CHAPTER FOUR

SIMULATION OF THREE-PHASE ACTIVE FILTER FORHARMONICS REDUCTION

4.1 Introduction

The main requirement of any electric power system is the supply of electricity with a determined power quality and reliability to the minimum possible cost. Among the possible corrective actions active power filters are one of the most effective .Before taking any corrective action, it is necessary to evaluate the distortion introduced by the installation into the distribution network and the expected reduction when the active filter is in use. In this chapter, simulation has been proved to be a useful tool. It allows quantifying the harmonic distortion created by a system and, when a corrective action is introduced, simulation will show the reduction in the distortion. Besides, simulation can be used as a tool for the design of the active filter.

The work presented based on the simulation of active filters for reducing harmonic distortion created by industrial loads. Simulations have been carried out under the (MATLAB/SIMULATION) environment with system supplying nonlinear loads. In order to perform the harmonic analysis of the voltage and current signals present in the industrial systems, a Simulink FFT is used to plot the harmonics spectrum of the waveforms'.

4.2 System configuration

The AC voltage source supplies the nonlinear load is 4160V, 50Hz power supply connected as Y balanced configuration with neutral and a series inductance circuit (L=10μH).

The load which are simulated is nonlinear load . Containing three-phase uncontrolled diode rectifier supplying RL load. there are three phase transformer connected in series between load and source.

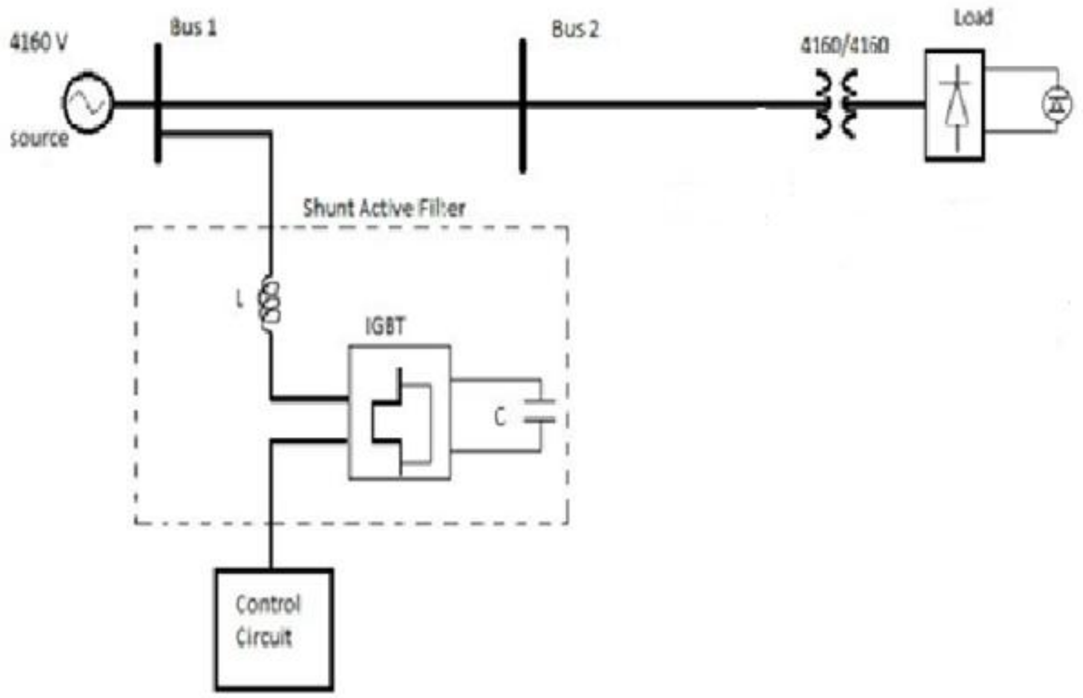

Figure 4.1: System Test Lay-out

4-3 Active Filter Control

- Dc Link Capacitor

It has two main functions, it keeps the constant DC voltage and storage device to provide real power difference between load and source during transient.

- PI Controller

Discrete pi controller is used. it takes the reference voltage and the actual voltage and the output it gives is the maximum value of the reference current depending on the error got from the reference and the actual values. It eliminates the steady state error DC component.

- Hysteresis current controller.
- Three phase (IGBT) transistor.
- Phase locked loops (PLL).

A common technique used for determining the phase of a Sinusoidal signal (or a phasor). Generally, a PLL is a circuit synchronizing it output signal with a reference or input signal in frequency as well as in phase. In the synchronized state, the phase error between the system output signal and the reference signal is zero, or it remains constant.

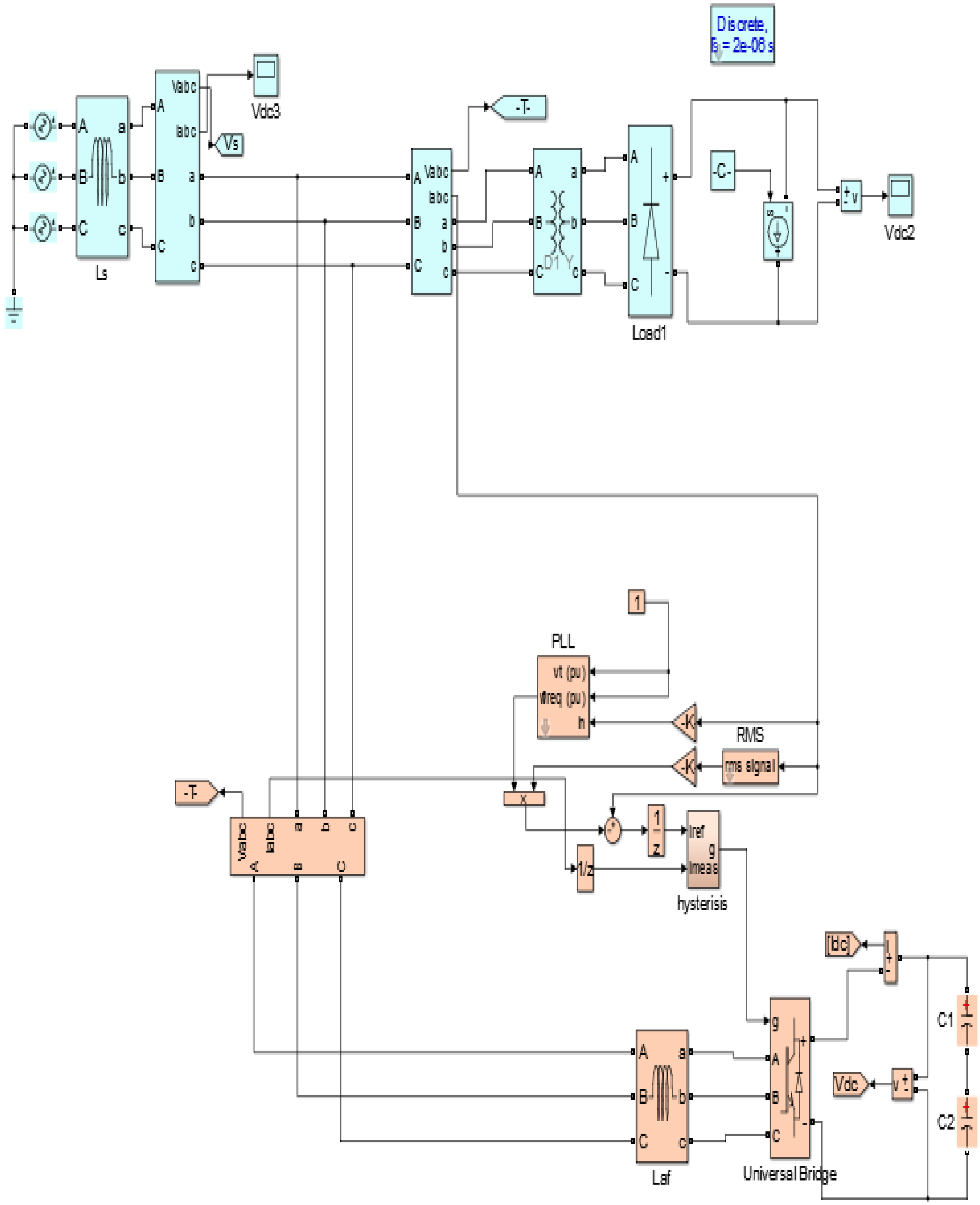

Figure 4.2: The control circuit of the active filter

4.4 Hysteresis current controller

Hysteresis current control is one of the most appropriate PWM switching methods to produce reference current in APFs. Hysteresis current control has desirable characteristics such as high stability, fast and accurate dynamic behavior. On the other hand, conventional hysteresis method includes some undesirable results, such as variable switching frequency that causes audio noises, high switching losses and injection of high-frequency current components to the source current that makes it difficult to design suitable filters to remove these high-frequency harmonics.

The hysteresis band current controller for active power filter can be carried out to generate the switching pattern of the inverter. There are various current control methods proposed for such active power filter configurations, but in terms of quick current controllability and easy implementation hysteresis current control method has the highest rate among other current control methods. The two-level PWM-voltage source inverter systems of the hysteresis current controller are utilized independently for each phase. Each current controller directly generates the switching signal of the three phases. In the case of positive input current, if the error current e(t) between the desired reference current $I_{ref}(t)$ and the actual source current $I_{actual(t)}$ exceeds the upper hysteresis band limit (+h), the upper switch of the inverter arm is become OFF and the lower switch is become ON as shown in the Figure.

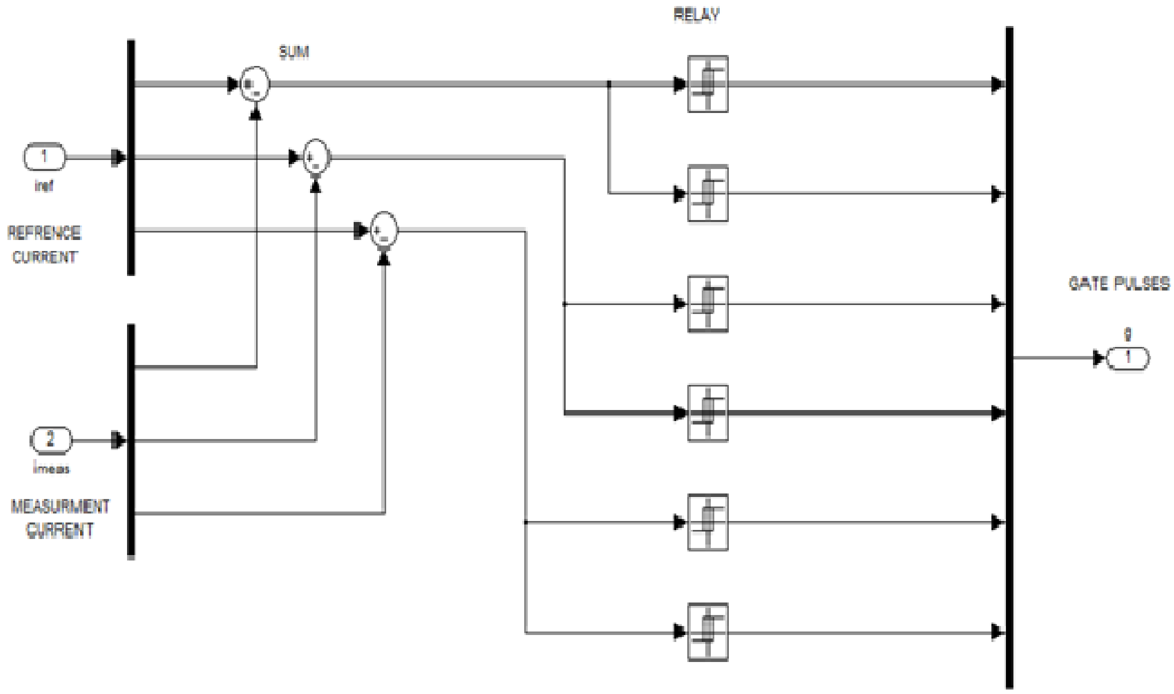

Figure 4.3: hysteresis current controller

4.5 Three phase (IGBT) transistor

An inverter is a circuit which converts a DC power into an AC power at desired output voltage and frequency. The AC output voltage could be fixed or variable voltage and frequency. This conversion can be achieved either by controlled turn on and turnoff devices (e.g. BJT, MOSFET, **IGBT**, and MCT etc.) or by forced commutated thyristors, depending on application. The output voltage waveform of an ideal inverter should be sinusoidal. The voltage waveforms of practical inverter are however, non-sinusoidal and contain certain harmonics. Square wave or quasi-square wave voltage maybe acceptable for low and medium power application and for high power application low distorted, sinusoidal waveform are required. The output frequency of an inverter is determined by the rate at which the semiconductor devices are switched on and off by the inverter control circuitry and consequently, an adjustable frequency AC output is readily provided. The harmonics content of output voltage can be minimized or reduced significantly by switching technique of variable high speed power semiconductor devices.

Pulse-width modulation (PWM) is the basis for control in power electronics. The theoretically zero rise and fall time of an ideal PWM waveform represents a preferred way of driving modern semiconductor power devices. With the exception of some resonant converters, the vast majority of power electronic circuits are controlled by PWM signals of various forms.

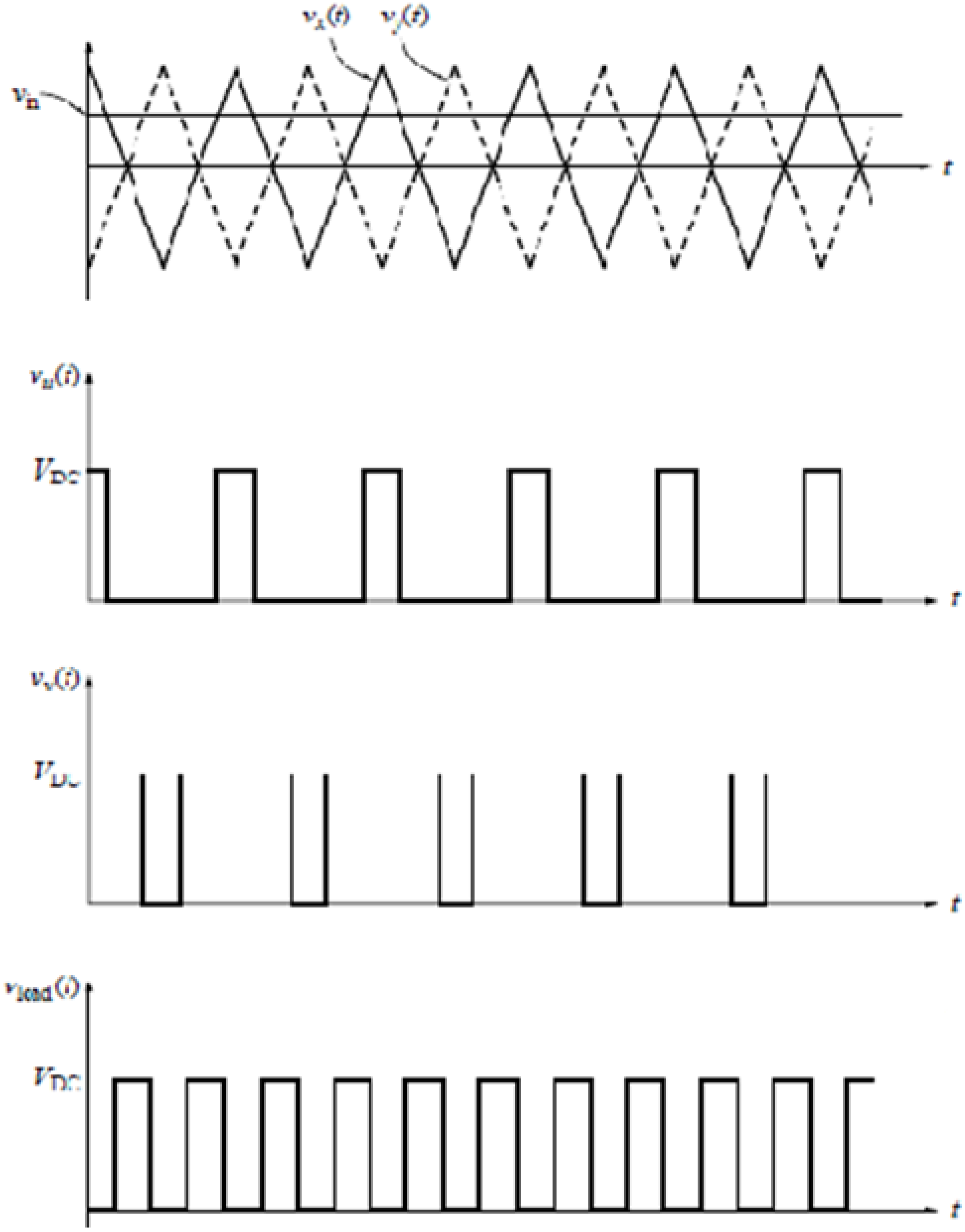

Figure 4.4: PWM signals

4.6 Control of Active filter by PWM:

To control the shunt active filter a PWM logic controller is developed. The difference between the injected current and the reference current determine the modulation wave of the reference voltage. This voltage is compared with two carrying triangular identical waves shifted one from other by a half period of chopping and generate switching pulses.

Shunt active power filters are normally implemented with pulse-width modulated voltage source inverters. In this type of applications, the PWM-VSI operates as a current controlled voltage source. Traditionally, tow level PWM-VSI have been used to implement such system. However, in the past years multilevel PWM voltage source inverters have been proposed to develop active power filters for medium voltage applications. Also, active power filters implemented with multiple VSI connected in parallel to a dc bus but in series through a transformer or in cascade has been proposed in the technical literature.

The use of VSI connected in cascade is an interesting alternative to compensate high power non-linear load. The use of two PWM-VSI of different rated power allows the use of different switching frequencies, reducing switching stresses and commutation losses in the overall compensation system. In recent years, there has been an increasing interest in using multilevel inverters for high power energy conversion, especially for drives and reactive power compensation. Multilevel PWM inverters can be connected to high voltage source without a coupling transformer. The use of neutral-point-clamped (NPC) inverters allows equal voltage shearing of the series connected devices in each phase. However, the neutral point potential deviates, resulting in an excess voltage stress to either the upper or lower set of devices. Basically, multilevel inverters have been developed for applications in high voltage ac motor drives and static-var compensation. For these types of applications, the output voltage of the multilevel inverter must be able to generate an almost sinusoidal output current. In order to generate a near sinusoidal output current, the output voltage should not contain low frequency harmonic components. For active power filter applications the three levels NPC inverter output voltage must be able to generate an output current that follows the respective reference current which contain the harmonic and reactive component required by the load. The power circuit topology of an active power filter implemented with a Neutral-Point-Clamped voltage-source inverter is shown in Figure 4.5. The three levels NPC voltage-source inverter is connected in parallel through a link reactor to the power distribution system.

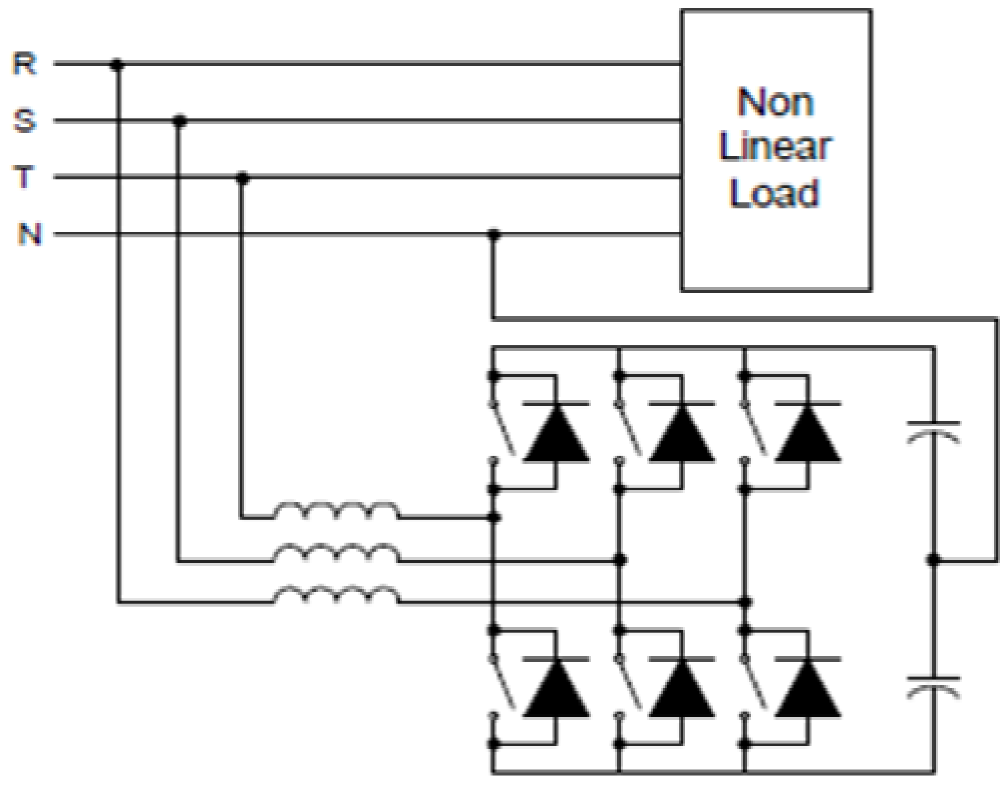

Figure 4.5: PWM- VSI as Active Power Filter

4.7 Simulation & Results

CASE (1): System without filter:

In this case the system supply anon-linear load and simulation time is 0.2 sec ,the result was shown below, the THD is 20.43%

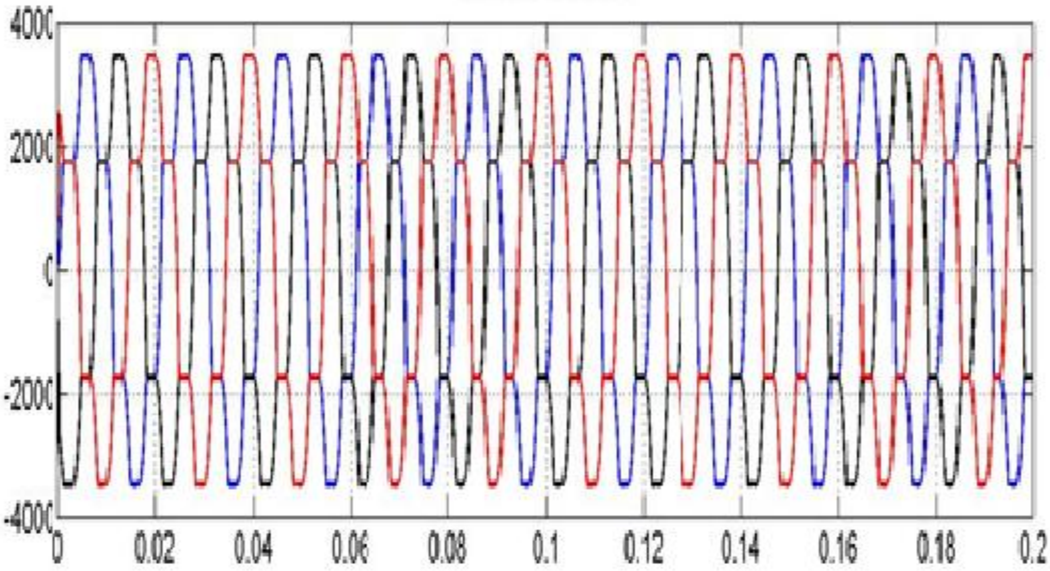

Figure 4.6: Source current without filtering

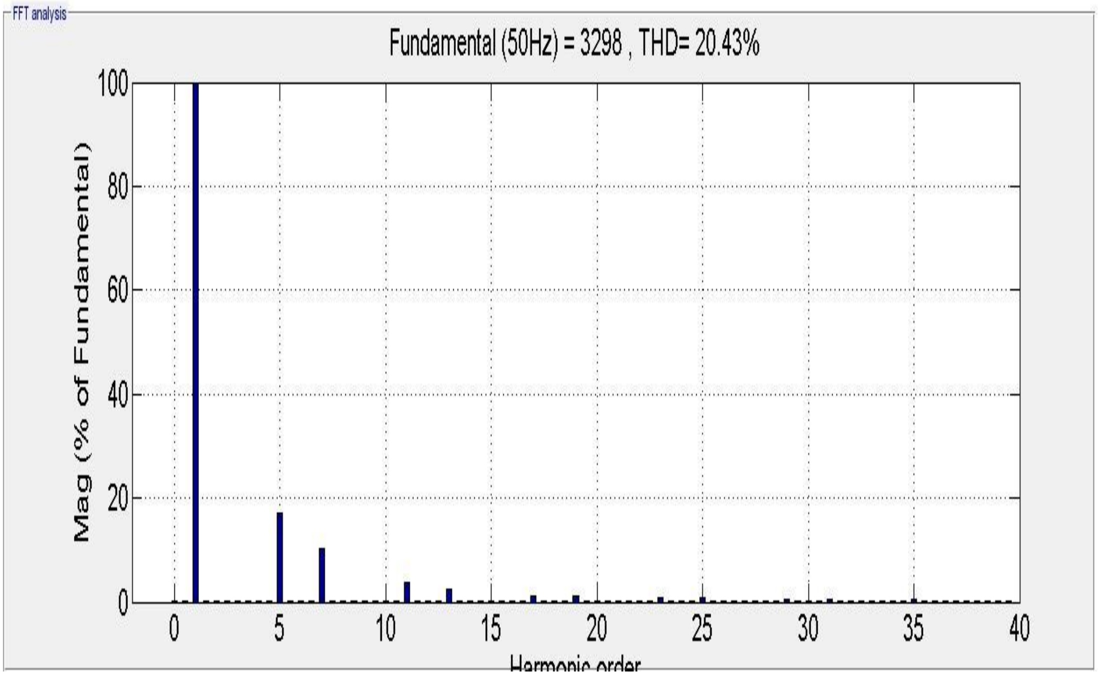

Figure 4.7: THD spectrum without filtering

CASE (2): System with passive Filter

In this case the passive filter is connected in parallel to the distribution supply, the simulation time is 0.2 sec, the result was shown below, the THD reduced to 2.19%

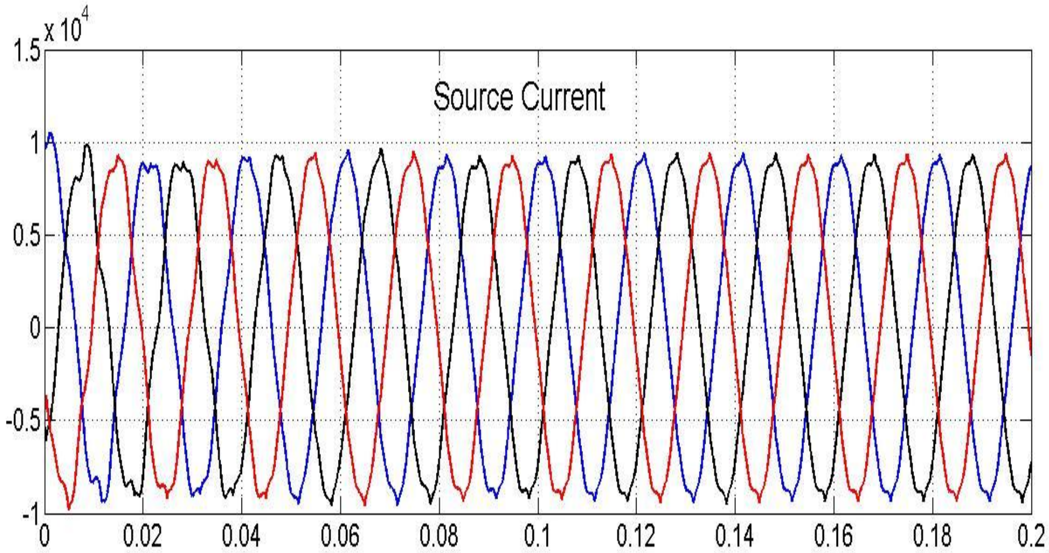

Figure 4.8: Source Current when passive filter is connected

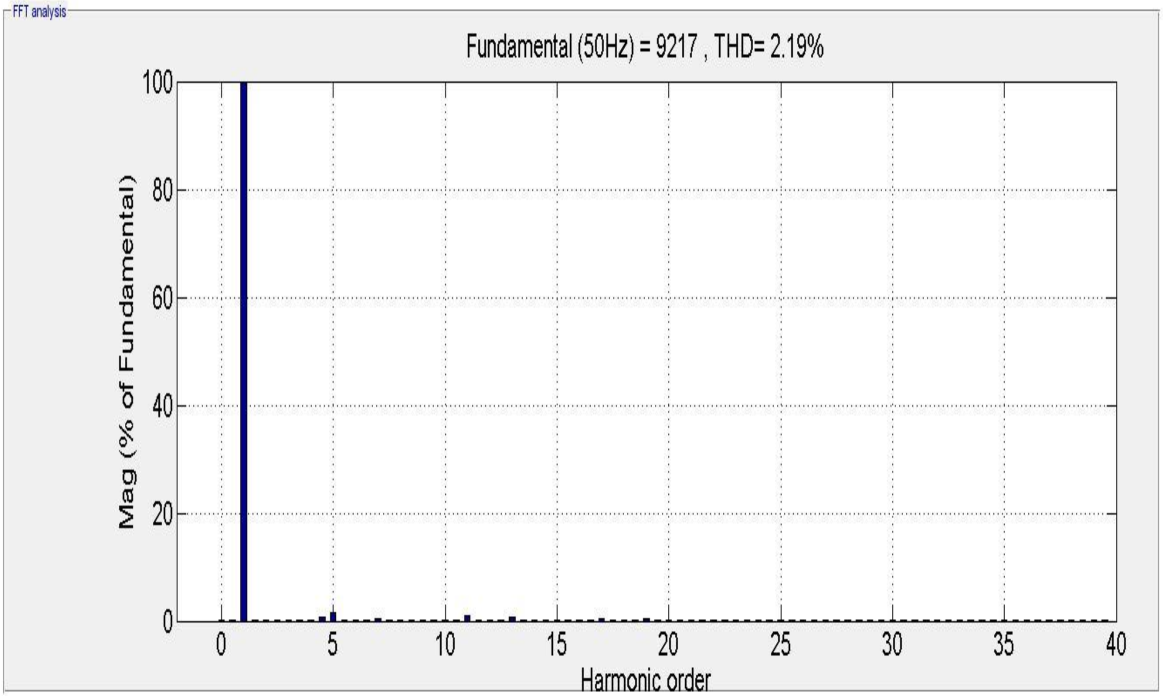

Figure 4.9: THD spectrum with passive filter connected

CASE (3): System with Active filter

In this case the Active filter is connected in parallel to the distribution supply, the simulation time is 0.2 sec, the result was shown below, the THD reduced to 0.49%

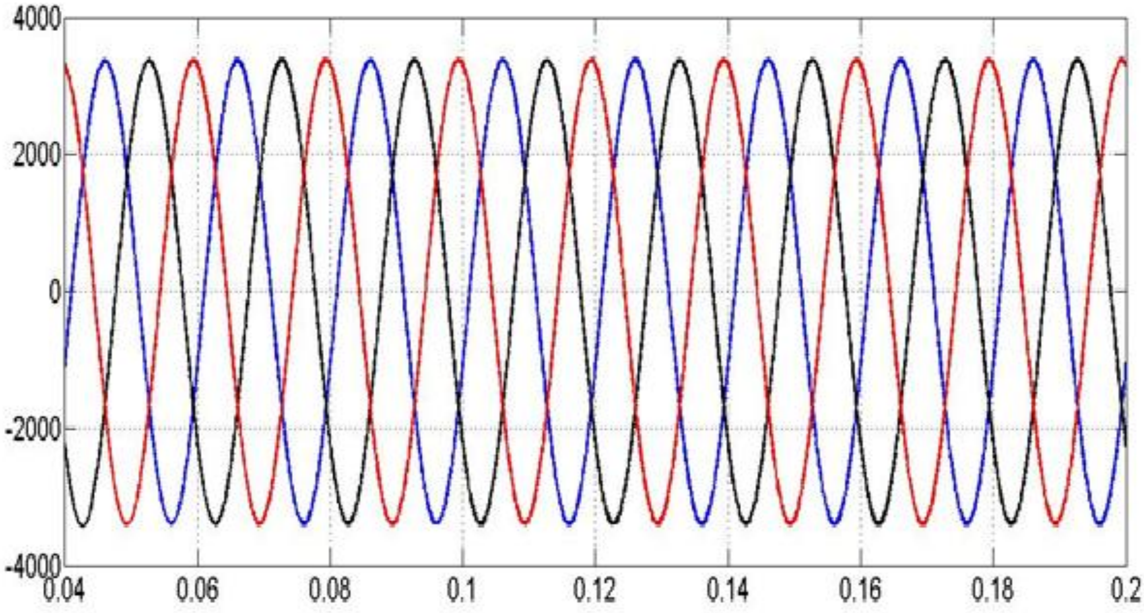

Figure 4.10: Source current when Active filter is connected

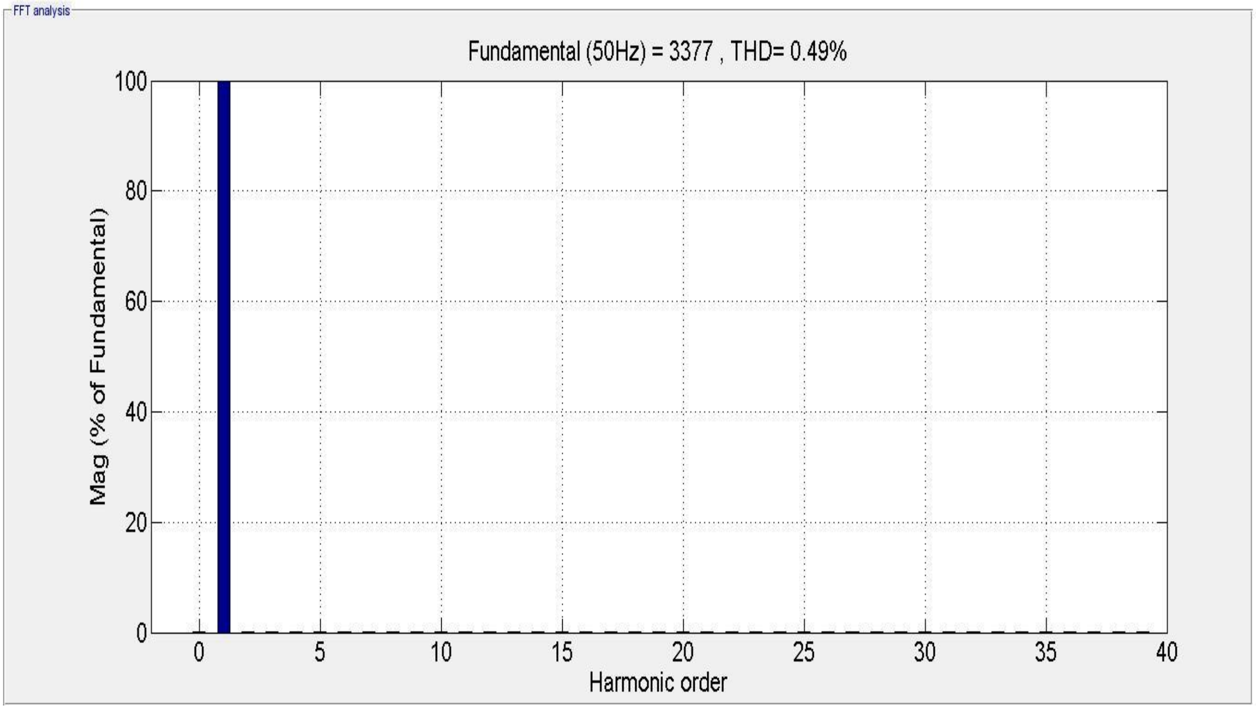

Figure 4.11: THD spectrum with active filter