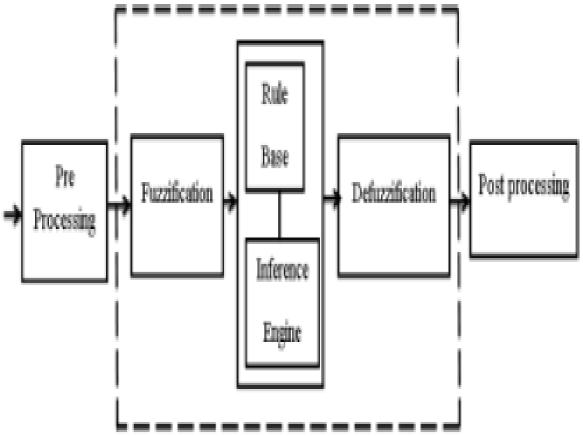


Fig.7 Structure of Fuzzy Logic Controller

A fuzzy controller consists of four stages, namely fuzzification, knowledge base, fuzzy inference mechanisms and defuzzification. The knowledge base is composed of a data base and a rule base, and is designed to obtain good dynamic responses under uncertainty in process parameters and external disturbances. The data base, consisting of input and output membership functions, provides information for appropriate Fuzzification operations, the inference mechanism and defuzzification. The inference mechanism uses a collection of linguistic rules to convert the input conditions into a fuzzified output. Finally, defuzzification is used to convert the fuzzy outputs. In order to implement the control algorithm of Fuzzy Logic Controller, the conventional PI controller is replaced by a fuzzy controller where in the optimum value of fuzzy gain (K) is calculated by a fuzzy inference system, which receives as inputs the slope of D.C. average bus voltage and D.C. voltage error. Both quantities (error and slope of DC voltage) are normalized by suitable values. Thus, each range is from -1 to 1 and normalized to unity. The value of K is chosen to be near unity. To characterize this fuzzy controller, five sets each respective to the error and slope inputs are chosen. The output is defined by five sets. The linguistic rules for the fuzzy logic controller are chosen. These fuzzy rules, used in the object to maintain the K gain not too far from unity, are shown in Table 1. The error 'e' and the change of error 'ce' are used as numerical variables from the real system. To convert these numerical variables into linguistic variables, the following five fuzzy sets are used: NB (negative big), NS (negative small), ZE (zero), PS (positive small) and PB (positive big). The fuzzy controller is characterized as follows: Five fuzzy sets for each input and output are of,

- Triangular membership functions for simplicity,
- Fuzzification using continuous universe of discourse,
- Implication using Sugeno type inference system and
- Defuzzification using the weighted average method.

4.4 Design of Control Rules

The fuzzy control rule design involves defining rules that relate the input variables to the output model properties as the FLC is independent of the system model. The design is mainly based on the intuitive feeling and experience of the process. The control rules are formed by using Table 1. Based on this, the elements of the rule table are obtained from an understanding of the filter behaviour and modified by the simulation performance [14-15].

Table1. Fuzzy Rules

Change In Error	Error						
	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PB	PM	PM	PS	Z
NM	PB	PB	PM	PM	PS	Z	Z
NS	PB	PM	PS	PS	Z	NM	NB
Z	PB	PM	PS	Z	NS	NM	NB
PS	PM	PS	Z	NS	NM	NB	NB
PM	PS	Z	NS	NM	NM	NB	NB
PB	Z	NS	NM	NM	NB	NB	NB

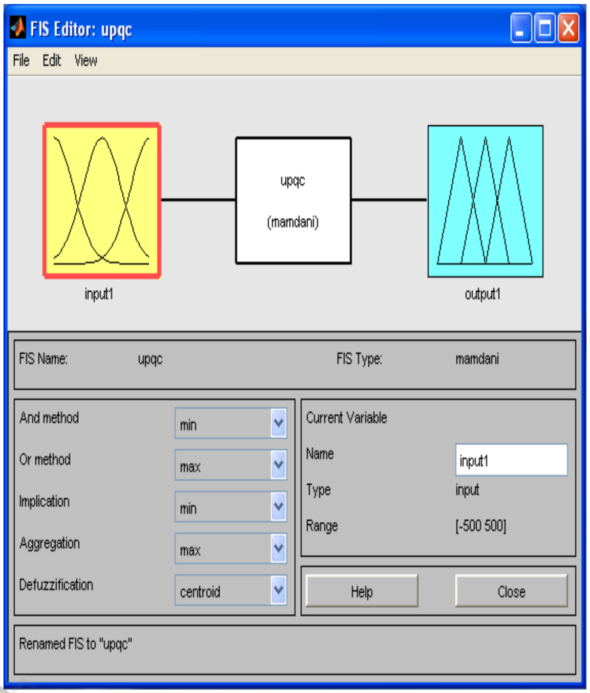
4.5 Fuzzy GUI Tools

There are five primary GUI tools for building, editing and observing fuzzy inference systems in the Fuzzy Logic Toolbox namely,

- The Fuzzy Inference Systems or FIS Editor,
- The membership Function Editor,
- The Rule Editor,
- The Rule Viewer and
- The Surface Viewer.

4.6 FIS Editor

The FIS Editor displays general information about a fuzzy inference system as shown in Fig.8 the FIS Editor handles the high level issues for the system, how many input and output variables are used in the system and their names. The Fuzzy Logic Toolbox does not limit the number of inputs. If the number of inputs is too large or the number of membership functions is too big, then it may also be difficult to analyze the FIS using the other GUI tools.



FIS Name: upqc

FIS Type: mamdani

And method: min

Or method: max

Implication: min

Aggregation: max

Defuzzification: centroid

Name: input1

Type: input

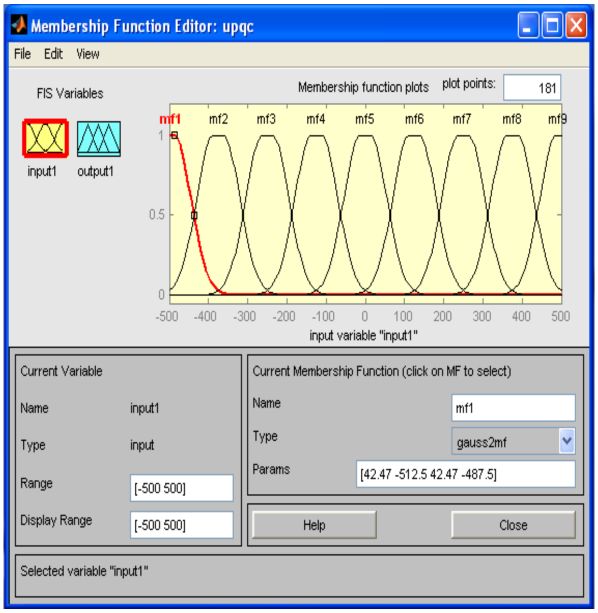
Range: [-500 500]

Renamed FIS to "upqc"

Fig.8 FIS Editor

4.7 Membership Function Editor

The Membership Function Editor tool is used to edit all of the membership functions associated with all of the input and output variables for the entire fuzzy inference system as in Fig.9 & Fig.10.



plot points: 181

Name: input1

Type: input

Range: [-500 500]

Display Range: [-500 500]

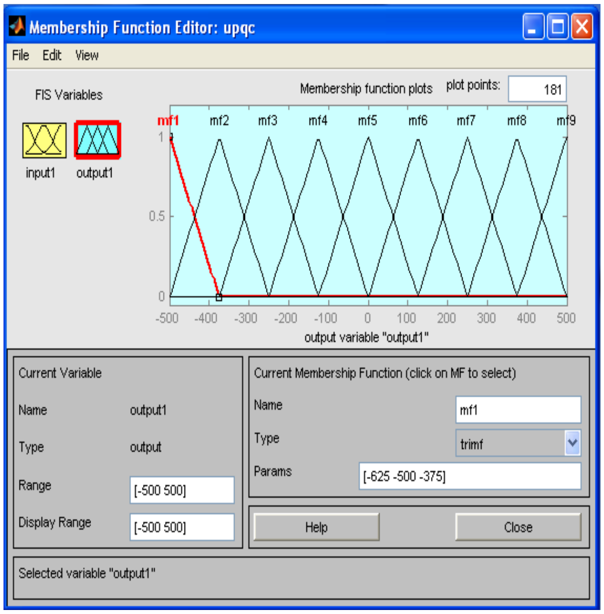
Name: mf1

Type: gauss2mf

Params: [42.47 -512.5 42.47 -487.5]

Selected variable "input1"

Fig.9 input variable



Current Variable
Name output1
Type output
Range [-500 500]
Display Range [-500 500]

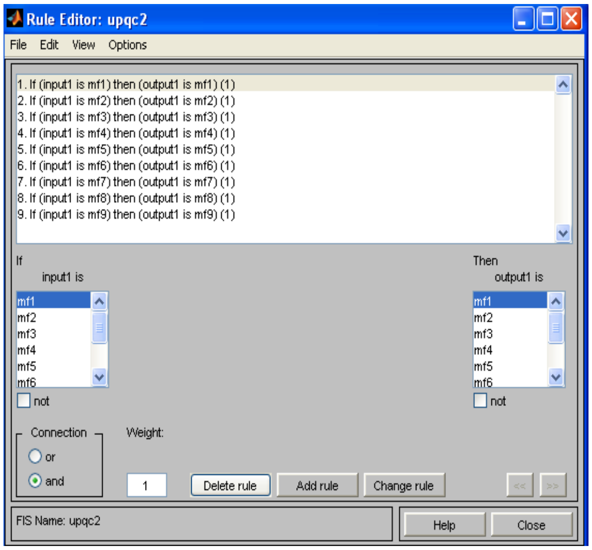
Current Membership Function (click on MF to select)
Name mf1
Type trimf
Params [-625 -500 -375]

Selected variable "output1"

Fig.10 output variable

4.8 Rule Editor

Based on the descriptions of the input and output variables defined with the FIS Editor, the Rule Editor allows to construct the rule statements automatically, by clicking on and selecting one item in each input variable box, one item in each output box and one connection item as in Fig.11 Choosing none as one of the variable qualities will exclude that variable from a given rule. Choosing not under any variable name will negate the associated quality. Rules may be changed, deleted or added by clicking on the appropriate button.



1. If (input1 is mf1) then (output1 is mf1) (1)
2. If (input1 is mf2) then (output1 is mf2) (1)
3. If (input1 is mf3) then (output1 is mf3) (1)
4. If (input1 is mf4) then (output1 is mf4) (1)
5. If (input1 is mf5) then (output1 is mf5) (1)
6. If (input1 is mf6) then (output1 is mf6) (1)
7. If (input1 is mf7) then (output1 is mf7) (1)
8. If (input1 is mf8) then (output1 is mf8) (1)
9. If (input1 is mf9) then (output1 is mf9) (1)

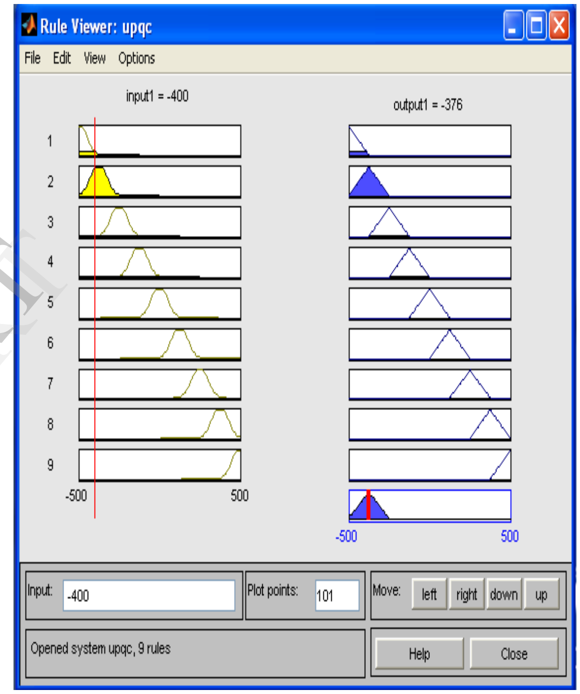
Weight: 1

FIS Name: upqc2

Fig.11 Rule Editor

4.9 Rule Viewer

The Rule Viewer displays a road map of the whole fuzzy inference process as in Fig.12 the three small plots across the top of the figure represent the antecedent and consequent of the first rule. Each rule is a row of plots and each column is a variable. The first two columns of the plots show the membership functions referenced by the antecedent, or the if-part of each rule. The third column of plots shows the membership functions referenced by the consequent, or the then-part of each rule. The Rule Viewer allows interpreting the entire fuzzy inference process at once. The Rule Viewer also shows how the shape of certain membership functions influences the overall result.



Input: -400

Plot points: 101

Opened system upqc, 9 rules

Fig.12 Rule Viewer

The Fuzzy control is basically a nonlinear and adaptive in nature, giving the robust performance in the cases where in the effects of parameter variation of controller is present. It is claimed that the Fuzzy logic controller yields [6, 7] the results which are superior to those obtained with the conventional PI controllers.

Fig.13 The Shunt active power filter control block diagram by using Fuzzy Logic Controller in Matlab/Simulink, Shunt inverter is able to reduce the harmonics from entering into the system

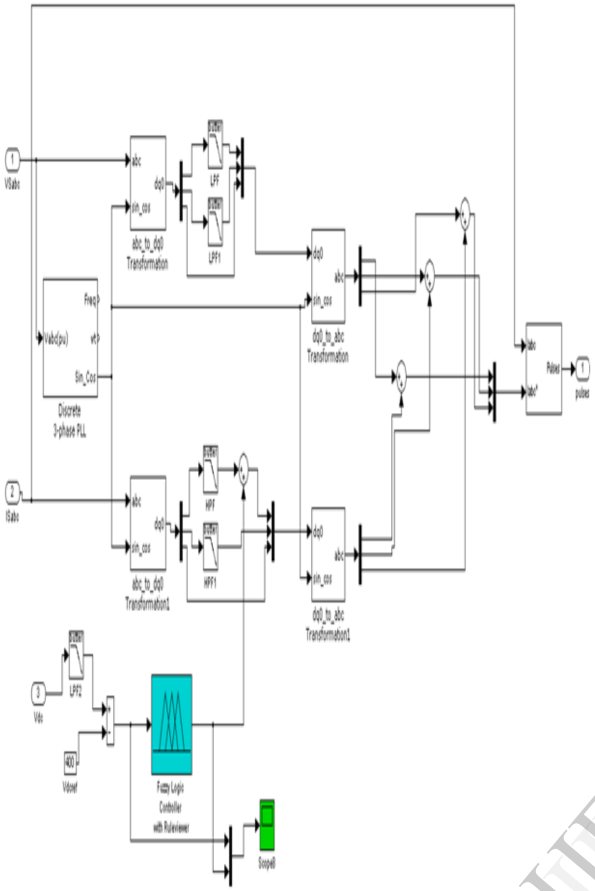


Fig.13 Simulink diagram of Shunt active power filter control block diagram by using FLC controller

5. Simulation Results

Using MATLAB toolbox the entire UPQC system has been modelled. The shunt compensator control circuit has been implemented using PI and FLC to regulate the capacitor voltage and to generate switching signals, whereas series compensator is independently controlled using conventional controllers. The performance of the UPQC system has been analyzed using shunt and series control circuits by using PI and Fuzzy controller. The validity of the system for control applications such as

- voltage and current harmonic eliminations,
- Reactive power compensation,
- Improving Power factor.

The Simulink diagram of UPQC before compensation and overall simulation diagram of UPQC is shown in Fig.14 & 15.

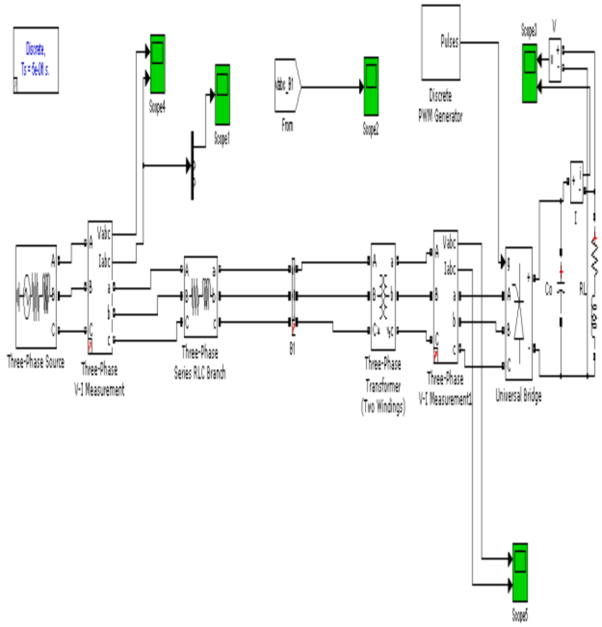


Fig.14 Simulink diagram of UPQC before compensation

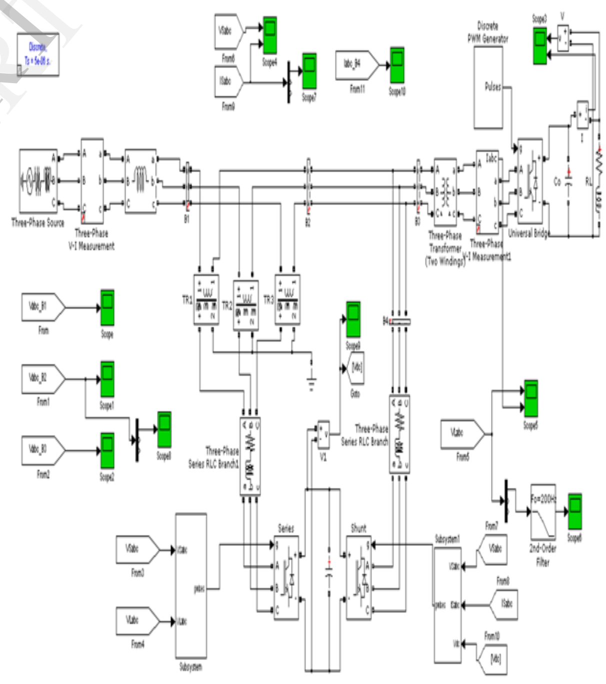


Fig.15 Overall Simulink diagram of UPQC

Simulation results are detailed in the following sub-sections. Simulation results clearly illustrate the successful application of PI and Fuzzy controllers for the implementation of UPQC. Timing Details of UPQC are tabulated in Table2.

Table.2 Simulation parameters of UPQC

	Parameters		**Value**
Source	Voltage	VSabc	380Vrms
	Frequency	f	50Hz
Load	3-Phase ac Line Inductance	LLabc	3mH
Shunt APF	AC Line Inductance	LCabc	4Mh
	Filter Resistor	RCabc	6 Ω
	Filter Capacitor	CCabc	10 µF
	Switching Frequency	Fpwm	10kHZ
Series APF	AC Line Inductance	Ltabc	2mH
	Filter Resistor	RTabc	6Ω
	Filter Capacitor	CTabc	20µF
	Switching Frequency	Fpwm	15kHZ

In this study, a new control algorithm for the UPQC is evaluated by using simulation results given in Matlab/Simulink software. The simulated UPQC system parameters are given in Table 2. In simulation studies, the results are specified before and after UPQC system are operated. Before harmonic compensation, the THD of the supply current is 12.56% and after is 1.76% with PI controller and by using Fuzzy logic controller the harmonic compensation is 1.06%.

The following results shows about the before compensation of UPQC, PI and Fuzzy logic controller by adding UPQC.

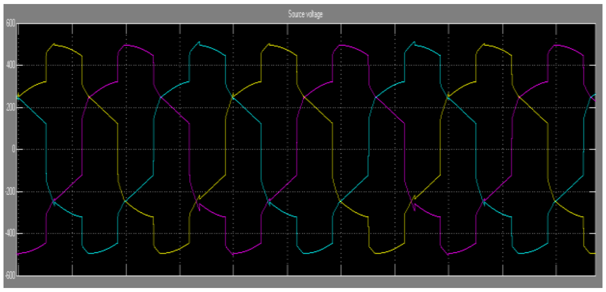


Fig.16 Three phase source voltage before compensation

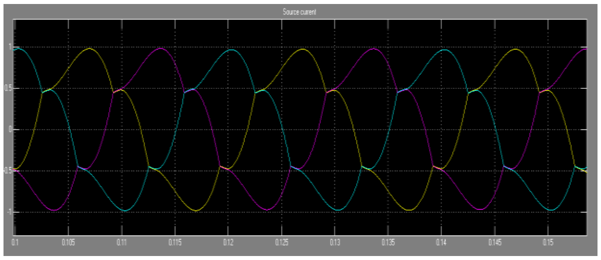


Fig.17 Three phase source current before compensation

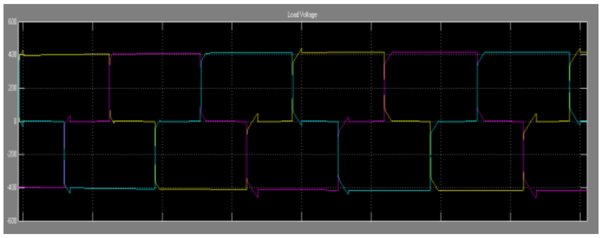


Fig.18 Three phase Load voltage before compensation

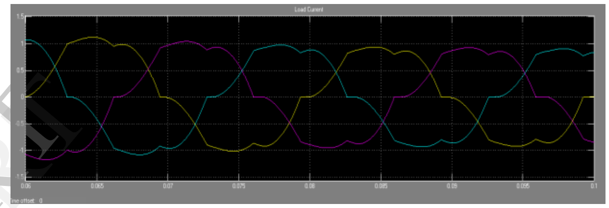


Fig.19 Three phase Load current before compensation

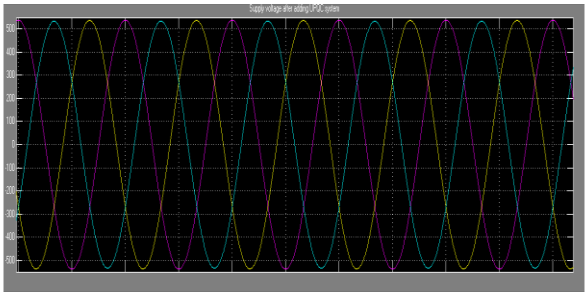


Fig.20 Source Voltage waveform with PI controlled UPQC

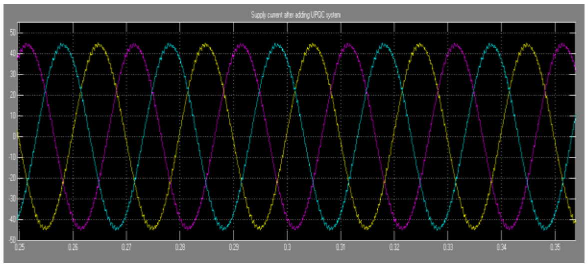


Fig.21 Source Current waveform with PI controlled UPQC

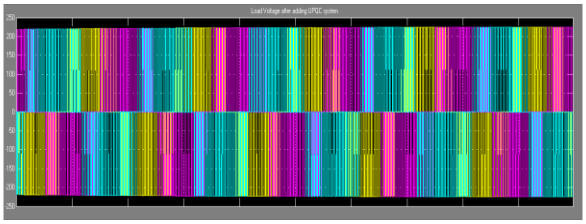


Fig.22 Load Voltage waveform with PI controlled UPQC

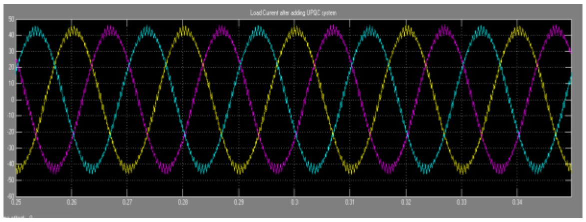


Fig.23 Load Current waveform with PI controlled UPQC

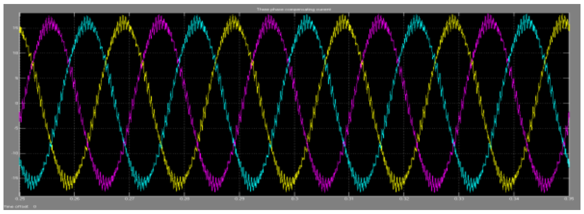


Fig-24 Three phase compensating current

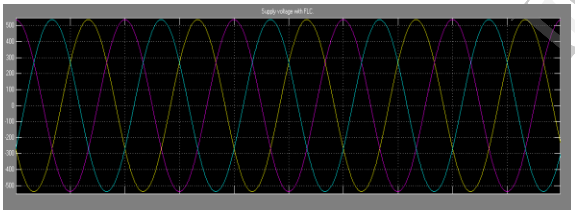


Fig.25 Source Voltage waveform With FLC controlled UPQC

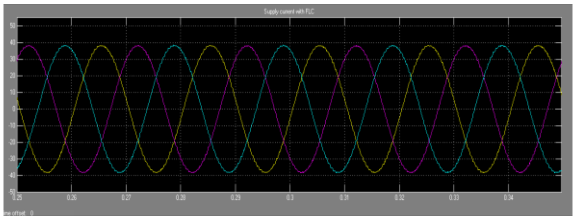


Fig.26 Source Current waveform with FLC controlled UPQC

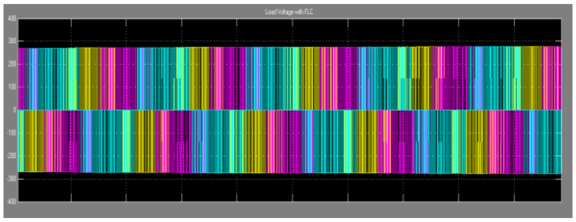


Fig.27 Load Voltage waveform with FLC controlled UPQC

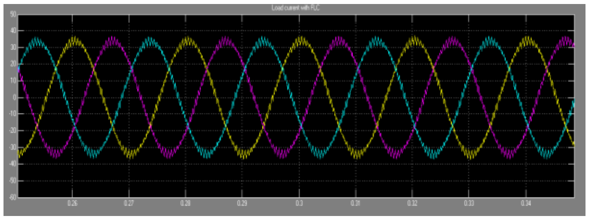
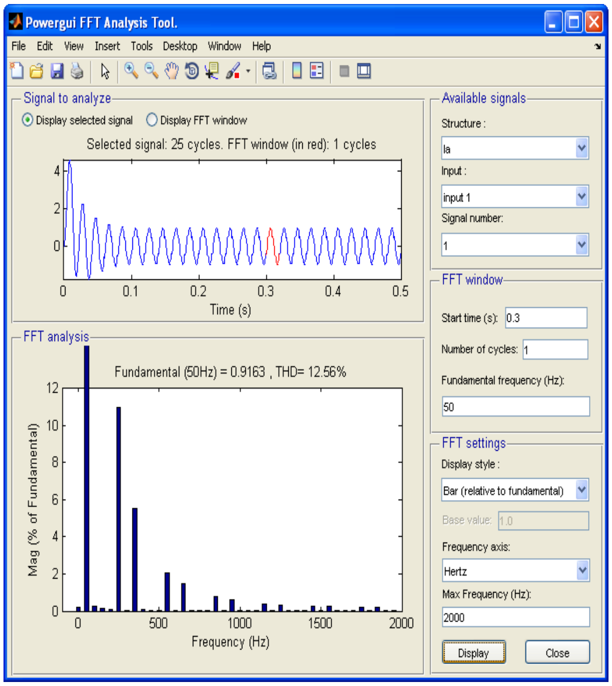


Fig.28 Load Current waveform with FLC controlled UPQC

In simulation studies, the results are specified before and after UPQC system are operated. In addition, when the UPQC system is operated, the load has changed and dynamic response of the system is tested. The proposed control method has been examined under non-ideal mains voltage and unbalanced load current conditions. The proposed control algorithm has considerably good simulation results as compared the PI control algorithms. The Source current THD, before compensation when UPQC not connected, source current THD is 12.56%, due to non linear RL load. Source current THD after compensation when UPQC connected at 0.5s and PI controller used, source current THD is reduced to 1.76%. But when PI controller replaced by the fuzzy logic controller, source current THD reduces to 1.06%. Therefore fuzzy controller proves to be more an advantageous. And Dynamic response this parameter is the measurement of how quickly controllers respond to the situation, in dynamic response shows the time taken by the controller to reduce THD from 12.56% to 1.06%. Hence it is proved that dynamic response of the FLC controller is faster than the PI controller.



Selected signal: 25 cycles. FFT window (in red): 1 cycles

Fundamental (50Hz) = 0.9163 , THD= 12.56%

Structure : Ia

Input : input 1

Signal number: 1

Start time (s): 0.3

Number of cycles: 1

Fundamental frequency (Hz): 50

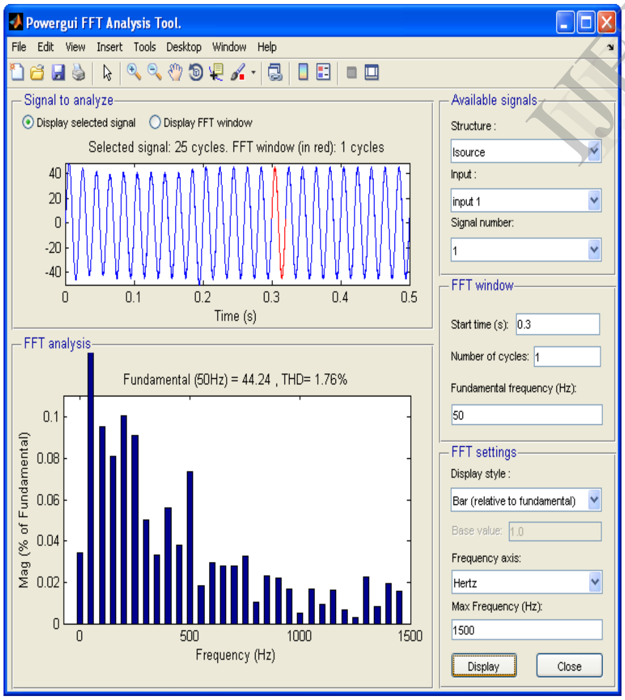
Display style : Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Hertz

Max Frequency (Hz): 2000

Fig.29 Total Harmonic Distortion of system without UPQC



Selected signal: 25 cycles. FFT window (in red): 1 cycles

Fundamental (50Hz) = 44.24 , THD= 1.76%

Structure : Isource

Input : input 1

Signal number: 1

Start time (s): 0.3

Number of cycles: 1

Fundamental frequency (Hz): 50

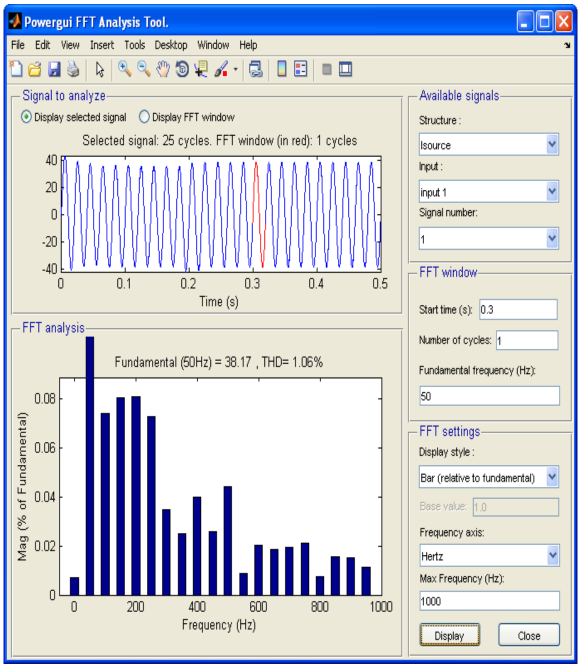
Display style : Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Hertz

Max Frequency (Hz): 1500

Fig.30 Total Harmonic Distortion of UPQC system with PI



Selected signal: 25 cycles. FFT window (in red): 1 cycles

Fundamental (50Hz) = 38.17 , THD= 1.06%

Structure : Isource

Input : input 1

Signal number: 1

Start time (s): 0.3

Number of cycles: 1

Fundamental frequency (Hz): 50

Display style : Bar (relative to fundamental)

Base value: 1.0

Frequency axis: Hertz

Max Frequency (Hz): 1000

Fig.31 Total Harmonic Distortion of UPQC system with FLC

6. Conclusion

In this proposed Unified Power Quality Conditioner (UPQC) is designed and simulated through synchronous reference frame theory with PI and Fuzzy logic controller. Simulation results show the proposed system. ability in voltage distortion, reactive power and current harmonics compensation. The instantaneous reactive power theory is used for shunt APF control algorithm by measuring mains voltage, currents and capacitor voltage. But the conventional methods require measurements of the load, source and filter voltages and currents. Meanwhile, the Series APF isolates the loads voltages and source voltage, the shunt APF provides three-phase balanced and rated currents for the loads. A suitable mathematical model of the UPQC has been developed with different shunt controllers (PI and FUZZY) and simulated results have been described which establishes the fact that in both the cases the compensation is done. Simulations are also conceded out to verify the performance of the proposed UPQC based fuzzy logic controller and compared with conventional PI controller and the results shown that the proposed UPQC based fuzzy logic controller has fast dynamic response and strong robustness to load parameters variation.

The operation of proposed system is analyzed using MATLAB/SIMULINK software. Simulation results confirm the correct operation of the proposed system.

References

[I]. C. Sankaran, Power Quality, Boca Raton: CRC Press, 2002, p. 202.

[2]. Alexander Kusko and Marc T.Thompson, “Power Quality in Electrical Systems”, McGraw Hill, 2007.

[3] V. Khadkikar, A. Chandra, "A New Control Philosophy for a Unified Power Quality Conditioner (UPQC) to Coordinate Load-Reactive Power Demand Between Shunt and Series Inverters, " IEEE Trans. on Power Delivery, vo1.23, no.4, pp. 2522-2534, 2008.

[4] G. M. Lee, D.C. Lee and 1. K. Seok, "Control of series active power filter compensating for source voltage unbalance and current harmonics, " IEEE Transaction on Industrial Electronics, vol. 51, no. I, pp. 132- 139, Feb. 2004

[5]. Y. Chen, X. Zha, and 1. Wang, "Unified power quality conditioner (UPQC): The theory, modeling and application, " Proc. Power System Technology Power Con Int. Corr!, vol. 3, pp. 1329-1333, 2000..

[6]Mariun N., A. Alam, S. Mahmod, H. Hizam, 2004. Review of Control Strategies for Power Quality Conditioners, Power and Energy Conference Proceedings, vol. 2, pp. 1515-1520.

[7] L. F. C. Monteiro, M. Aredes, and L. A. M. Neto, "A control strategy for unified power quality conditioner," in Proc. IEEE Int. Symp. Ind. Electron., Jun. 2003, vol. I, pp. 391-396.

[8]. H. Fujita, and H. Akagi, "The unified power quality conditioner: The integration of series and shunt-active filters, " IEEE Trans. Power Electron., vol. 13, no. 2, pp. 315-322, Mar. 1998.

[9]. M. Aredes, "A combined series and shunt active power filter, " in Proc. IEEE/KTH Stockholm Power Tech Conf., Stockholm, Sweden, pp. 18-22, June 1995.

[10]. H. Akagi, E. H. Watanabe and M. Aredes, Instantaneous Power Theory and Applications to Power Conditioning. WileyIEEE Press. April 2007.

[11]. M. Kesler Synchronous reference frame based application design and analysis of unified power quality conditioner, 2010

[13] Jain S. K., Agrawal P. and Gupta H. O., “Fuzzy logic controlled shunt active power filter for power quality improvement,” IEE Proc. Electr. Power Appl, vol. 149, no. 5, pp. 317-328, 2002.

[14] Singh G. K., Singh A. K. and Mitra R., “A simple fuzzy logic based robust active power filter for harmonics minimization under random load variation,” Elect. Power Syst. Res., vol. 77, 8, pp. 1101-1111, 2007.

[15] Singh B. N., Chandra A., Al-Haddad K. and Singh B., “Fuzzy control algorithm for universal active filter,” IEEE Conf. Proc. Power Quality, pp. 73-80, 1998.