

Control of Shunt Active Power Filter Using LabVIEW

M. Chakravarthy, Dr. S N Saxena, Dr. B V Sanker Ram

Department of Electrical & Electronics Engineering

Gokraju Rangaraju Institute of Engineering & Technology, Jawaharlal Nehru Technological University, Hyderabad, India.

Abstract-Because of the wide spread use of power electronic drives, such as power electronics controlled furnaces, traction and other industrial systems, power quality has suffered a great damage. This has necessitated designing various devices that can improve the power quality. Various control strategies have been studied and implemented in hardware using various technologies. In this paper, it is proposed to implement voltage source instantaneous power control algorithm using LabVIEW, and explain step-by-step procedure for implementation of voltage source instantaneous power control technique of shunt Active power filter using LabVIEW[7].

I. INTRODUCTION

The devices required for power quality improvement are to be connected near the load which is the cause of affecting the power quality so that the source is not affected by the poor power quality and hence other loads are saved. The shunt active power filter is a power electronic device which is controlled in such a way that it supplies a current to make the source current sinusoidal.

The main function of a shunt active power filter (SAF) is compensation of the load harmonic current, so that active filter confines the load harmonic current at the load terminals, hindering its penetration into the power system. It draws an additional harmonic current in order to keep the load terminal voltage sinusoidal. Due to the non-linear characteristics of power electronics loads, THD of source current and terminal voltage fall below of IEEE 519 standard and in principle SAF is used to inject a current equal in magnitude but in opposite phase to residual current to achieve a sinusoidal current wave in phase with the supply voltage. An active power filter can be considered as a modified voltage source inverter. Fig.1 shows the detailed circuit diagram of an active power filter. Power electronic devices, normally used as converters, cause various harmonics to be produced and also cause low power factor in the system. Earlier, passive filters were used to reduce harmonics and improve power factor, but their disadvantages are that they are not responsive to changes in load and contribute to unwanted resonance in the circuit. In this paper, control algorithm for active power filter is implemented in LabVIEW. Shown in Fig.2 is

diagrammatic representation of the shunt active filter. The modified inverter injects currents into the system to compensate for harmonics and for reactive power requirements.

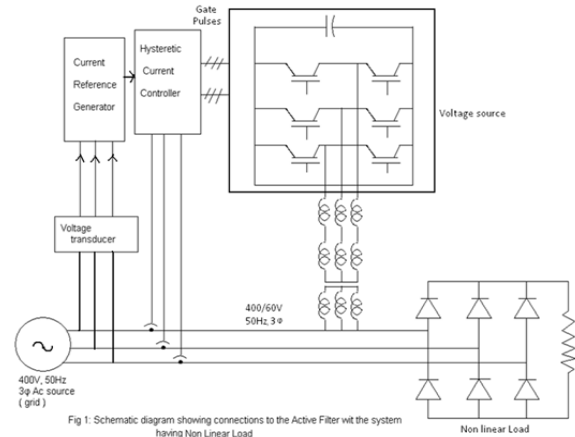


Fig. 1 Schematic Diagram Showing Connections to the Active Filter With Non-Linear Load

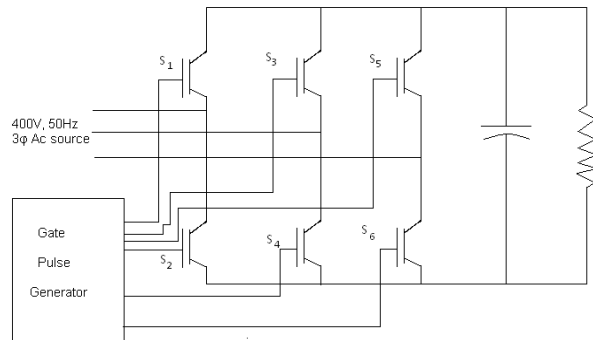


Fig. 2 Diagram of Voltage Source Inverter With Gate Pulse Generation

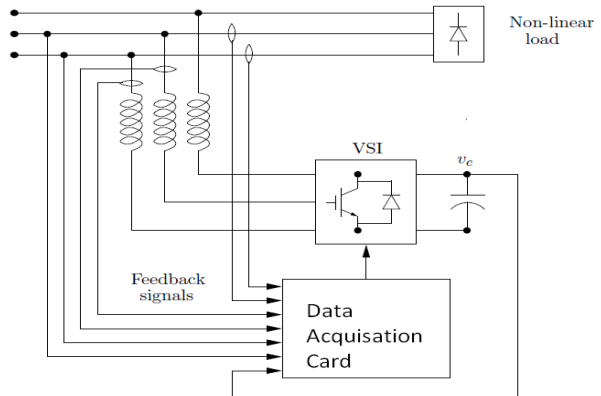


Fig. 3 Current and Voltage Signals acquired through DAC

The actual currents and voltages of the system at various locations are acquired by a data acquisition card and fed to the computer in which all the calculations are done. Using a Data Acquisition board, the required signals for the control of SAPF are generated. LabVIEW Programming can be used to implement the control strategy of choice. The required voltage, current etc signals are used to acquire signals with proper signal conditioning.

In scope of acquiring the input signals, PCI 6221 with the following features is used

- 16 analog inputs, 250kS/s, resolution 16 bits
- 2 analog outputs, 740kS/s, resolution 16 bits
- 10 digital I/O compatible TTL

As shown in the figure, we need the following measurements

- Source voltages
- Source currents
- Load currents
- Inverter currents
- Capacitor voltage

Firstly, the three voltages are measured reducing their amplitudes permissible to the DAQ, using the three analog inputs of the DAQ, its software representation is shown in Fig.4. The measured voltages are then multiplied with the gain to get the original values of the Power System. Acquiring signals can be made using DAQ Assistant block. Signals are acquired with N= 4000 samples/period and a sampling rate f=200 kHz.

II. CONTROL ALGORITHM

The three voltages V_a , V_b and V_c from the voltage transducers are given to the controller, which converts them to V_o , V_α and V_β using the following equations.

$$V_o = \frac{1}{\sqrt{3}}(V_a + V_b + V_c) \quad \dots\dots\dots (1)$$

$$V_\alpha = \sqrt{\frac{2}{3}}\left(V_a - \frac{V_b}{2} - \frac{V_c}{2}\right) \quad \dots\dots\dots (2)$$

$$V_\beta = \sqrt{\frac{2}{3}}\left(\frac{\sqrt{3}}{2}V_b - \frac{\sqrt{3}}{2}V_c\right) \quad \dots\dots\dots (3)$$

Similarly, the controller is fed with current signals from the current transducers, which are converted to i_o , i_α and i_β using the following equations.

$$i_o = \sqrt{\frac{2}{3}}\left(\frac{i_a}{\sqrt{2}} + \frac{i_b}{\sqrt{2}} + \frac{i_c}{\sqrt{2}}\right) \quad \dots\dots\dots (4)$$

$$i_\alpha = \sqrt{\frac{2}{3}}\left(i_a - \frac{i_b}{2} - \frac{i_c}{2}\right) \quad \dots\dots\dots (5)$$

$$i_\beta = \sqrt{\frac{2}{3}}\left(\frac{\sqrt{3}}{3}i_b - \frac{\sqrt{3}}{2}i_c\right) \quad \dots\dots\dots (6)$$

The real and reactive powers are obtained from the following equations.

$$P_o = V_o I_o \quad \dots\dots\dots (7)$$

$$p = V_\alpha I_\alpha + V_\beta I_\beta \quad \dots\dots\dots (8)$$

$$q = -V_\beta I_\alpha + V_\alpha I_\beta \quad \dots\dots\dots (9)$$

This calculation is represented diagrammatically in Fig.(4).

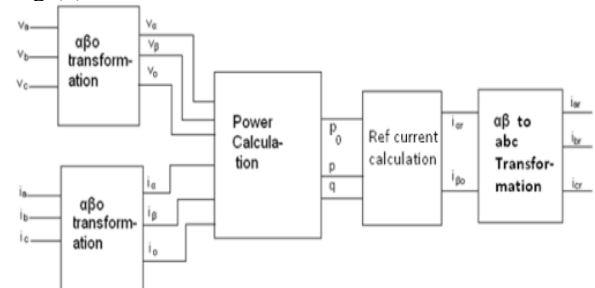


Fig.4 Block Diagram Representation of Calculation of Reference Currents

The active power signal p has a steady component and a fluctuating component. The steady component only should be drawn from the grid, whereas the fluctuating component should be drawn from the active power filter. If this can be done, the grid will not be affected by harmonic currents. If q can be supplied entirely from the active power filter, the power factor will also be improved. If reference currents can be calculated with this in view, the shunt active power filter will contribute in a great way to improve the power quality. The power signal p is passed through a high pass filter. A diagrammatic representation of this scheme is shown in Fig.5.

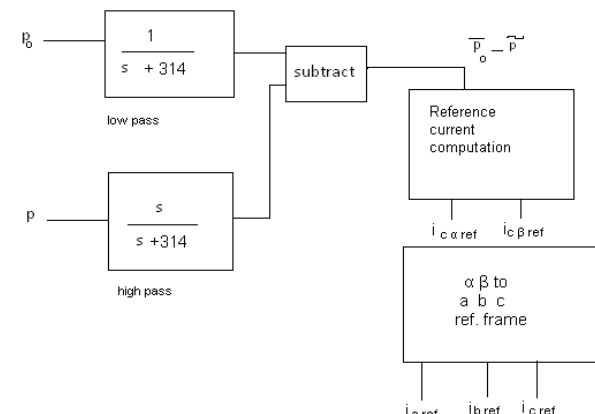


Fig.5 Calculation of Reference Currents

P_o (zero sequence power signals) is passed through low pass filter and the active power signal is passed through high pass filter. The output of low pass filter is steady component of zero sequence power. In high pass filter, output is fluctuating component of power.

So, this difference is $\bar{p}_o - \hat{p}$, which is used to calculate the reference currents using the following expressions.

$$i_{ca\text{ref}} = \frac{1}{V_{\alpha}^2 + V_{\beta}^2} [V_{\alpha} (\bar{p}_o - \hat{p}) + V_{\beta} q] \dots(10)$$

$$i_{cb\text{ref}} = \frac{1}{V_{\alpha}^2 + V_{\beta}^2} [V_{\beta} (\bar{p}_o - \hat{p}) + V_{\alpha} q] \dots(11)$$

These reference currents in the α - β frame are converted to a-b-c frame, using the reverse transformation given below.

$$i_{caref} = \sqrt{\frac{2}{3}} \left[\frac{-i_o}{\sqrt{2}} + i_{caref} \right] \dots\dots\dots(12)$$

$$i_{cbref} = \sqrt{\frac{2}{3}} \left[\frac{-i_o}{\sqrt{2}} - \frac{1}{2} i_{caref} + \frac{\sqrt{3}}{2} i_{cbref} \right] \dots\dots\dots(13)$$

$$i_{ccref} = \sqrt{\frac{2}{3}} \left[\frac{-i_o}{\sqrt{2}} - \frac{1}{2} i_{caref} - \frac{\sqrt{3}}{2} i_{cbref} \right] \dots\dots\dots(14)$$

This scheme involves selection of two levels of current; one slightly above the reference current and other slightly below the reference current. Feedback signal from the actual current is taken. When the actual current is below lower value, the MOSFETs are switched on, and when the current crosses the upper value, the MOSFETs are switched off. As a result, the actual current remains within the upper and lower bands of the current reference. The scheme is explained diagrammatically in Fig.6.

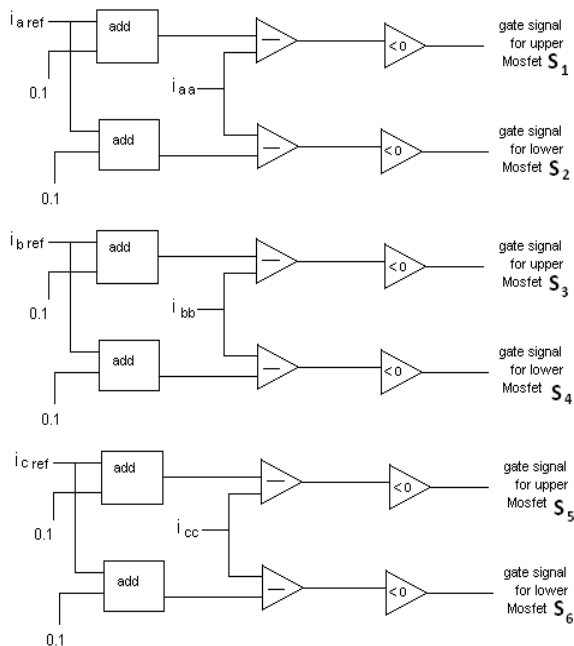


Fig.6 Control Algorithm for Hysteretic Band Current Controller

III. VSI IMPLEMENTATION

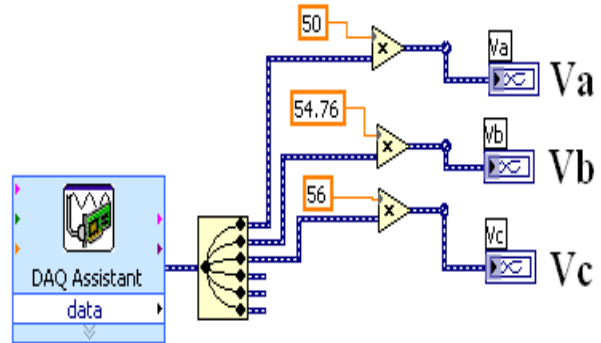


Fig.7 Measurement of Three Phase Voltages Using Lab view DAQ Assistant Block

Fig.7 represents the three phase voltages multiplied by the required constants to compensate for the PT ratio and the signal conditioning.

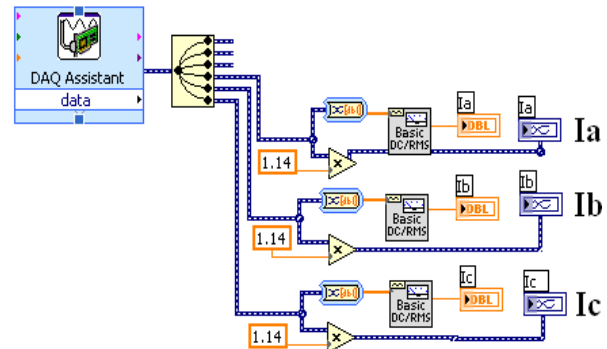


Fig.8 Measurement of Three Phase Currents

The fig.8 represents multiplication by the required constants to compensate for the CT ratio and the signal conditioning. In this way, the load currents, source currents and inverter currents are made available in the software for further processing. The non-linear load, which normally consists of power electronic devices like diodes, thyristors, GTOs etc., cause distortion in the load current waveform which is used to generate the compensation current to be supplied by the inverter. Performance of this control algorithm will be discussed towards the end of this paper. The three voltages V_a , V_b and V_c from the voltage transducers are given to the controller, which converts them to V_o , V_{α} and V_{β} using the equations 1, 2 & 3. LabVIEW representation of the equations 1, 2 & 3 is implemented programmatically as shown in Fig.9

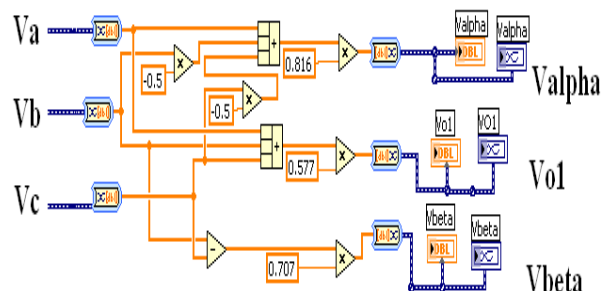


Fig.9 Conversion of Phase Voltages to Alpha and Beta

Similarly, the controller is fed with current signals from the current transducers, which are converted to i_0 , i_α and i_β using the equations 4,5&6. LabVIEW representation of the equations 4,5&6 is implemented programmatically as shown in Fig.10.

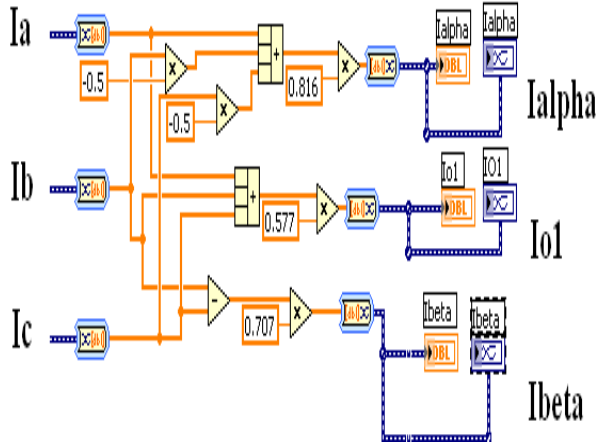


Fig.10 Conversion of Phase Currents to Alpha and Beta
The real and reactive powers are obtained from equations 7, 8 &9. LabVIEW representation of the equations 7, 8 &9 is implemented programmatically as shown in the Fig.11

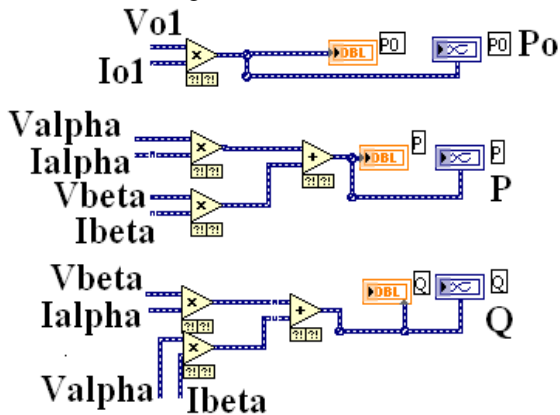


Fig.11 Calculation of P_0 , P and Q

The active power signal p has a steady component and a fluctuating component. The steady component only should be drawn from the grid, whereas the fluctuating component should be drawn from the active power filter. If this can be done, the grid will not be affected by harmonic currents. If q can be supplied entirely from the active power filter, the power factor will also be improved. If reference currents can be calculated with this in view, the shunt active power filter will contribute in a great way to improve the power quality. The power signal p is passed through a high pass filter representation in LabVIEW. p_0 (zero sequence power signal) is passed through low pass filter representation in LabVIEW and the active power signal is passed through high pass filter representation in LabVIEW. The output of low pass filter is steady component of zero sequence power. In high pass filter, output is fluctuating

component of power. So, this difference is $\overline{p_0} - \tilde{p}$, which is used to calculate the reference currents using the equations 10 &11. LabVIEW representation of the equations 10 & 11 is implemented programmatically as shown Fig.12.

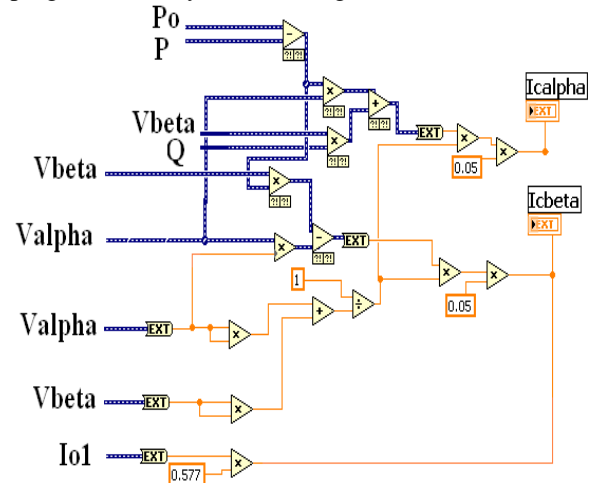


Fig.12 Obtaining $I_{c\alpha}$ and $I_{c\beta}$

These reference currents in the α - β frame are converted to a-b-c frame, using the reverse transformation given by equations 12, 13 &14. LabVIEW representation of the equations 12, 13 &14 is implemented programmatically as shown in Fig.13.

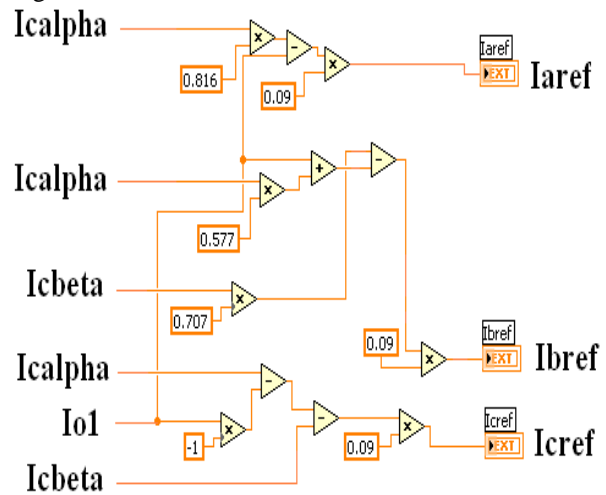


Fig.13 Obtaining Reference Currents

LabVIEW representation of the control scheme is implemented programmatically as shown in Fig.15. Logic for generation of PWM pulses is explained in Fig.14. Fig.16. Presents the hardware set-up of Shunt Active power filter.

IV. RESULTS

Fig.17 & 18 presents the phase voltages and currents before and after compensation. Fig.19. presents THD of phase currents of the non linear load after compensation.

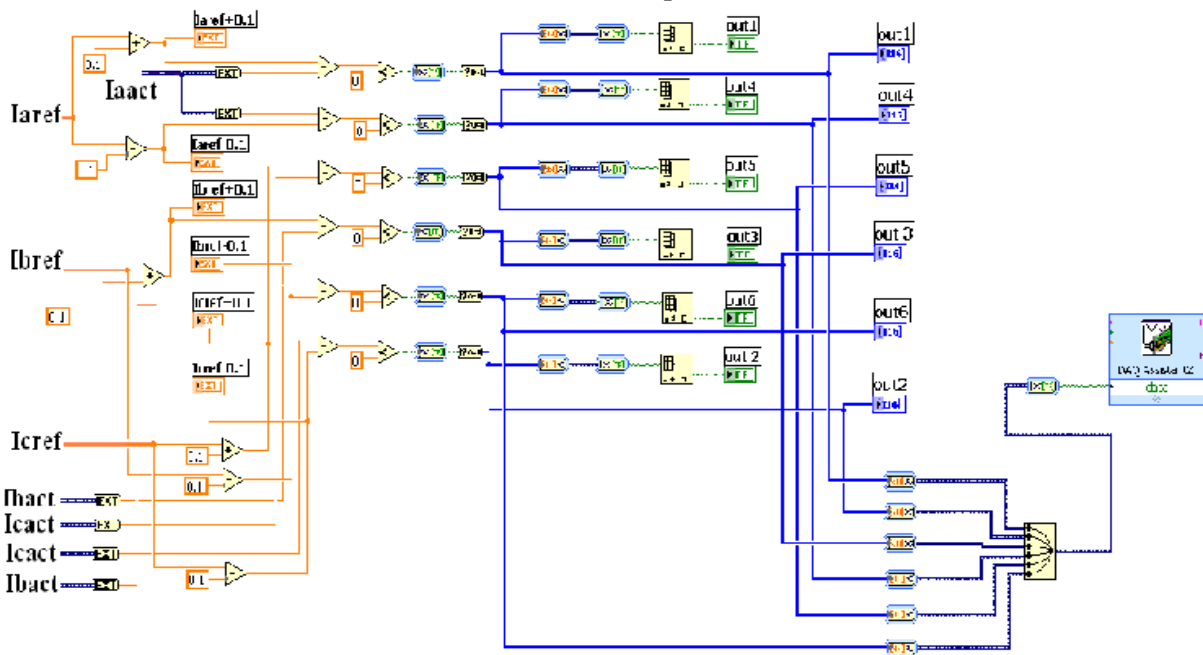


Fig.14 Generation of PWM Pulses

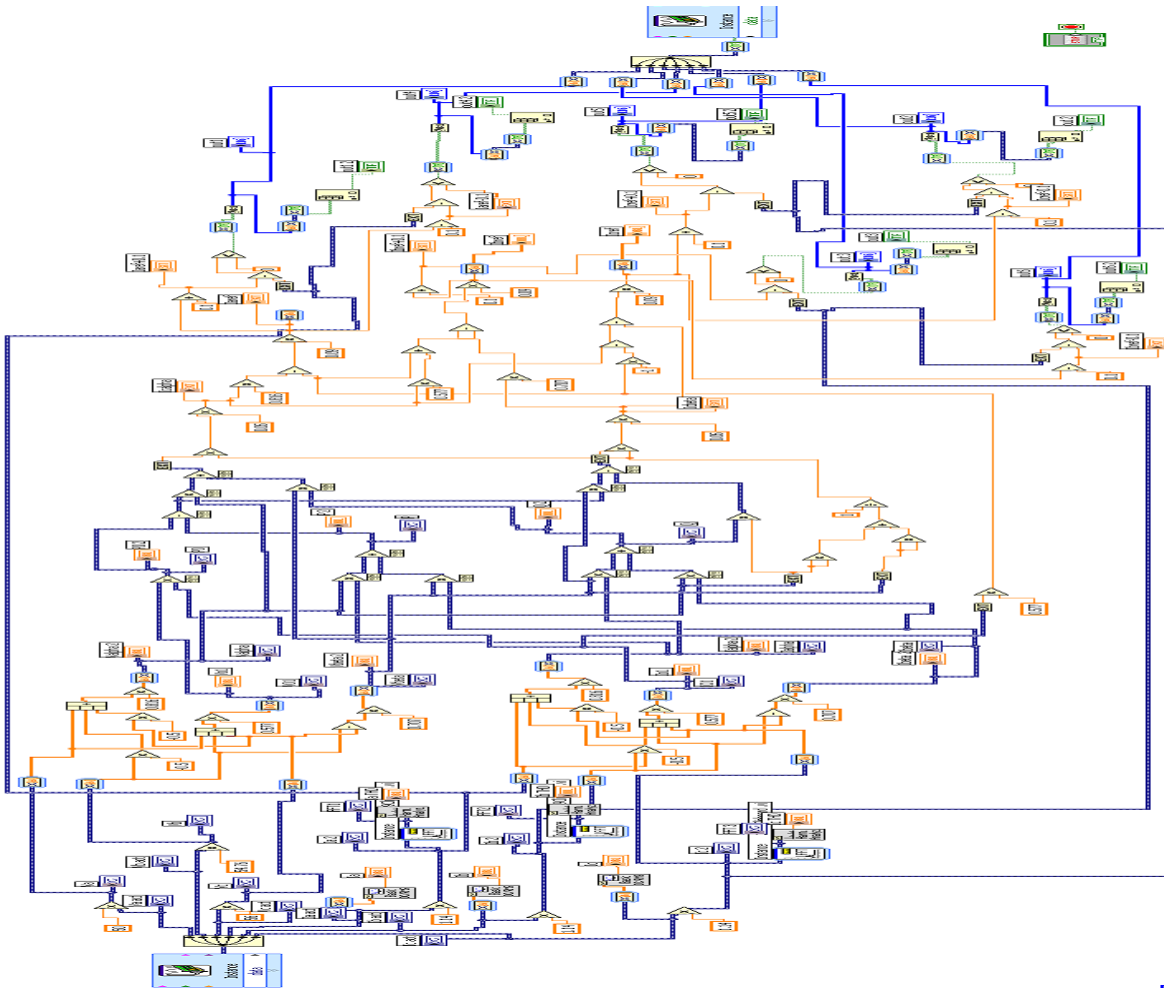


Fig.15.Implementation of Voltage Source Instantaneous Control Technique in LabVIEW



Fig.16 Hardware set-up of Shunt Active Power Filter

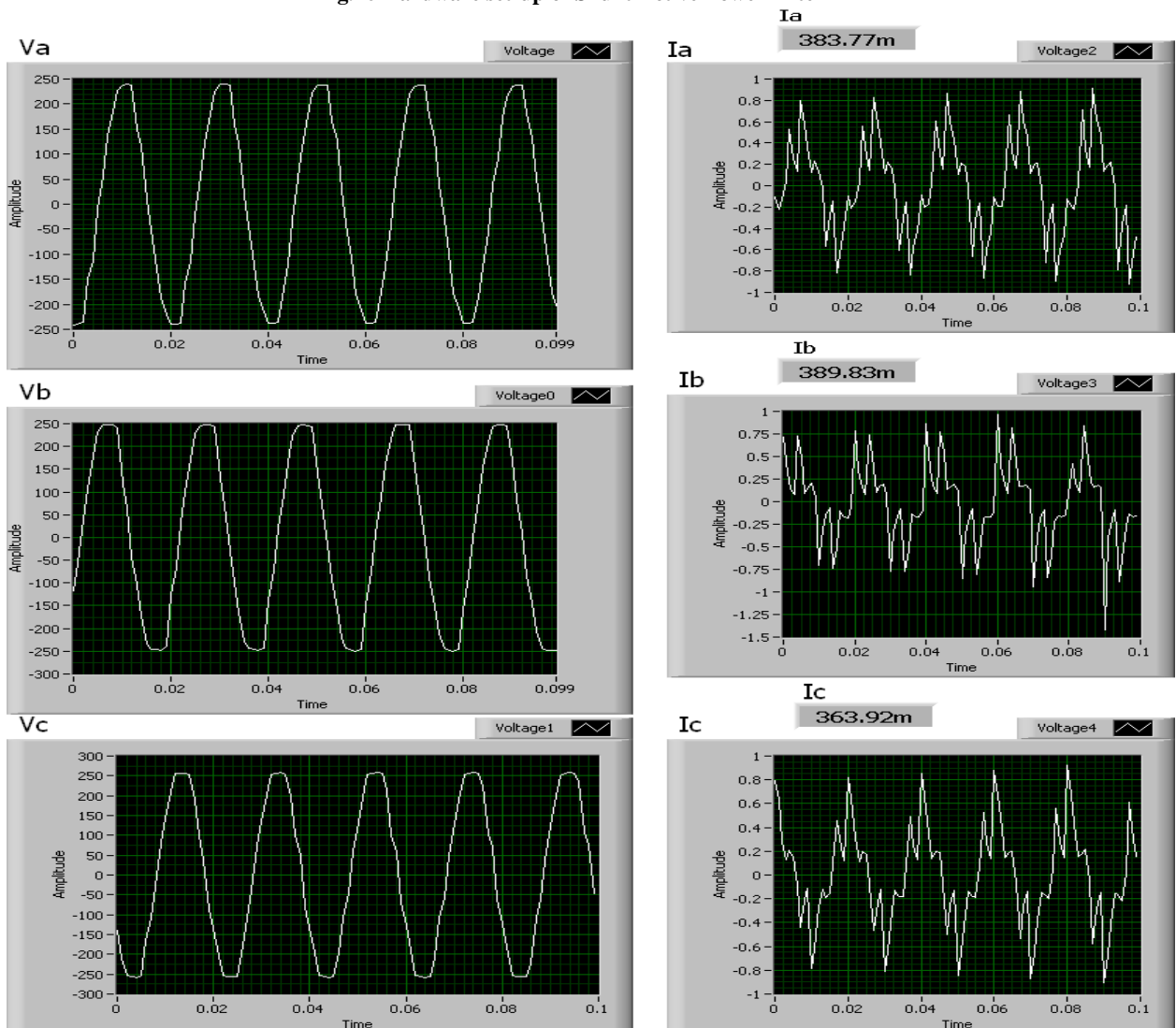


Fig.17.Phase Voltages and Currents before Compensation of a Non-Linear Load

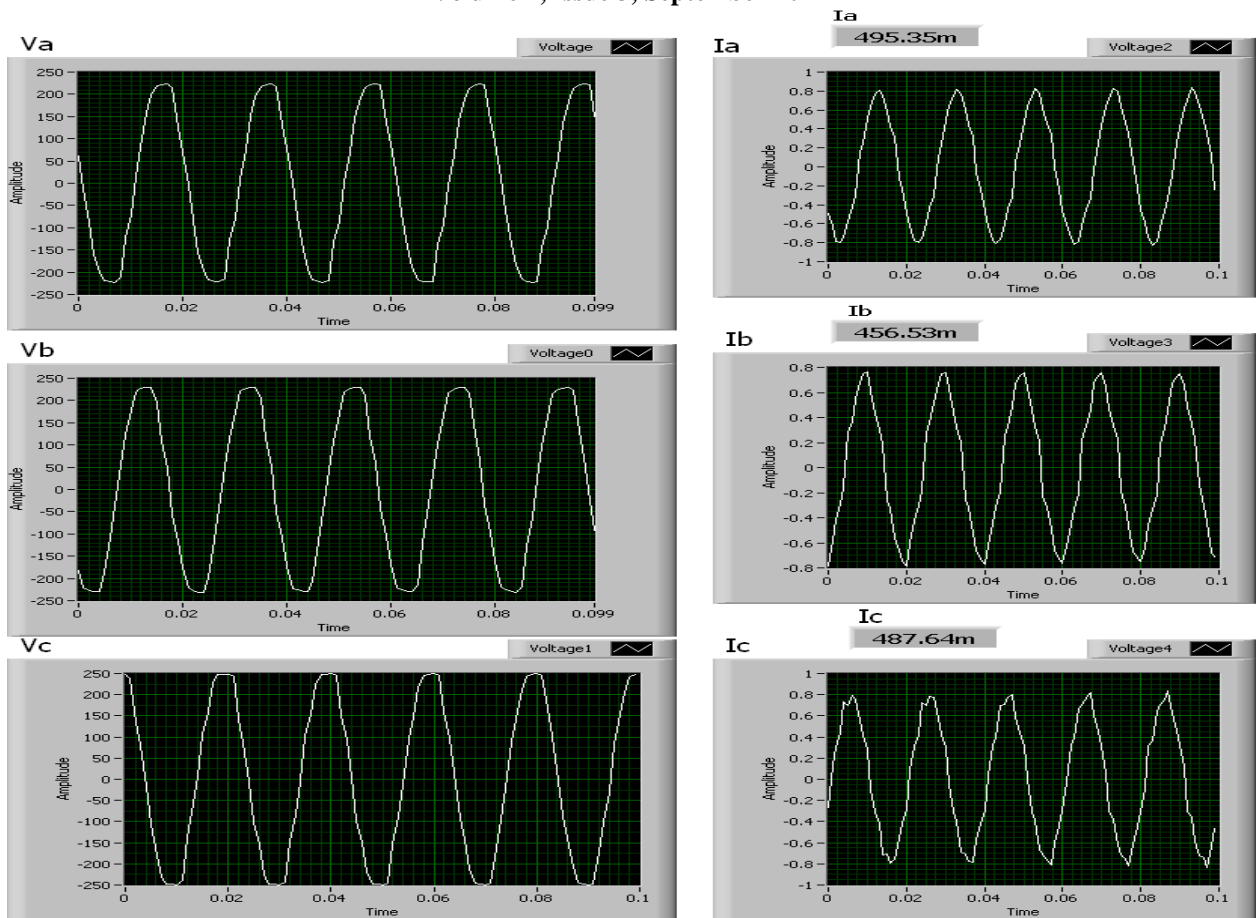


Fig.18 Phase Voltages and Currents after Compensation of a Non-Linear Load

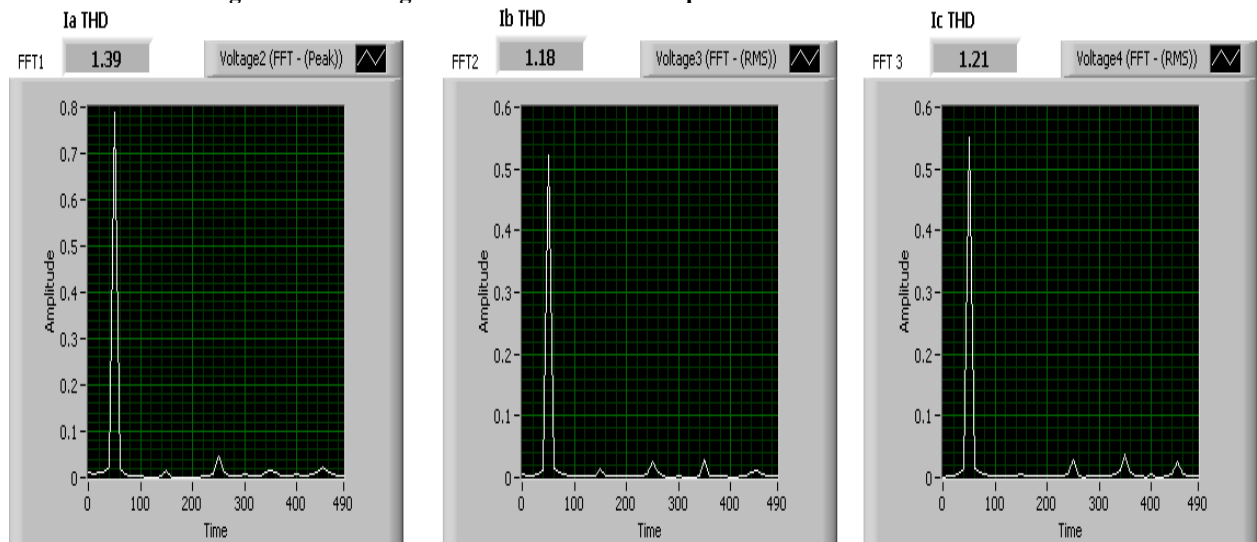


Fig.19 FFT Analysis of Currents after Compensation of a Non-Linear Load

V.CONCLUSION

This paper presents a method to obtain the compensation currents that are necessary to be injected in power system connected to a nonlinear load. The designed filter consists of six IGBT transistors that are controlled using LabVIEW through a data acquisition card.

REFERENCES

- [1] D.Sutanto and M.Bou-Rabee, "Active filter with reactive power compensation capability," in Int.Power Eng. Conf., Singapore, Mar 1993, pp 73-78.
- [2] H.Akagi, Y.Kanazawa, and A.Nabae, "Generalized theory of the instantaneous reactive power in three-

phase circuits,” in IPEC’83- Int Power Elec Conf, Tokyo, Japan, 1983, pp 1375-1386.

- [3] Silcy George, Vivek Agarwal, “A DSP Based Optimal Algorithm for shunt Active filter Under Non-Sinusoidal supply and unbalanced load conditions”, in IEEE transactions on Power Elec. Vol-22, Mar 2007.
- [4] C.A.Quinn and N.Mohan, and H.Mehta,”A four-wire, current-controlled converter provides harmonic neutralization in three-phase, four-wire systems,” in APEC’93-Applied Power Elec. Conf, 1993, pp. 841-846.
- [5] M.Aredes,J.Hafner, and K.Heumann, “A three-phase four-wire shunt active filter using six IGBT’s,”inEPE’95-ur.Conf.Power Elec.Appl.Sevilla,Spain,Sept.1995,vol.1, pp 1.874-1.879.
- [6] Joachim Holtz “Pulse width Modulation-A-Survey,” IEEETrans.IndustrialElectronics, Vol.39, No.5, Dec1992, pp-410-420.
- [7] M.Chakravarthy, P.M.Sarma, Dr.S.N.Saxena, “Comparative studies of Different control Strategies for Shunt Active Filter,”ARPN Journal of Engineering and Applied Sciences, Vol.6, N0.11, November 2011.