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Three Phase Active Shunt Power Filter with Simple Control in PSIM Simulation

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Abstract
Generally the electrical system used by many consumer and industry usually uses passive filter and capacitor bank to compensate, harmonics and reactive power absorbed by the loads .The passive filter and capacitor bank make harmonic resonance with input impedance so that magnitude of harmonic current increased with harmonic frequency generated by nonlinear load. In this paper a simple active filter with PSIM simulation model used, the reference current generated by simple method of power synchronous detection and gate pulses generated by the use of modulated hysteresis current controller. The proposed model compensates current harmonics, and it does power factor correction. The active filter designed in PSIM software and control of active filter is done in Simulink environment. PSIM and MATLAB software is linked by Sim coupler. The capacitor voltage is maintained constant by using PI controller. Simulation results with PSIM software shows that the designed active filter is very effective in harmonic elimination and power factor correction
Keywords: : Active filter, Modulated Hysteresis current control, power synchronous detection (PSD),current harmonics, Pulse Width Modulation, , PSIM software

1. Introduction

Maintaining good quality of Power is one of the research area in power distribution systems due to the significant increase of harmonic pollution, caused by the nonlinear loads such as Fluorescent lamps and phase-angle controlled lamp dimmers; the dc power supplies of any electronic product, whether linear or switch-mode; Three phase power converters; Arc welding electric furnace furnaces, electrolytic processes, and other industrial applications. Harmonic currents, reactive power and unbalanced currents in power distribution systems cause serious problems, such as increase of line losses, transformer overheating, machine vibration and malfunction of sensitive equipment. Active power filters (APF) have been considered as an effective solution for power quality improvement. [1].In literature different topologies applied to compensate the harmonics such as filtering like passive, active, and hybrid with shunt, series for two-wire single phase, three-wire three-phase and four-wire three-phase systems [2].

As well known, the parallel active filters are controlled to generate in real time the harmonic currents produced by the non-linear loads [3]. The performances of an active filter mainly depend on the reference current generation strategy. Active filter is superior than passive filter because of the following observation such as, design of the active filters is almost independent of power system parameters. No lengthy tuning effort is required in the design of active filters, which is usual in the case of passive filters. Possibility of resonance with system impedance is excluded in the active filter. [4].Several papers studied and compared the performances of filter with different reference current generation technique. Generally the reference current generation technique is classified in to two major classifications that is frequency domain method and time domain method. In this frequency domain method Fourier transform, DFT, FFT, RDFT are used for extracting harmonic component from polluted voltage and current signals. There are many types available Time domain method such as P-Q theory, Instantaneous reactive power theory, Synchronous reference frame theory ,P-Q-R theory, among all models power synchronous detection is simplest one for calculation and it reduce the complexity for calculation of extraction of current harmonics. [5].In this paper power synchronous detection (PSD) method is used for reference current generation and modulated hysteresis current controller is used for gate pulse generation. The principle of APF is injects a current equal in magnitude but in phase opposition to harmonic current.Fig.1shows the active filter principle.

2.Configuration of shunt active filter system

According to configuration the Active filter classified into Series, shunt, hybrid active filter .Among all configuration shunt active filter is superior for reduction of current harmonics present in the system[8].Fig. 2 presents the shunt active filter topology based on a three phase voltage source inverter, using IGBT switches, connected in parallel with the AC three-phase three-wire system through three inductors *LF*. The capacitor C is used in the DC side to smooth the DC terminal voltage. The non-linear load is a three-phase diode rectifier supplying a RL load. This load generates harmonic currents in the supply system.

3. Control strategy

The first part of control strategy has reference current generation. The second part is the current control of the power converter. The controller generates the suited switching pattern to drive the IGBTs of the inverter.

3.1. Reference current Generation

The critical problem of Shunt active filter is to find the methodology to pick accurate harmonic current. There are many algorithms in time domain and frequency domain, generally frequency domain algorithm requires large computational delay compare to time domain. However traditional controllers in time include many disadvantages such as fixed compensation, bulkiness, and electromagnetic interference, possible resonance etc. So need to develop adjustable and dynamic solutions using compensator. The best one is power synchronous detection (PSD) method for reference current generation. It requires lesser number of sensor count and computational delay. The algorithm is explained in the following Fig.3.1.For Analysis three phase three wire system is considered and the load used as single phase, three phase diode bridge rectifier with RL, RC load. The main part of the APF system is the IGBT based Voltage Source Inverter (VSI). A dc capacitor is used to deliver power for the VSI. For the good operation of APF, capacitor voltage should be at least 150% of maximum Line-line supply voltage.PSD method is basically used to find out the amplitude of the source currents. The real power P (t) consumed by the load could be calculated from the instantaneous Voltage and load current. The input voltage and load current is measured by voltage and current sensor in the input and output side. The input side voltage v_{sa}, v_{sb}, $v_{sc}$is measured by voltage sensor and load current I_{la}, I_{lb}, $I_{lc}$is measured by current sensor.

$$p(t) = [v_{ab}(t)\ v_{bc}(t)\ v_{ca}(t)] \begin{bmatrix} I_{la}(t) \\ I_{lb}(t) \\ I_{lc}(t) \end{bmatrix} \quad (1)$$

Whereas $v_{sa}(t)$, $v_{sb}(t)$, vsc(t) are the instantaneous Values of supply voltages and $I_{la}(t)$, $I_{lb}(t)$, $I_{lc}(t)$are the instantaneous values of load currents.The average value Pdc is determined by applying P(t) to a low pass filter. The real power in the three phases is calculated by the formula is:

$$ica(t) = isa(t) - ila(t) \quad (2)$$

$$P_a = P_b = P_c = \frac{Pdc}{3} \quad (3)$$

$$i_{sa}(t) = \frac{2\ \ Vsa(t)\ Pa}{(Vsma)^2} \quad (4)$$

$$i_{sb}(t) = \frac{2\ Vs\ b(t)\ Pb}{(Vsmb)^2} \quad (5)$$

$$i_{sc}(t) = \frac{2\ Vsc(t)\ Pc}{(Vsmc)^2} \quad (6)$$

The control system of above method is explained in the following Fig.3

3.2. Control scheme of shunt Active Power Filter

Linear current controller with pulse width modulation technique having constant switching frequency but its dynamic property is limited. Compared with other controllers, non-linear based on hysteresis strategies allows faster dynamic response and better robustness with respect to the variation of the non-linear load [6]. Nevertheless, with non-linear current controllers, the switching frequency is not constant and this technique generates a large side harmonics band around the switching frequency. Number of solution is there, to control switching frequency; one among them is using a variable hysteresis bandwidth [6]. Here, we implemented a non-linear current controller, i.e modulated hysteresis current controller [7].

The carrier frequency is chosen equal to the desired switching frequency for the voltage inverter. The resulting signal (*H*) constitutes then the new reference of a classical hysteresis controller with a bandwidth of 2*Bh*. The outputs of the hysteresis block are the switching pattern. Fig 3.2 shows the hysteresis current controller. To control the active filter at fixed switching frequency, the triangular signal amplitude $A_{tr}$and the hysteresis bandwidth $B_h$for the modulated hysteresis current controller must be carefully selected.[9]

4.Simulation results

The active filter model is designed in PSIM, but proposed algorithm is simulated using Mat lab and its tools Power System Blocks et and Simulink. The PSIM model and Simulink environment is coupled with Sim coupler in Matlab library browser. Simulation results are obtained under with APF and without APF.The Simulation Diagram is shown Fig.4.1,4.2.The essential parameter selected for simulation study are given in the Table.1
The proposed control algorithm was simulated with and without active filter and THD value are also shown in Fig 4.3 to 4.11

5. conclusion

This paper presents simple control method of Active filter with power Synchronous detection topology for reference current generation and modulated hysteresis for gate pulse generation to compensate current harmonics and power factor correction The proper operation of the presented topology and control algorithms is validated trough computer simulation results, developed with PSIM 9.1 software package. The performance of AF in steady state condition is evaluated using FFT simulation with and without active filter. The control algorithm is developed in Simulink and active filter model developed in PSIM package. Both software packages are connected through sim coupler. The presented results show a good performance of the developed shunt active filter working in steady state conditions. The next step of this work is to construct a test workbench to assess the prototype in different control strategy, and also to evaluate the behavior of the active power filter in transient conditions with unbalanced and non-stiff supply and load conditions.

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4.1 Table of Power system parameters.

System Frequency	*50 Hz*
System Voltage	$380V_{max}$
System Resistance R_s	25 ohm
System Inductor : L_s	0.3mH
Load side Resistance R_l	10 ohm
Load side Inductor : L_l	0.1mH
Filter side Resistance R_f	20 ohm
Filter side Inductor : L_f	0.1mH
Load Resistance (single phase)R_d	50 ohm

Load Inductor(single phase) : L_d	40 mH
Load Resistance (Three phase) : R_d	100 ohms
Load Capacitor (Three phase) : L_d	100µF

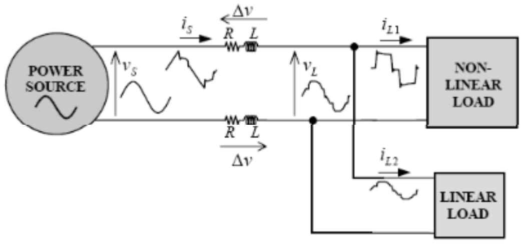

Fig.1 Principle of Active filter

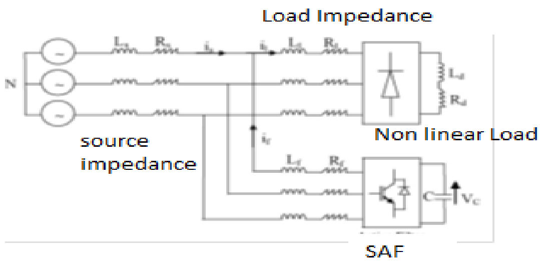

Fig.2.1Block Diagram of Three Phase APF with nonlinear Load.

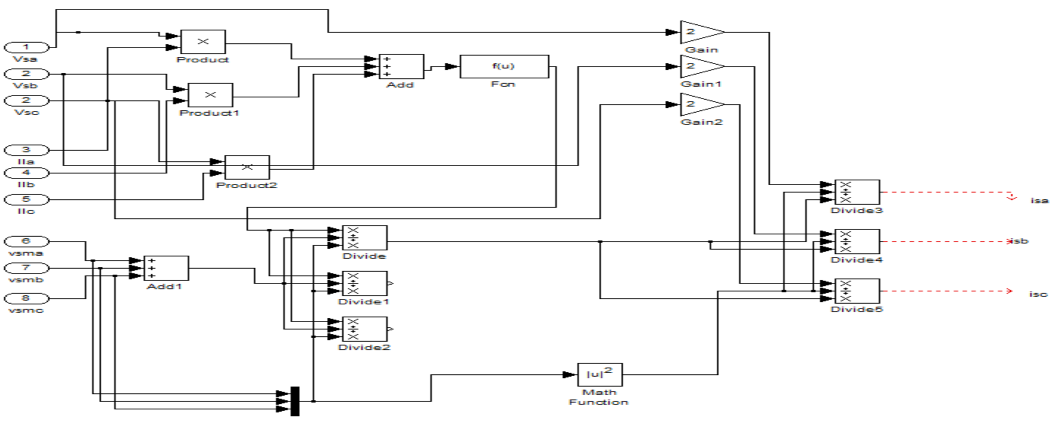

Fig.3.1 control system reference current generation

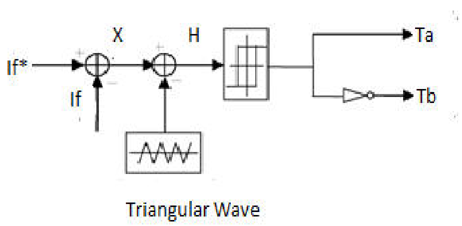

Fig.3.2 Hysteresis current control

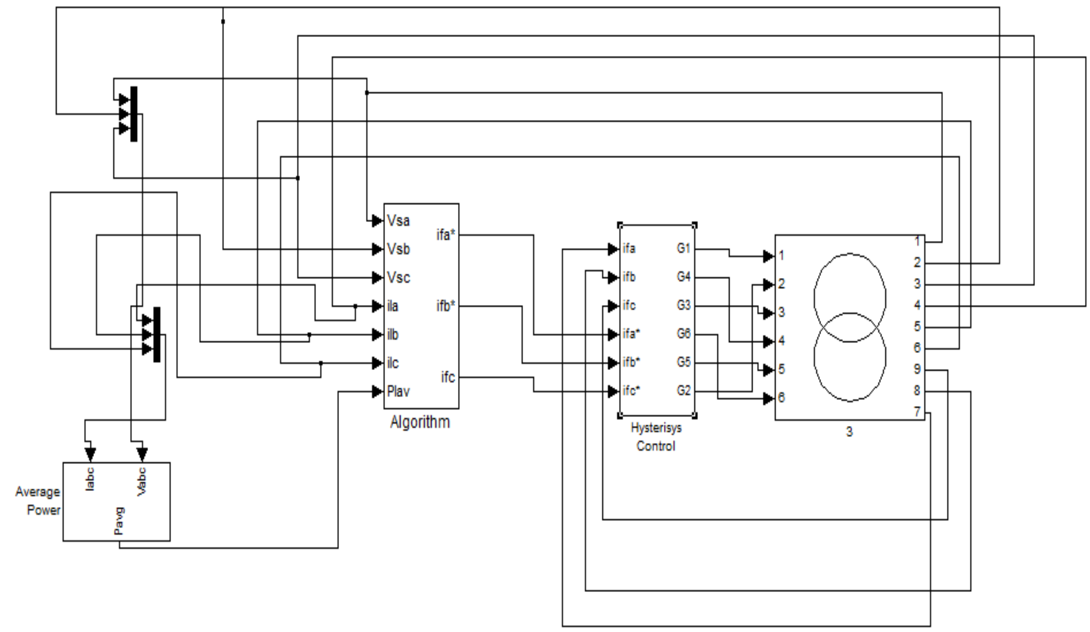

Fig.4.1.PSIM coupled Simulink diagram

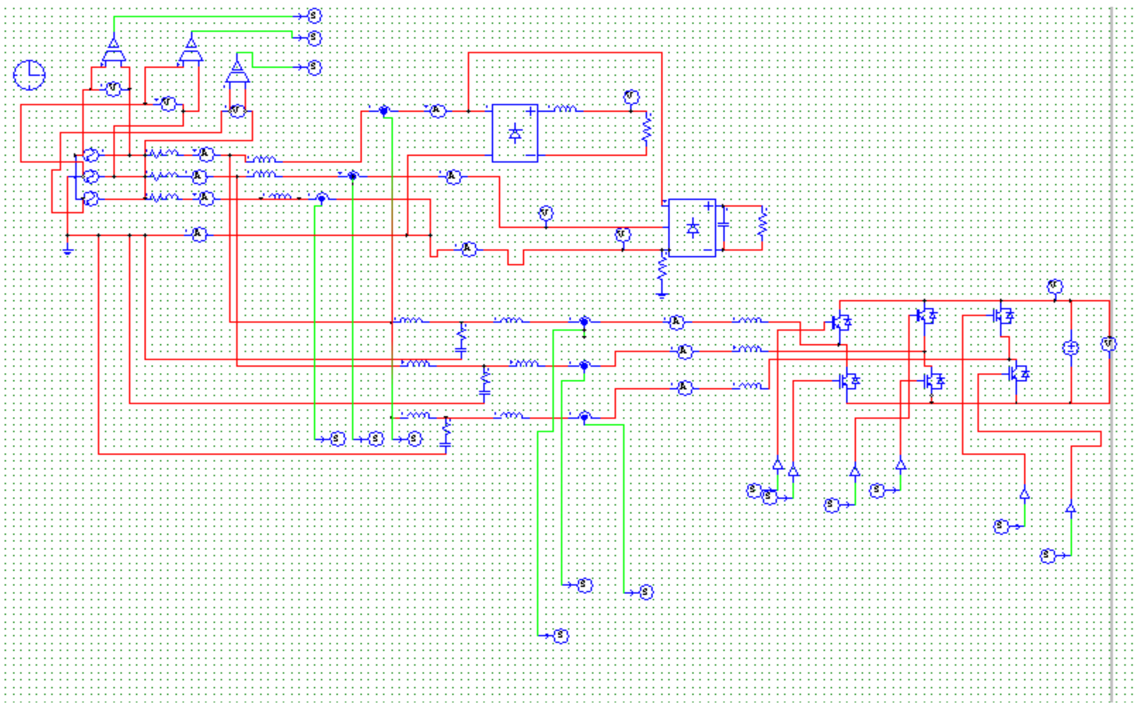

Fig.4.2. Simulation diagram of Active filter in PSIM

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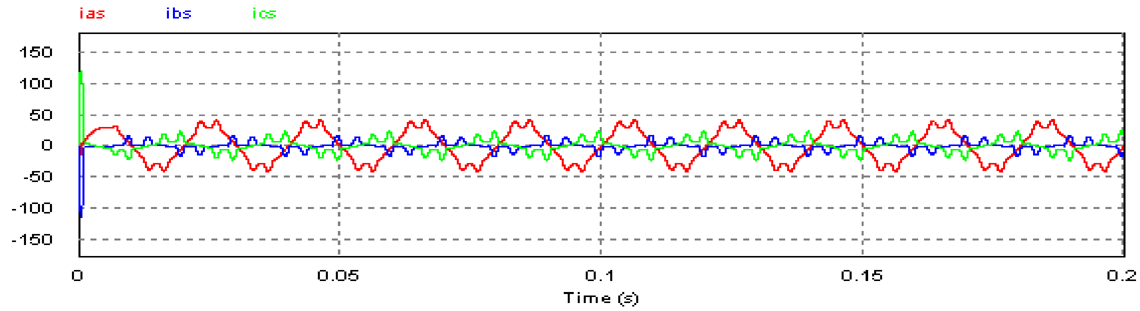

Fig 4..3 Source current before compensation

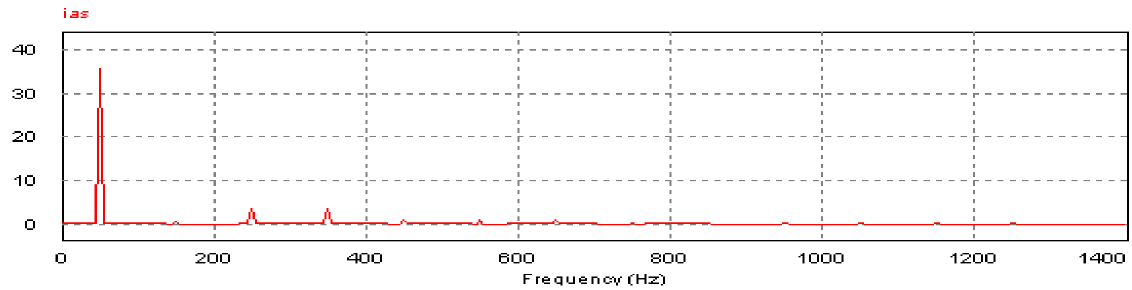

Fig 4.4 source current THD spectrum A phaseBefore compensation.

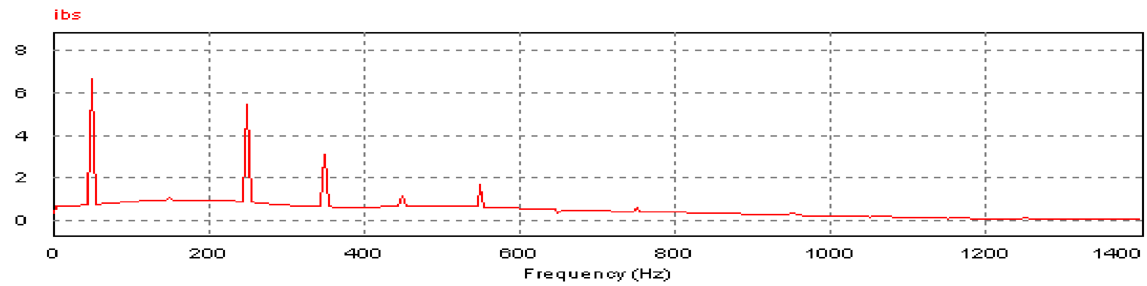

Fig 4.5. source current THD spectrum B phase Before compensation

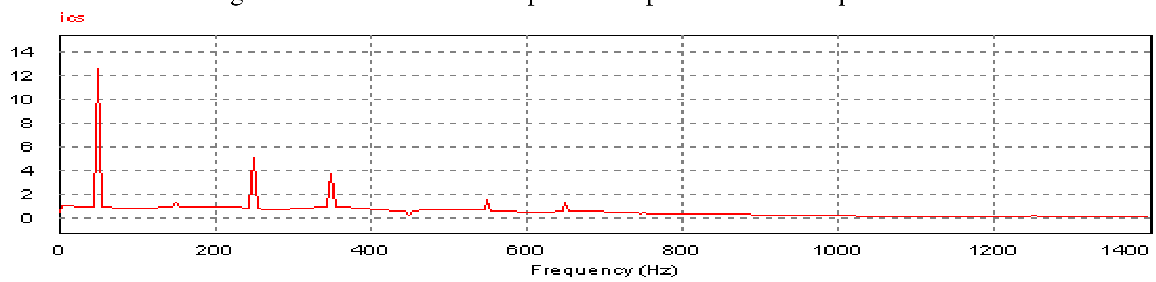

Fig 4.6 source current THD spectrum C phaseBefore compensation

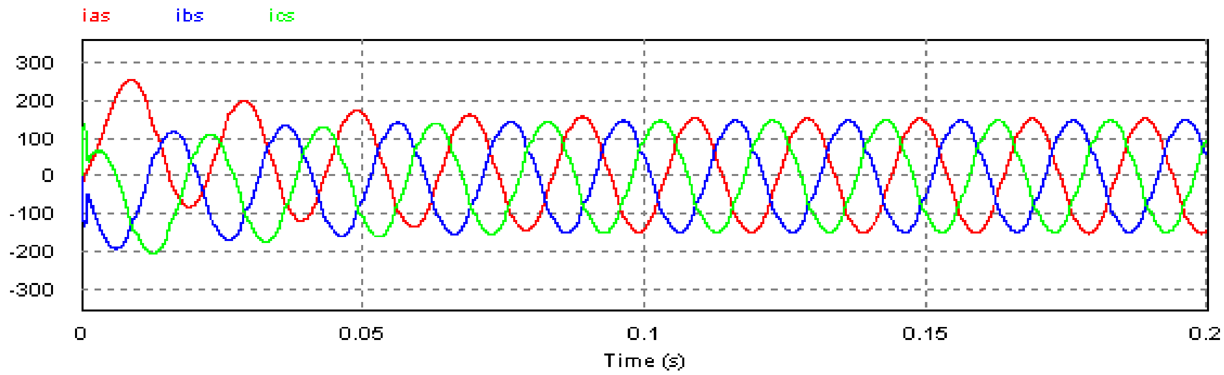

Fig 4.7. source current After compensation

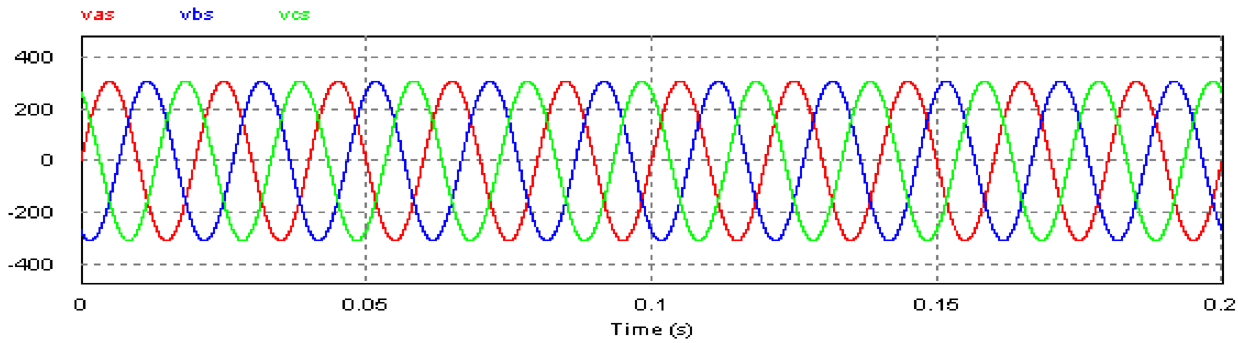

Fig 4.8 source voltage after compensation

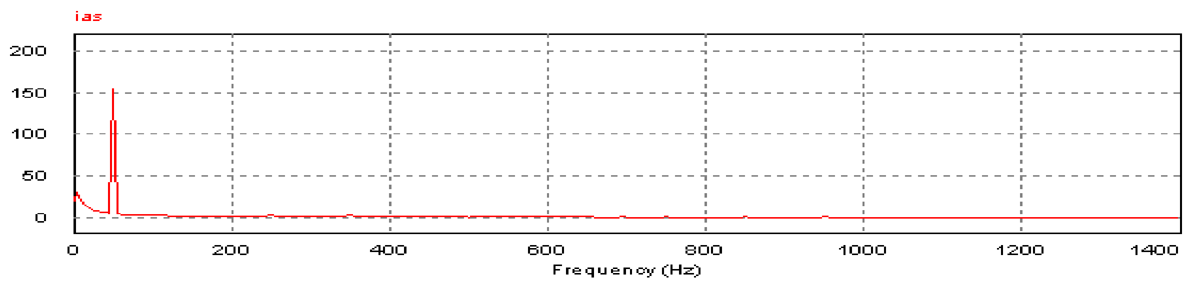

Fig 4.9 source current THD spectrum A phase after compensation

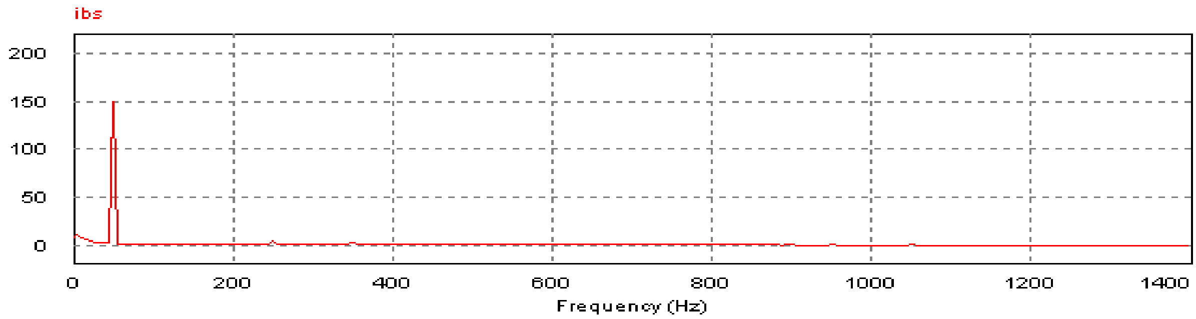

Fig 4.10 source current THD spectrum B phase after compensation

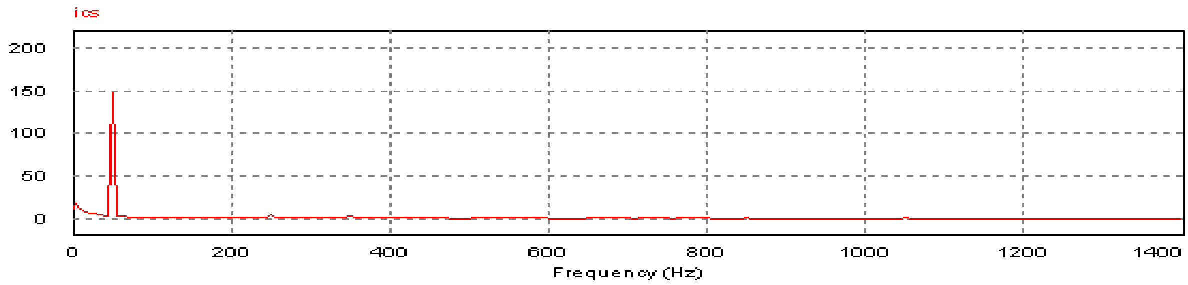

Fig 4.11source current THD spectrum C phase after compensation.