Available online at www.ijaeee.com & www.sestindia.org/volume-ijaeee ISSN: 2319-1112

Matlab Simulation of Single Phase Shunt Active Filter Based on PQ Theory

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ABSTRACT- **This paper presents the simulation of single phase shunt active filter based on PQ theory. Generally PQ theory is used for 3 phases 3 wires or 3 phases 4 wire system but here it is used for single phase system. This paper also concentrates hardly on reduction of THD of load current. Since the system has only single phase signal for both voltage and current, thus the dummy signal with 120 º different angels must be generated for input of the p-q theory. During simulation the six pulses will be generated for switching of IGBT but only two will be used. MATLAB/SIMULINK power system toolbox is used to simulate the proposed system.**

Keywords: Shunt active filter, THD (Total harmonic distortion), PQ Theory

I. INTRODUCTION

The tendency of connecting the Power Electronic loads and distributed power plants through the power Electronic converters are increasing day by day**.** These Power Electronic converters and Loads are the sources of harmonics and reactive power which greatly affect the performance of the power system network [1]. In a weak power grid, the voltage unbalance and non-sinusoidal regimes are very common. Under such circumstances not only the controllability of the power grid itself but also the controllability of the electronic connected to power system equipment's is heavily affected. So, power quality of the modern power grid (smart grid) is an important issue to address**.**

To overcome the problem of power quality, recent efforts have been made on active filtering. The active power filters have gained much more attention because of excellent performance to mitigate the harmonic and reactive power issues. But the performance of the active filters depends upon shunt active power filter with controller based on Instantaneous active and reactive power (p-q) theory has been purposed to verify its performance and ability to compensate the harmonics [3]. The advantage of p-q theory is that it is instantaneous and works in time domain. The shunt active power filter connected to AC distribution system in the presence of different shares of Power Electronic loads is investigated. It has been investigated through simulations that even under unbalanced and distorted conditions of AC distribution supply voltage and unbalanced loading, shunt active filter is able to mitigate the harmonics (THD) specified by power quality standards the control theory that is employed to formulate the control algorithm of the active filter**.**

Due to extreme use of power converters and other non-linear loads in industry it is observed that it deteriorates the power systems voltage and current waveforms. Static power converters such as single phase and three phase rectifiers, thyristor converters and large number of power electronic equipment are nonlinear loads which generate considerable disturbances in the ac mains. Mainly voltage harmonics and power distribution problems arise due to current harmonics produced by nonlinear load. As nonlinear currents flow through electrical system and the distribution-transmission lines, additional voltage distortion produce due to the impedance associated with the electrical network. The presence of harmonics in the power system cause greater power loss in distribution, interference problem in communication system and, sometimes result in operation failure of electronic equipment's which are more and more sensitive because it contains microelectronic controller systems, which work with very low energy levels. It is noted that non-sinusoidal current results in many problems for the utility power supply company, such as low power factor, low energy efficiency, electromagnetic interference (EMI), distortion of line voltage etc.

II. PRINCIPLE OF WORKING

The shunt-connected active power filter, with a self-controlled dc bus, has a topology similar to that of a static compensator (STATCOM) used for reactive power compensation in power transmission systems [8]. Shunt active power filters compensate load current harmonics by injecting equal- but opposite harmonic compensating current. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase- shifted by 180°. Fig1 shows the basic compensation principle of a shunt active power filter. It is controlled to draw/supply a compensating current I from / to the utility, so that it cancels current harmonics on the AC side, and makes the source current in phase with the source voltage. The load current waveform, the desired mains current and compensating current injected by the active filter are containing all the harmonic components to make mains current sinusoidal.

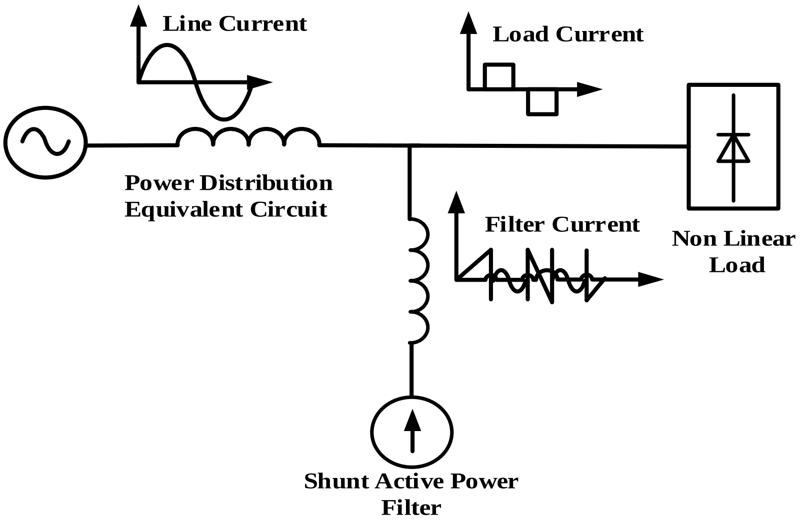

FIGURE 1 COMPENSATING PRINCIPLE OF SHUNT ACTIVE FILTER

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III. MATHEMATICAL MODEL

This method uses algebra transformation also known as Clarke transforms for three phase voltage and current. The three phase voltage and current are converted into α-β transformation. Although this theory using three current and three voltage signals, it also can be used for single phase active filter by duplicating two more current and voltage signal with 120ºangel shifting. This theory based on separation power component separation in mean and oscillating values. Consider load current of single phase load as phase "a "and others phase (phase "b" and phase "c") are generated by duplicating technique. The load current can be assumed as phase "a" current and with be expressed mathematically as shows in eq. (1). By assuming that eq. (1) as phase "a" load current, load current for phase "b" and c can be represented as eq. (2) and eq. (3)

$$i_a = \sum_{i=0}^{n} \sqrt{2} I_i \sin(w_i + \theta_i) \qquad (1)$$

$$i_b = \sum_{i=0}^{n} \sqrt{2} I_i \sin(w_i + \theta_i - 120^0) \qquad (2)$$

$$i_c = \sum_{i=0}^{n} \sqrt{2} I_i \sin(w_i + \theta_i + 120^0) \tag{3}$$

Equation (1), (2) and (3) can be transformed in matrix form as shown in (4) and (5) for load current and load voltage respectively:

$$\begin{pmatrix} i_a \\ i_b \\ i_c \end{pmatrix} = \begin{pmatrix} 1\angle 0^0 \\ 1\angle 120^o \\ 1\angle 240^0 \end{pmatrix} [i_a] \tag{4}$$

$$\begin{pmatrix} v_a \\ v_b \\ v_c \end{pmatrix} = \begin{pmatrix} 1\angle 0^0 \\ 1\angle 120^o \\ 1\angle 240^0 \end{pmatrix} [v_a] \tag{5}$$

Determine the α and β reference current by using Clarke transformation as shown in (6) for load current and in (7)for load voltage.

$$\begin{pmatrix} i_\alpha \\ i_\beta \\ i_o \end{pmatrix} = \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} i_a \\ i_b \\ i_c \end{pmatrix} \tag{6}$$

$$\begin{pmatrix} v_\alpha \\ v_\beta \\ v_o \end{pmatrix} = \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{pmatrix} \begin{pmatrix} v_a \\ v_b \\ v_c \end{pmatrix} \tag{7}$$

The active and reactive power is written as:

$$p = v_\alpha i_\alpha + v_\beta i_\beta + v_o i_o \tag{8}$$

$$q = v_\alpha i_\alpha - v_\beta i_\beta \tag{9}$$

$$\begin{pmatrix} p \\ q \end{pmatrix} = \begin{pmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{pmatrix} \begin{pmatrix} i_\alpha \\ i_\beta \end{pmatrix} \tag{10}$$

Active power and reactive power consist of two part which are mean part and oscillating part also known as DC part and AC part. The equations of active power and reactive power can be given as:

$$p = \overline{p} + \widehat{p} \tag{11}$$

$$q = \overline{q} + \widehat{q} \tag{12}$$

The DC part can be calculated by using low-pass filter, which is can remove the high frequency and give the fundamental component or the DC part. From DC part active power and reactive power, the α-β reference current can be represented in (13)

$$i_{\alpha\beta} = \frac{1}{v_\alpha + v_\beta}\begin{pmatrix} v_\alpha & v_\beta \\ v_\beta & -v_\alpha \end{pmatrix} \tag{13}$$

The three phase current reference of active power filter is given in (14) before the signal will subtracted to load current. The subtracted three phase current will be used to generate PWM signal using hysteresis band. Hysteresis band will produce six PWM signals and for single phase active filter it is only two are used as input

$$i^*_{abc} = \sqrt{\frac{2}{3}}\begin{pmatrix} 1 & 0 \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} \end{pmatrix} i_{\alpha\beta}\,* \tag{14}$$

The process for the calculation of the compensating current can also be represented by the flow chart as shown in figure2.Here Iac*,Ibc*and Ica*shows the compensating current in the a-b-c coordinates and Iαc and Iβc Shows the compensating current in αβ coordinates .

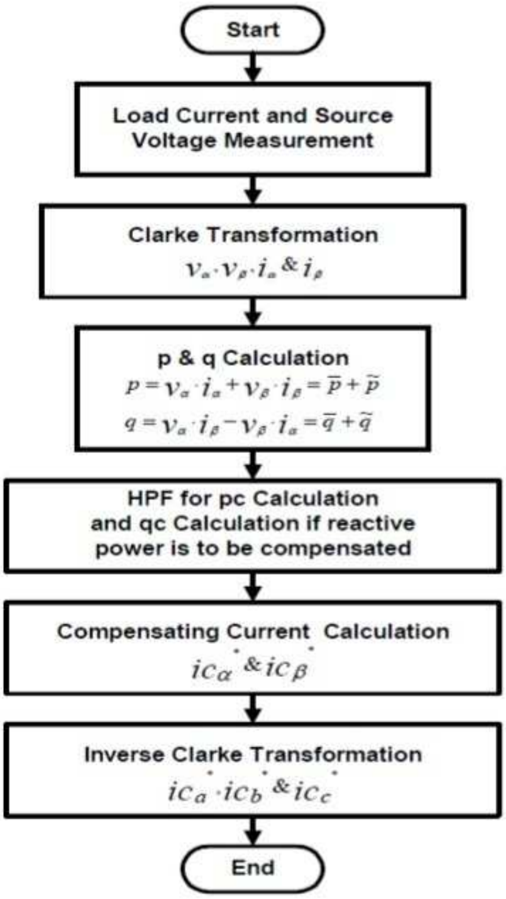


FIGURE2. FLOW CHART FOR THE CALCULATION OF COMPENSATING CURRENT

IV. SINGLE PHASE SHUNT ACTIVE FILTER

Figure 3 shows a system configuration of a single-phase or three-phase shunt active filter for harmonic-current filtering of a single-phase or three-phase diode rectifier with a capacitive dc load. This active filter is one of the most fundamental system configurations among various types of pure and hybrid active filters. The dc load may be considered as an ac motor driven by a voltage-source PWM inverter in many cases. This active filter with or without a transformer is connected in parallel with the harmonic-producing load. The active filter can be controlled on the basis of the following “feed forward” manner.

1. The controller detects the instantaneous load current
2. It extracts the harmonic current from the detected load current by means of digital signal processing.
3. The active filters draw the compensating current from the utility supply voltage so as to cancel out the harmonic current

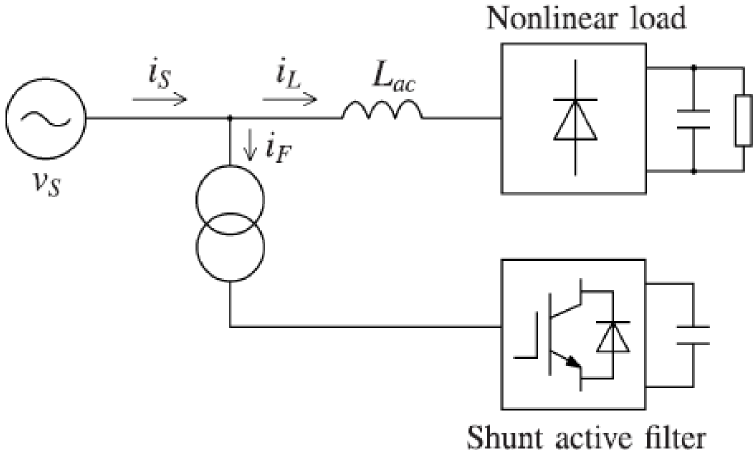


FIGURE 3 SINGLE PHASE SHUNT ACTIVE FILTER

The control strategy based on p-q theory that is used to generate PWM signal for single phase shunt active filter is shown with the help of block diagram in figure 4.

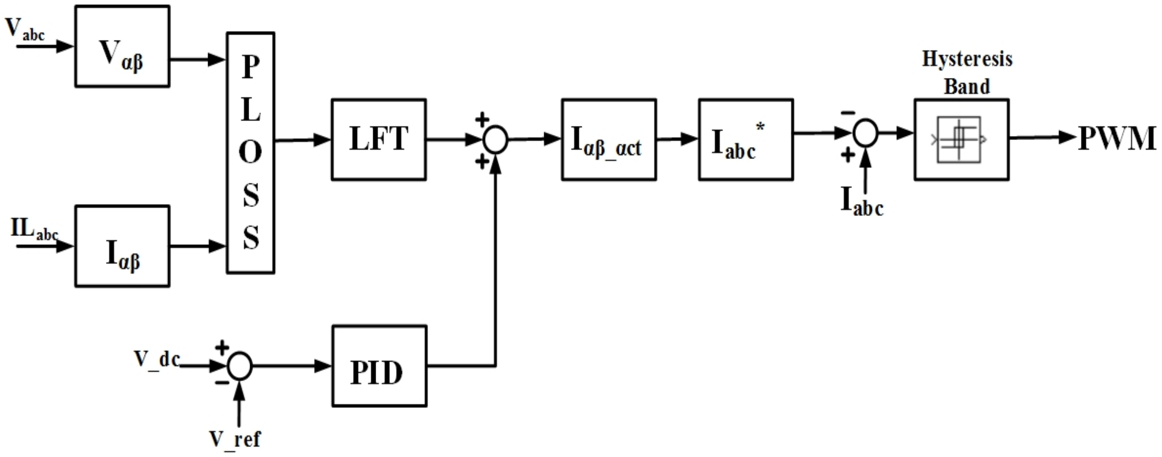


FIGURE 4 CONTROL STRATERY OF PQ THEORY

V. SIMULATION RESULT

A simulation of single phase shunt active filter is simulated using MATLAB/Simulink. The simulation use Single phase system 325V 50Hz directly from source as shows in Fig. 5

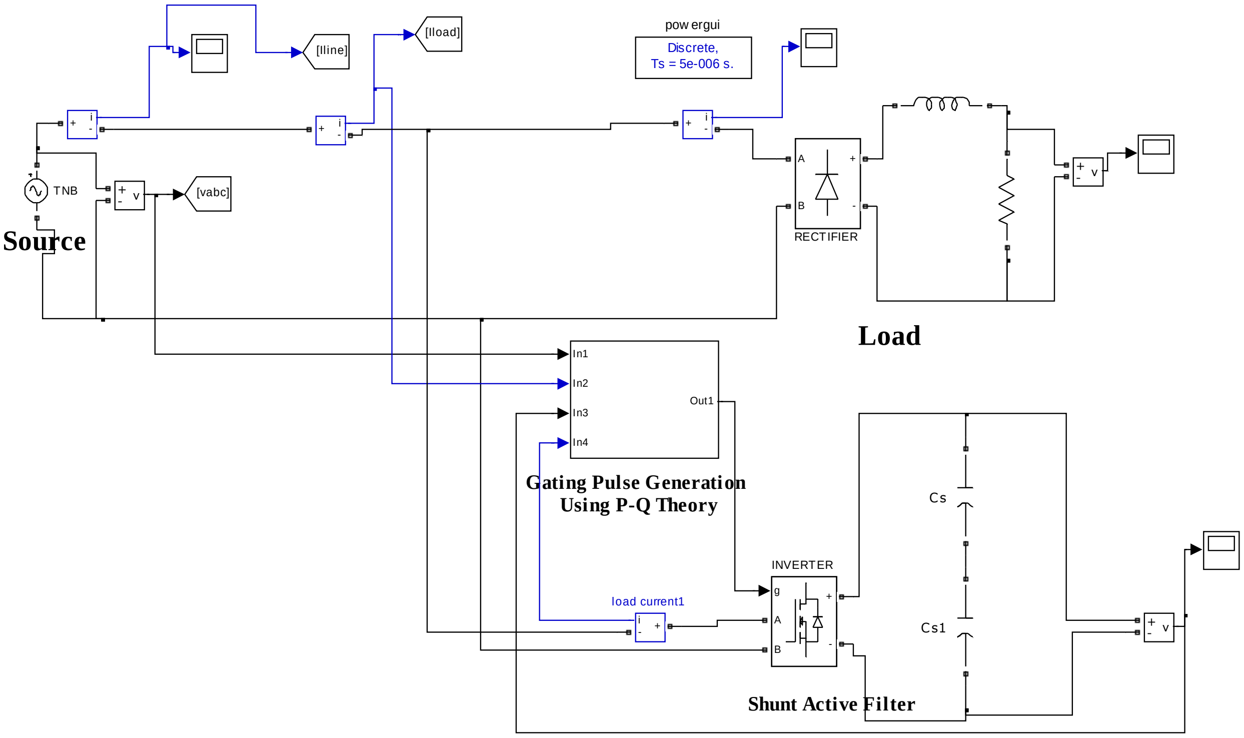


FIGURE 5 SIMULINK MODEL OF SHUNT ACTIVE FILTER

The modeling of p-q theory which consists of single to three phase block, algebra transformation of p-q theory three phase to two phase, two phase to three phase transformation and hysteresis band is shown in figure 6. Hysteresis band will produce six signals PWM and for single phase active filter only use two signals to control the single phase active filter.

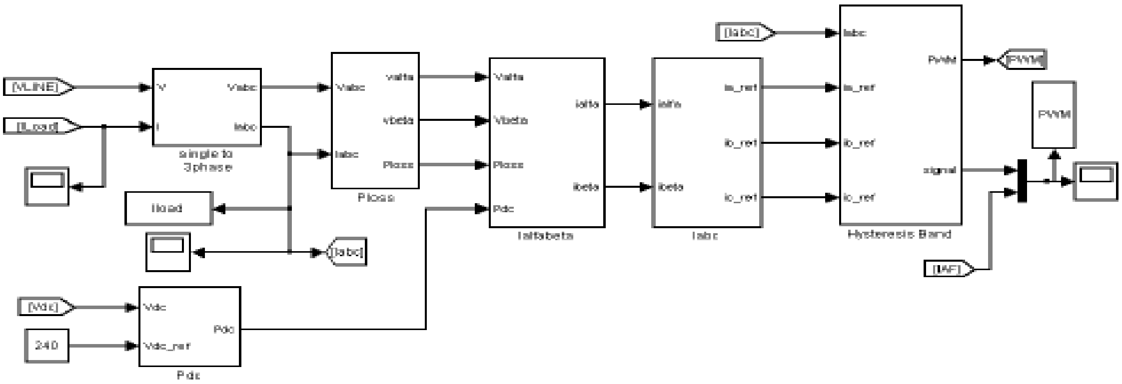


FIGURE 6 MODELLING OF PQ THEORY

Various waveform of line current, load current and shunt active filter are shown in figure 7(a), 7(b) & 7(c)

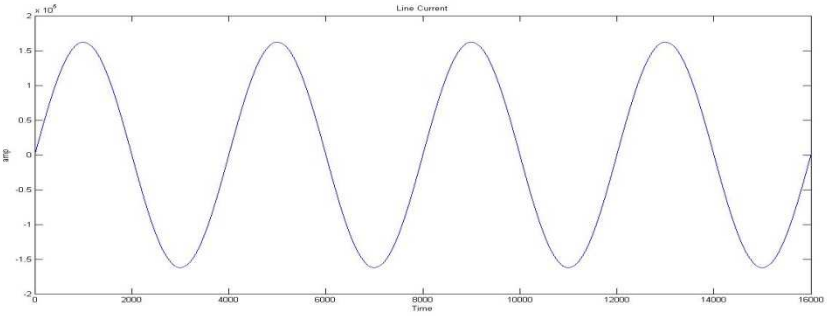


FIGURE 7(A) LINE CURRENT

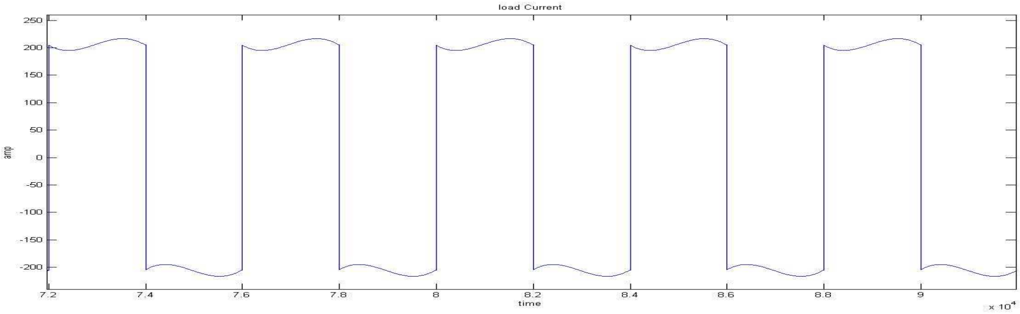


FIGURE 7(B) LOAD CURRENT

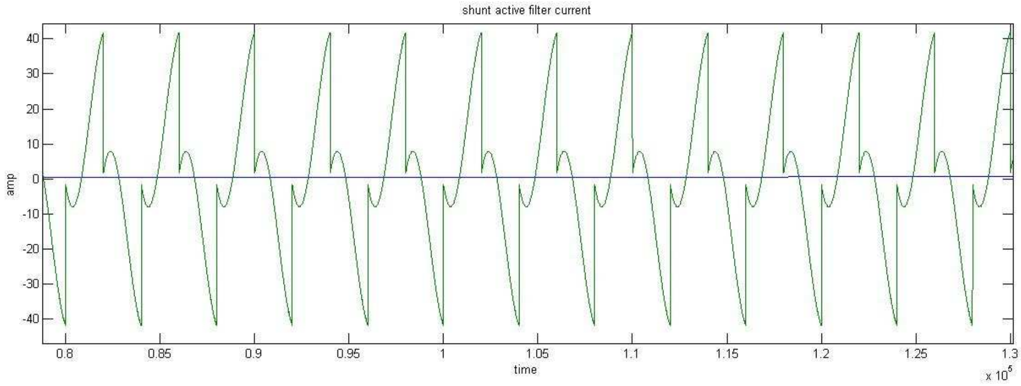
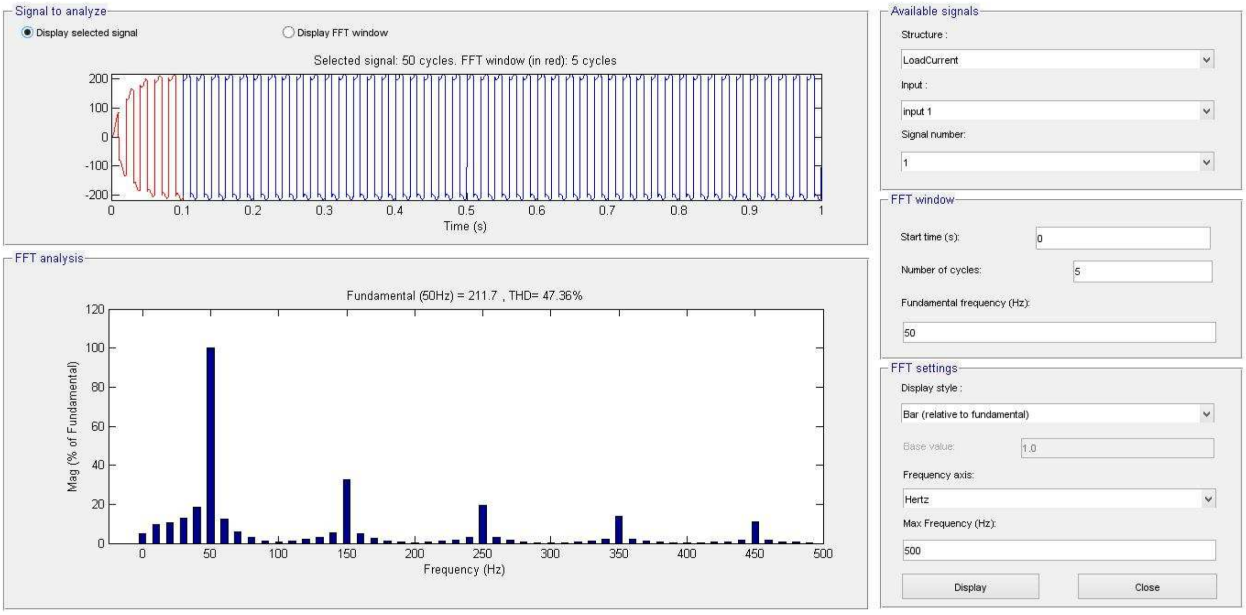


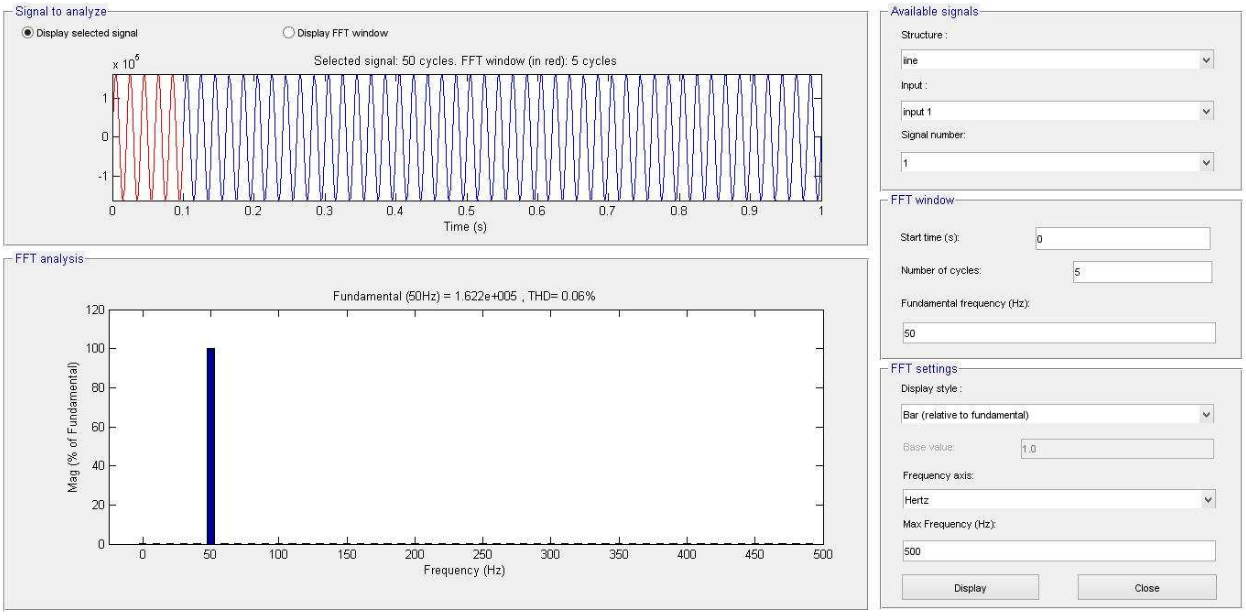
FIGURE 7(C) ACTIVE FILTER CURRENT

The effected non-linear load of the system will make the THD of load current increase up to 47.822% as shown in Fig. 8. By injecting the active filter current the THD offline current will reduce to 0.85% as shown in Fig 9



Structure : LoadCurrent
Input : input 1
Signal number: 1
Start time (s): 0
Number of cycles: 5
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz
Max Frequency (Hz): 500

FIGURE 8 THD OF LOAD CURRENT



Structure : iine
Input : input 1
Signal number: 1
Start time (s): 0
Number of cycles: 5
Fundamental frequency (Hz): 50
Display style : Bar (relative to fundamental)
Base value: 1.0
Frequency axis: Hertz
Max Frequency (Hz): 500

FIGURE 9 THD OF LINE CURRENT

VI.CONCLUSION

With the development of power electronics technology, people have paid more attentions to harmonics. Using active Power filter is an effective method to suppress harmonics. This paper has studied the simulation of single phase shunt active power filter. The design parameter is reasonable from the simulation results.This paper proves that pq theory can be implemented to control single phase active filter, which the theory widely used to control three phase active power filter. It is discovered from simulation that by implemented the p-q theory the THD of the load current can be reduced from 47.82% to 0.85%.

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