



Power Quality Improvement in Three Phases four Wire System Using Pi and Fuzzy Logic Controller

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ABSTRACT: This paper present Power quality problem which is the most sensitive problem in the power system. The objective of the project is to reduce one of the power quality issue called “harmonics” using compensation technique. Shunt Active Power Filter (SAPF) is used to eliminate harmonic current and also it compensates reactive power. In this project, both PI controller and Fuzzy Logic Controller based three-phase shunt active filter is employed for a three-phase four wire systems. The advantage of fuzzy control is that it provides linguistic values such as low, medium, high that are useful in case where the probability of the event to occur is needed. It does not require an accurate mathematical model of the system. A MATLAB/SIMULINK has been used to perform the simulation. Simulink model is developed for three phase four wire system under balanced source condition and three phase three wire system for balanced load condition. The performance of Fuzzy Logic Controller and PI controller and their Simulink results is compared. Simulation results obtained shows that the performance of fuzzy controller is found to be better than PI controller.

Keywords: Fuzzy logic controller, PI controller, Shunt Active power filter, SRF method

1. Introduction

Modern semiconductor switching devices find a wide range of applications in distribution networks, particularly in domestic and industrial loads which are being utilized quite often. technique which is based on sensing the load current. A Scheme which is simple and easy to implement is proposed by modifying the above scheme and it works by sensing line Currents only. In the recent years, Fuzzy Logic Controllers (FLCs) have generated a good deal of interest in certain applications. The advantages of FLCs over conventional controllers are that they do not need an accurate mathematical model, they can handle non-linearity, they can work with imprecise inputs, and they are more robust than conventional nonlinear Controllers. Examples of such applications that are widely used are adjustable–speed motor drives, uninterruptible power supplies (UPSs), computers and their peripherals, consumer electronics appliances (TV sets for example), to name a few. Those power electronic devices offer economical and reliable solutions to control and manage the use of electric energy effectively. However, most of the power electronic circuits, exhibit nonlinear operational characteristics, which introduce Contamination to voltage and current waveforms at the point of common coupling in case of industrial loads.

An increase in such nonlinearity results in various undesirable features such as: increased harmonics in current from AC mains, low system efficiency and a poor power factor, cause disturbance to other consumers, interference in nearby communication networks, unexplained computer network failures, premature motor burnouts, etc. Therefore thermal trip devices (circuit breakers and fuses) could activate to remove the loads on that path from the lines. These are only a few of the damages that power quality problems may Bring into home and industrial installations. This may seem like minor quality problems but may bring whole factories to a standstill.

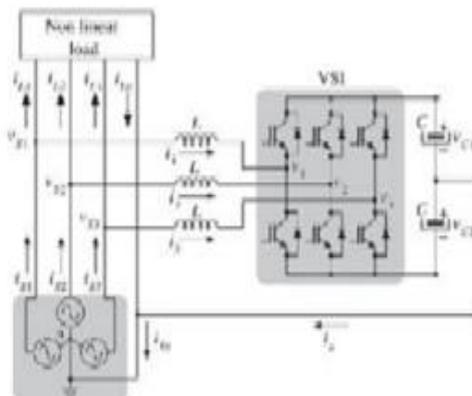


Fig 1: Structure of three phase four wire APF

The proposed work contains the three phase source connected to the diode bridge rectifier. The active filter is connected in parallel to load. The SAPF contains VSI connected in series with an inductor which acts as filter connected to the PCC. The inverter uses IGBT because of its high switching frequency. So inverter itself produces high frequency current with low state loss. The structure of SAPF for three phase four wire system is shown in Fig.1. The inverter circuit triggering depends on the control circuit output. The proposed system use PWM control to produce the pulse to trigger gate of IGBT. Instantaneous Synchronous reference frame (SRF) method is used in the proposed system to derive the compensating signal.

2. PROPOSED CONTROL STRATEGIES

2.1 (a) Phase Locked Loop (PLL)

The basic function of the PLL is a feedback system with a PI-regulator tracking the phase angle. Input is the three phases of the grid voltage and output from the PLL is the phase angle of one of the three phases. In the power supply substation there will be one inverter leg for each of the three phases. There are two alternatives, either assuming the grid voltages are in balance and track only one of the phases and then shift with 120 degrees for each of the other two phases or having three PLL system one for each phase. The main advantage of this method is best suitable for harmonic compensation with sinusoidal and non sinusoidal source voltage.

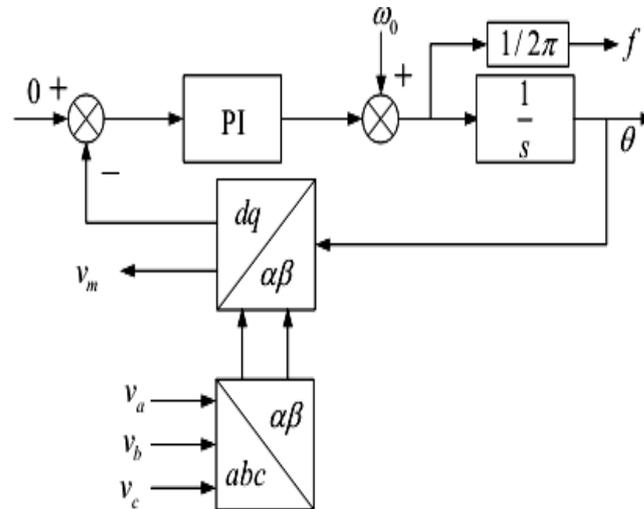


Fig.2. Block diagram of SF-PLL

2.1 (b) Synchronous Reference Theory

In this method only the currents magnitudes are transformed and the p-q formulation is only performed on the instantaneous active i_d and instantaneous reactive i_q components. If the d-axis has the same direction as the voltage space vector, then the zero-sequence component of the current remains invariant. Therefore, the i_d - i_q method can be expressed as follows given below

$$\begin{bmatrix} i_d \\ i_q \\ i_o \end{bmatrix} = \frac{1}{v_{\alpha\beta}} \begin{pmatrix} v_\alpha & v_\beta & 0 \\ -v_\beta & v_\alpha & 0 \\ 0 & 0 & v_{\alpha\beta} \end{pmatrix} \begin{bmatrix} i_{L\alpha} \\ i_{L\beta} \\ i_{L0} \end{bmatrix} \quad (1)$$

In this strategy, the source must deliver the constant term of the direct-axis component of the load (for harmonic compensation and power factor correction).

The reference source Current can be calculated as follows:

$$\left. \begin{aligned} i_{sd} &= \overline{i_{Ld}} \\ i_{sq} &= i_{so} = 0 \end{aligned} \right\} \quad (2)$$

$$i_{Ld} = \frac{v_\alpha i_{L\alpha} + v_\beta i_{L\beta}}{v_{\alpha\beta}} = \frac{P_{L\alpha\beta}}{\sqrt{v_\alpha^2 + v_\beta^2}} \quad (3)$$

The dc component of the above equation will be:

$$\overline{i_{Ld}} = \left(\frac{P_{L\alpha\beta}}{v_{\alpha\beta}} \right)_{dc} = \left(\frac{P_{L\alpha\beta}}{\sqrt{v_{\alpha}^2 + v_{\beta}^2}} \right)_{dc} \quad (4)$$

Where the subscript “dc” means the average value of the expression within the parentheses.

Since the reference source current must to be in phase with the voltage at the PCC it is calculated (in the α - β -0 coordinates) by multiplying the above equation by a unit vector in the direction of the PCC voltage space vector (excluding the zero-sequence component).

$$\overline{i_{sref}} = \overline{i_{Ld}} \frac{1}{v_{\alpha\beta}} \begin{bmatrix} v_{\alpha} \\ v_{\beta} \\ 0 \end{bmatrix} \quad (5)$$

$$\begin{bmatrix} i_{s\alpha ref} \\ i_{s\beta ref} \\ i_{s0 ref} \end{bmatrix} = \left(\frac{P_{L\alpha\beta}}{v_{\alpha\beta}} \right)_{dc} \frac{1}{v_{\alpha\beta}} \begin{bmatrix} v_{\alpha} \\ v_{\beta} \\ 0 \end{bmatrix} \quad (6)$$

$$\begin{bmatrix} i_{s\alpha ref} \\ i_{s\beta ref} \\ i_{s0 ref} \end{bmatrix} = \left(\frac{P_{L\alpha\beta}}{\sqrt{v_{\alpha}^2 + v_{\beta}^2}} \right)_{dc} \frac{1}{\sqrt{v_{\alpha}^2 + v_{\beta}^2}} \begin{bmatrix} v_{\alpha} \\ v_{\beta} \\ 0 \end{bmatrix} \quad (7)$$

2.2. PI CONTROLLER

The control scheme consists of a PI controller, a limiter, and a three phase sine wave generator for reference current and switching signal generation. The peak value of the reference currents is estimated by regulating the DC link voltage. The actual capacitor voltage is compared with a set reference value.

The error signal is then processed through a PI controller, which contributes to the zero steady error in tracking the reference current signal. The output of the PI controller is considered as the peak value of the supply current (I_{max}), which is composed of two components: (a) the fundamental active power component of the load current, and (b) the loss component of the APF; to maintain the average capacitor voltage at a constant value. The peak value of the current (I_{max}) so obtained, is multiplied by the unit sine vectors in phase with the respective source voltages to obtain the reference compensating currents. These estimated reference currents (I_{sa}^* , I_{sb}^* , and I_{sc}^*) and the sensed actual currents (I_{sa} , I_{sb} , and I_{sc}) are compared to a pwm, which gives the error signal for the modulation technique. This error signal decides the operation of the converter switches.

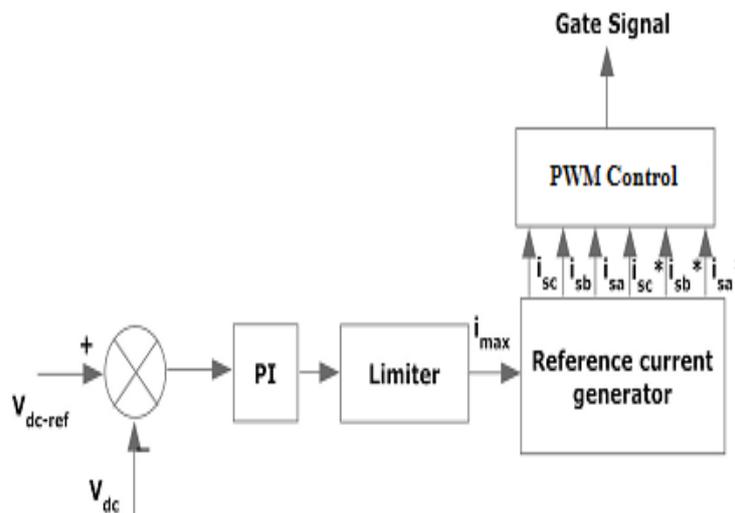


Fig.3 PI Controller

2.3 FUZZY LOGIC CONTROLLER

Fuzzy Logic Tools introduced in 1965 is a mathematical tool for predicting uncertainties. The FLC can provide linguistic components like low, high and medium. Fuzzy control system is very useful when the processes to be controlled are complex using the conventional controller. The conventional method of controlling involves more mathematical calculation and the traditional method best suits for crisp events that either occur or not occur. But for the event which includes uncertainties can be eliminated using FLC as it does not need accurate modeling. Fuzzy Logic Tool is based on relative graded membership function. These membership functions possess the degree of membership between the real values [0, 1]. The FLC system comprises mainly of four components the fuzzifier, the rule base, the inference engine and the defuzzifier.

2.3 (a) Fuzzification

The process of converting numerical variable to linguistic variable is done in fuzzification. Here seven triangular shaped membership functions are used and their linguistic variables are Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero Error (Z), Positive Small (PS), Positive Medium (PM) and Positive Big (PB). Each membership function is defined using three vertices {a,b,c} which represents the values corresponding to the left minimum, peak and right minimum of a triangle representing the membership function.

2.3 (b) Fuzzy Rule Base

The rule base store the linguistic control rule base need by rule evaluator. Large errors in transient state need coarse control and in small errors need fine control in steady state. Based on these elements, 49 rules of the rule table used in the paper are shown in Table I as in [1].

Table-1 Fuzzy Rules

e							
Ce	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

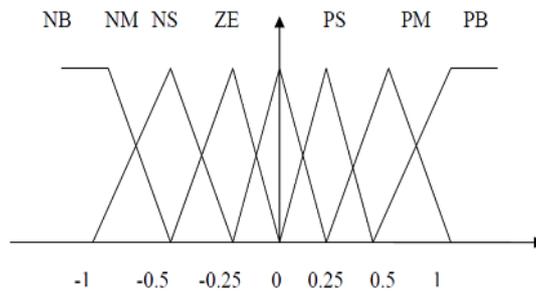


Fig.4 Membership function of fuzzifier input variables

2.3 (c) Inference Engine and Defuzzification:

To determine a specific or crisp value, the rule base has to be used with an inference method or engine followed by defuzzification. Mamdani’s fuzzy implication and max-min composition rule are used for inference. Centroid method is used for defuzzification. This fuzzy rule can be design based on experience.

Here the error (e) and change in error (Δe) are considered as input to FLC and the output of FLC is the control current I_{max} . This is the required active current needed to maintain the dc link voltage. This current is used as the part of the reference current ($I_{sa}^*, I_{sb}^*, I_{sc}^*$) to the current controller which controls the inverter to provide the required compensation current.

This estimated reference current ($I_{sa}^*, I_{sb}^*, I_{sc}^*$) and the actual sensed current (I_{sa}, I_{sb}, I_{sc}) are compared in the hysteresis current controller and the error signal controls the operation of the converter switches as in [10]. Each switch of the converter is controlled independently.

3. SIMULATION AND RESULTS

The Fig.5 and Fig.6 shows the simulation circuit of PI controller based shunt active power filter for harmonic reduction. In PI controller the value of error can be minimized by comparing it with the reference value. The reference value for the current is extracted by using the synchronous reference frame theory. The resultant waveforms of source voltage and current and the load voltage and current in the Figures 7 to 10. The THD value of load current using PI

controller is shown in the Fig.13. The simulation of fuzzy logic controller is shown in Fig.11 with its reference current extraction in Fig.12. THD value is given in Fig.14. From the THD analysis it is proved that FLC is better than the PI controller.

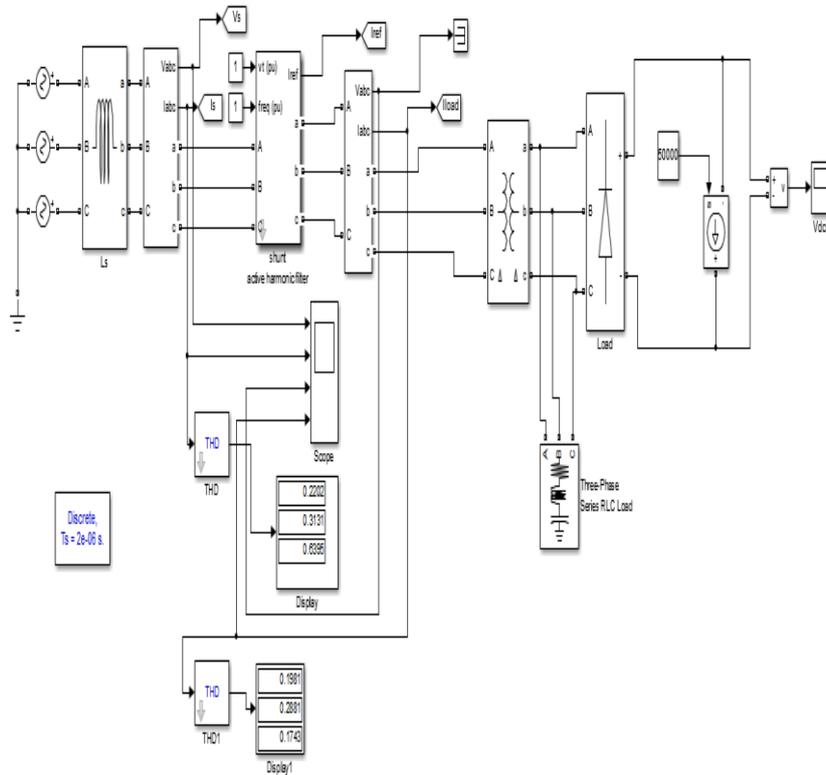


Fig.5 Simulation with PI controller

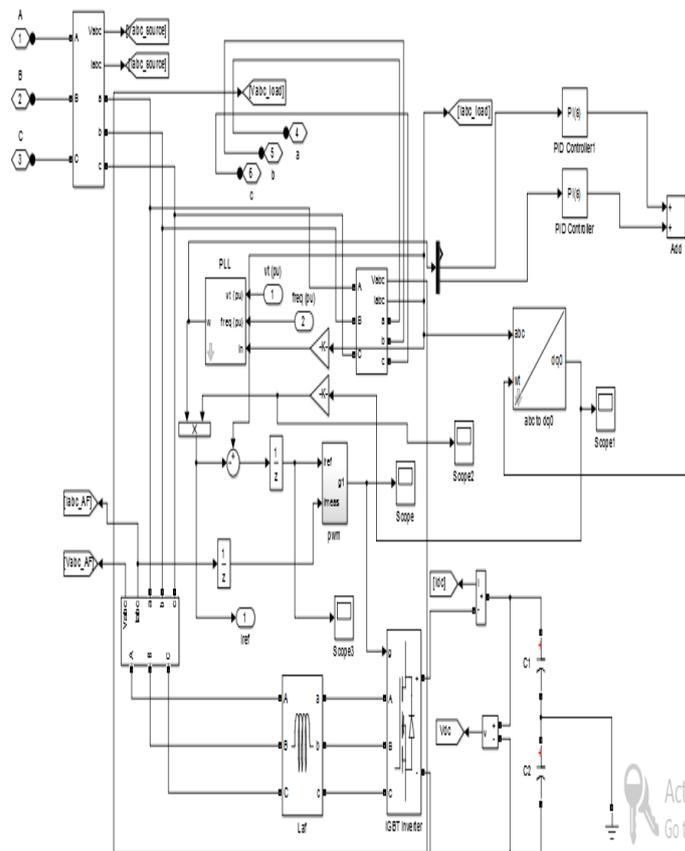


Fig.6 Simulation for reference current extraction with SRF method using PI controller

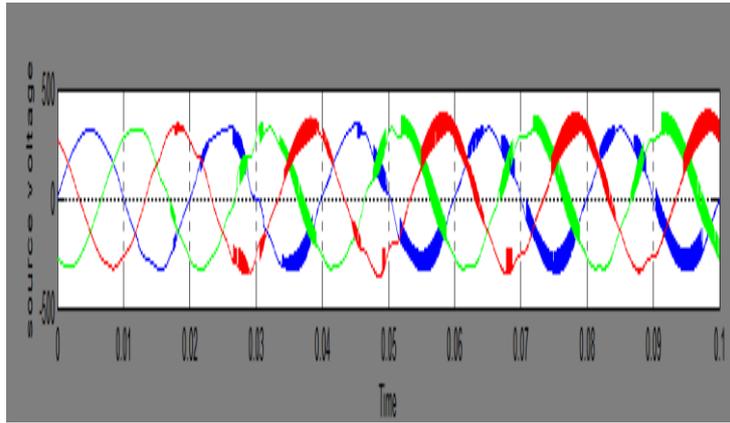


Fig.7 Source Voltage

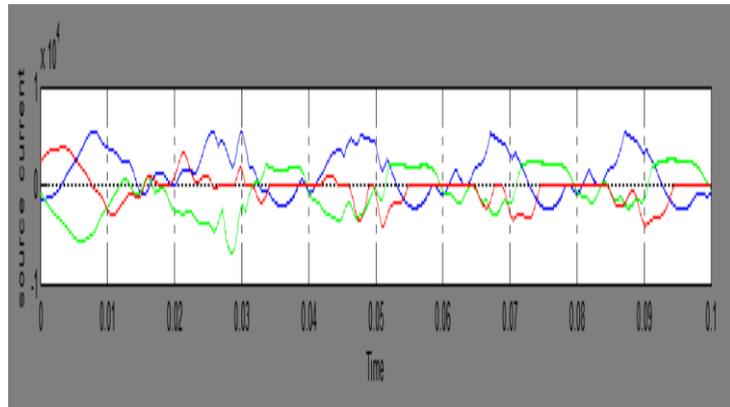


Fig.8 Source Current

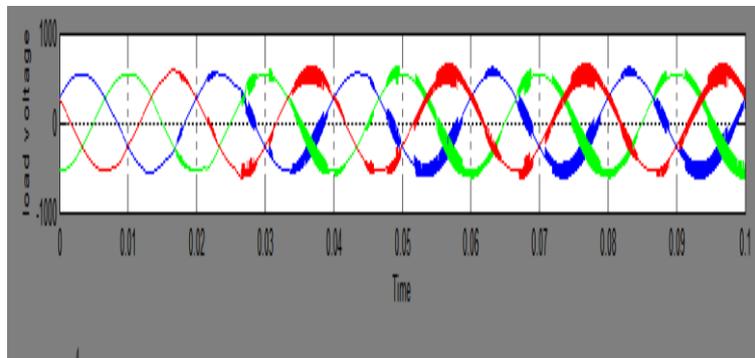


Fig.9 Load Voltage with PI controller

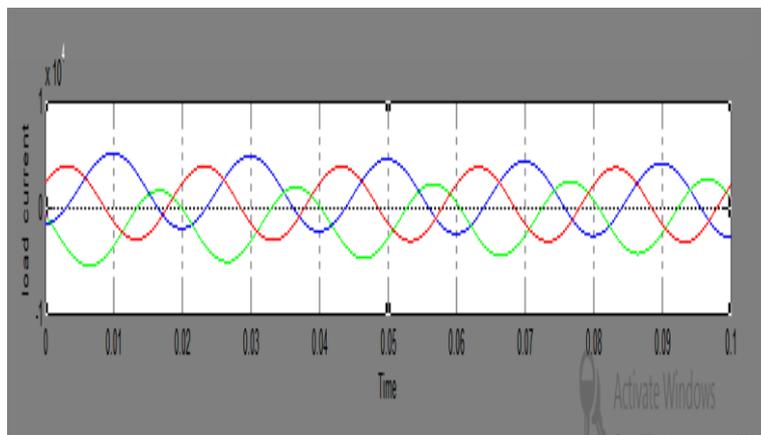


Fig.10 Load Current with PI controller

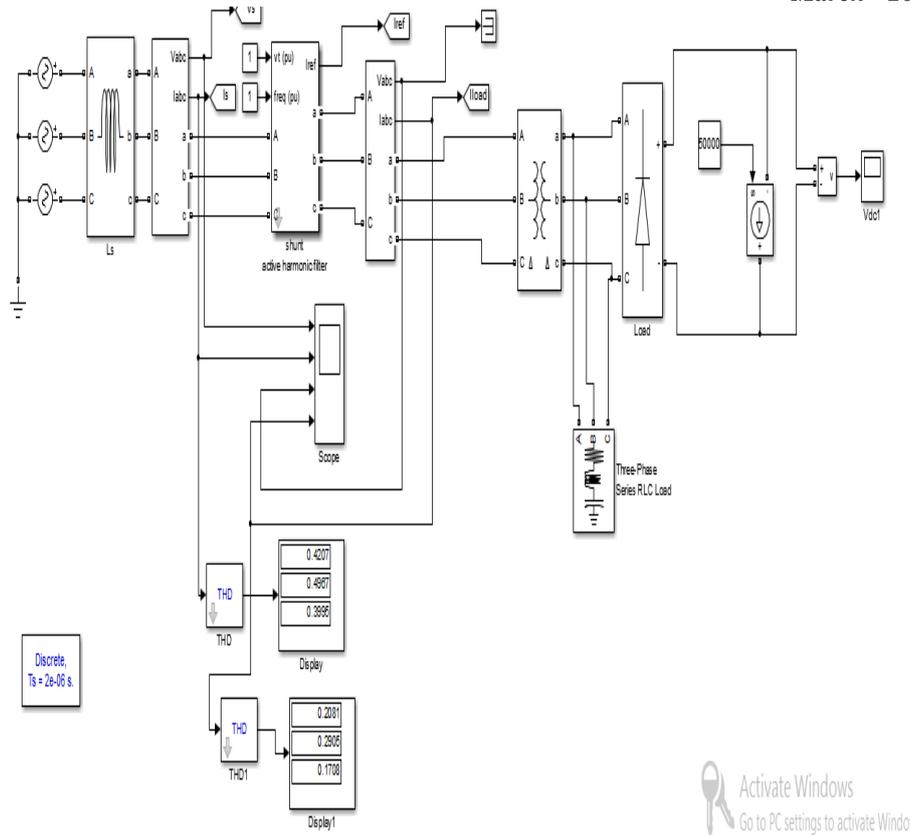


Fig.11 Simulation with Fuzzy Logic Controller

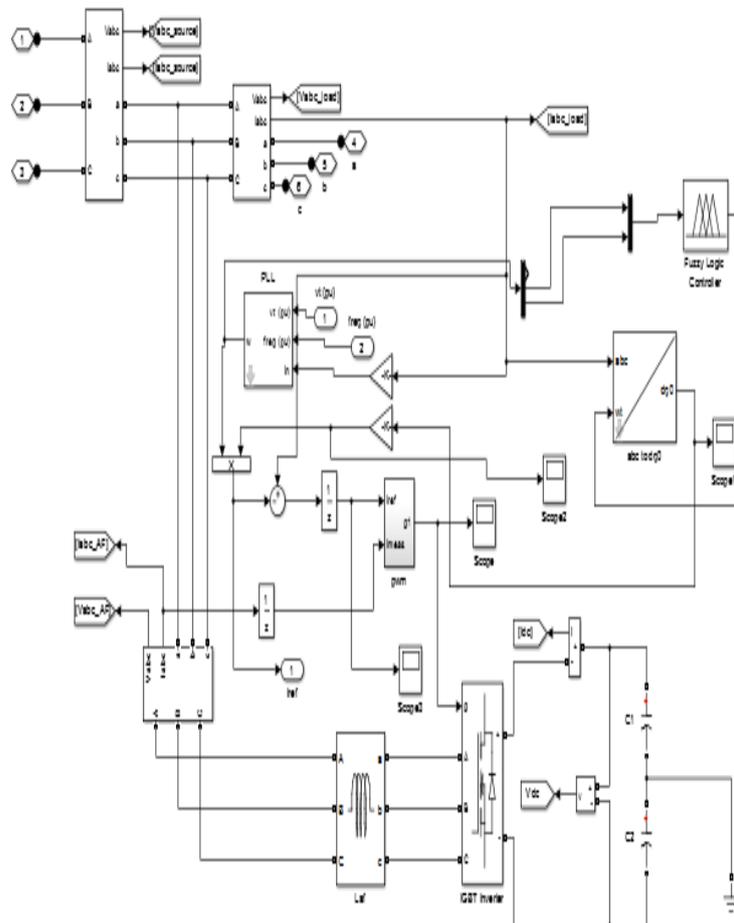


Fig.12 Reference current extractions with SRF Method using fuzzy logic controller

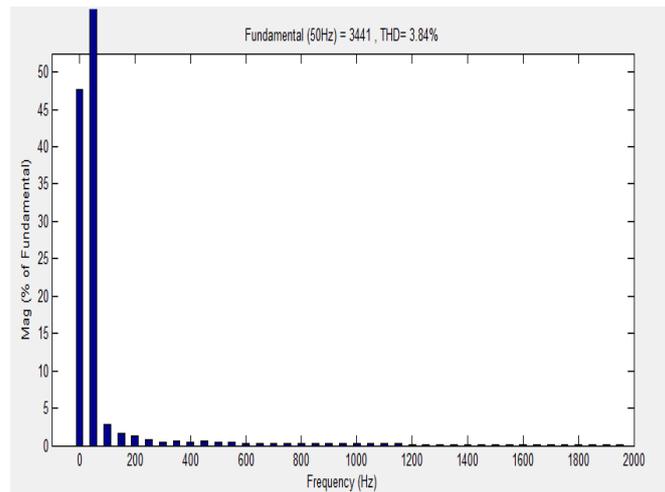


Fig.13 THD using PI controller

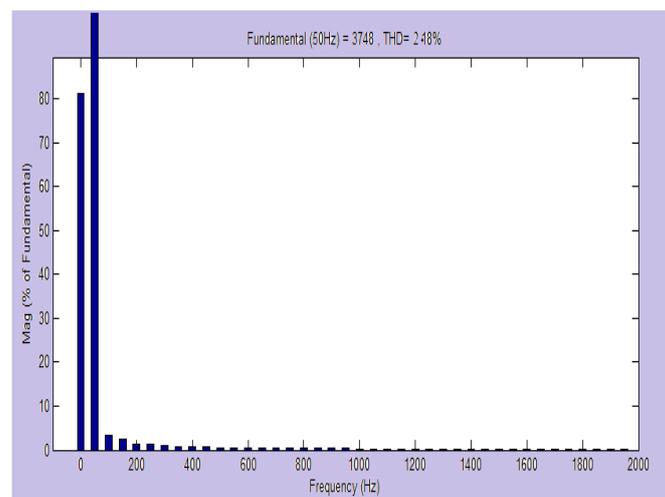


Fig.14 THD using Fuzzy Logic Controller

4. CONCLUSION

In the present paper two controllers are developed and verified for three phase four wire systems. Even though both of the presented controllers are capable of compensating current harmonics in 3 phase 4-wire systems, it can be seen that the Fuzzy Logic controller has a better dynamic performance than the conventional PI controller. PWM pattern generation based on carrier-less hysteresis current control is used for quick response. Additionally, in contrast to the different control strategies; the id-iq method is used for obtaining the reference currents in the system. This is due to the fact that the angle ' θ ' is calculated directly from the main voltage which enables an operation which is frequency independent. As a result, this technique avoids large number of synchronization problems. It can also be seen that the DC voltage regulation system is a stable and steady-state error free system. Thus with fuzzy logic and the (id-iq) approach, a novel shunt active filter can be developed. Simulation results are presented to validate the performance of the shunt active filter.

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