JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

SHUNT ACTIVE POWER FILTER FOR HARMONIC REDUCTION IN MICROGRID USING ANN TECHNIQUE

[1]Kondapalli Kusuma Kumari, [2]Dr. K. Padma, [3]K. Akhila, [4]M. Manogna

[1]M. Tech 2nd year student, [2]Associate professor, [3]M.Tech 2nd year student, [4]Research Scholar

Electrical Engineering Department,

Andhra University, Visakhapatnam, Andhra Pradesh, India.

ABSTRACT:
This paper focuses on the mitigation of harmonics of a grid connected PV system at the distribution level using Shunt Active Power Filter (SAPF). The major objective of this thesis is to develop an effective control strategy for the grid interfacing inverter to function as a SAPF and compensate for harmonics. The regulation of DC link capacitor's voltage plays a vital role in improving the device's capability to mitigate harmonics. This can be achieved by the closed loop action of PI Controller. Here, it has also been suggested to apply Artificial Neural Networks (back propagation algorithm) to enhance SAPF performance. The efficiency of employing ANN based controller over PI Controller to lower Total Harmonic Distortion in the source current waveform is clearly analysed and displayed in the results. The 3 phase, 4 wire distribution system is simulated and these control techniques are verified using MATLAB SIMULINK software.

Keywords: Power Quality, Microgrid, SAPF, ANN, THD, PI Controller.

I. INTRODUCTION

In today's world, Renewable Energy Sources(RES) are playing a vital role in electric power distribution leading to power quality disturbances. Power Quality disturbances include voltage sag, voltage swell, noise, harmonic distortion, voltage unbalance etc…The most significant influences on the power quality of microgrids are the harmonic currents produced by power electronic equipments, unbalanced and non-linear loads. The widespread use of these non-linear devices is the main cause of disruptions in the electrical network. These will introduce harmonics into the power supply, leading to issues such as equipment overheating, device damage, and EMI-related problems, among others[1],[2].

One of the most important issues with electrical power systems is Current harmonics. Harmonics are nothing but the unwanted frequency componenets added to the fundamental frequency thereby degrading the sinusoidal nature of the waveform. This can be measured by a parameter called Total Harmonic Distortion (THD). It is as defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency.

There are many techniques to reduce harmonic Distortion[3]. Filters are typically added when excessive harmonic voltage and current are generated. Compared to Passive Power Filters, Active Power Filters are widely used to mitigate harmonics because they employ power electronic switches and have control over the switching[4]. By converting Direct Current (DC) into harmonic currents that are out of phase with the load and injecting them into the AC line, these devices prevent harmonic currents from flowing into the supply.

There are different kinds of Active Power Filter topologies such as Series, Shunt, Series-Shunt, Hybrid etc.. available in the market. Out of all those mentioned above, Shunt Active Power Filter (SAPF) is considered in this research because it can simultaneously correct issues including current imbalances and current harmonics and has the ability to maintain balanced and sinusoidal mains current. It is connected in parallel with the load and compensate harmonics for various load conditions[5][6].

II.MICROGRID

In the past, the generating units were all located in one location, and the power generated was sent to the load over a lengthy transmission and distribution system, causing a power loss. Because of the enormous demand, the system's efficiency has decreased. As a means of overcoming the disadvantages of the traditional electrical grid, micro grid is used. Microgrid is a part of Distributed Generation where a group of Renewable Energy Sources (RES) like PV, wind, fuel cells etc.. come together or each of them individually serve load. This thesis consists of a PV array interconnected with main electrical grid system through an inverter which is acting as a Shunt Active Power Filter[13]. Loads are connected to AC bus line which may be balanced or unbalanced non-linear loads. The power quality of the system can be improved by interconnecting this SAPF in between source and load at the Point of Common Coupling (PCC).

III.HARMONIC DETECTION AND ELIMINATION

A.DESCRIPTION OF THE PROPOSED SYSTEM

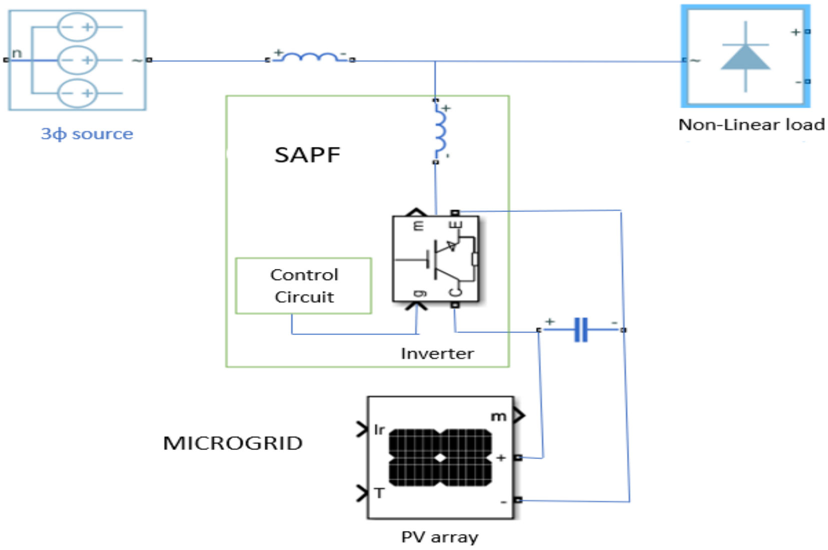


Fig.1 circuit diagram of proposed system

The proposed system is Three Phase Four wire which consists of shunt active power filter connected to the dc-link of a grid-interfacing inverter as shown in Fig.1. The voltage source inverter is a key element of a PV system as it interfaces the renewable energy source to the grid and delivers the generated power. The active power filter is connected to grid with an inverter coupled to dc-link. The dc-capacitor decouples the Photovoltaic system from grid and also allows independent control of converters on either side of dc-link [13].

B.VOLTAGE SOURCE CONVERTER (VSC)

A voltage-source converter is a power electronic device that connected in shunt or parallel to the system. It can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. It also converts the DC voltage across storage devices into a set of three phase AC output voltages. It is also capable to generate or absorbs reactive power. If the output voltage of the VSC is greater than AC bus terminal voltages, is said to be in capacitive mode. So, it will compensate the reactive power through AC system. The type of power switch used is an IGBT in anti-parallel with a diode. The three phase four leg VSI is modeled in Simulink by using IGBT[11].

C.CONTROL TECHNIQUE USED FOR INTERFACING INVERTER TO ACT AS SAPF

The turn on and turn off instants of inverter switches should be such that the load and the connected renewable energy sources could appear as balanced load to the system[10]. The dc link voltage, Vdc is sensed at a regular interval and is compared with its reference counterpart Vdc*. The error signal is processed in a PI-controller. The output of the pi controller is denoted as Im. The reference current templates (Ia*, Ib*, and Ic*) are obtained by multiplying this peak value (Im) by the three-unit sine vectors (Ua, Ub and Uc) in phase with the three source voltages. These unit sine vectors are obtained from the three sensed line to neutral voltages. The reference grid neutral current (In*) is set to zero, being the instantaneous sum of balanced grid currents. Multiplication of magnitude Im with phases (Ua, Ub, and Uc) results in the three phase reference supply currents (Ia*, Ib*, and Ic*). The grid synchronizing angle (ϴ) obtained from phase locked loop (PLL) is used to generate unity vector template as

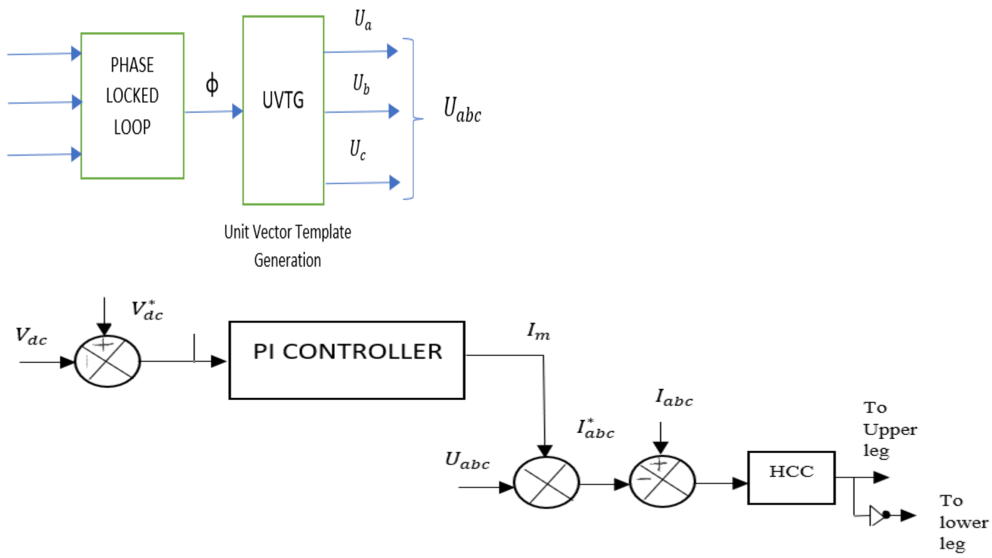


Fig.2 control scheme

$$U_a = \sin\theta \qquad (i)$$

$$U_b = \sin(\theta - \frac{2\pi}{3}) \qquad (ii)$$

$$U_c = \sin(\theta + \frac{2\pi}{3}) \qquad (iii)$$

The instantaneous values of reference three phase grid currents are compute as

$$I_a^* = I_m * U_a \qquad (iv)$$

$$I_b^* = I_m * U_b \qquad (v)$$

$$I_c^* = I_m * U_c \qquad (vi)$$

The neutral current is considered as

$$I_n^* = 0 \qquad (vii)$$

The reference grid currents(I_a*, I_b^*, I_c^* and I_n^*) are compared with actual grid currents(I_a, I_b, I_c and I_n) to compute the current errors as

$$I_{aerr} = I_a^* - I_a \qquad (viii)$$

$$I_{berr} = I_b^* - I_b \qquad (ix)$$

$$I_{cerr} = I_c^* - I_c \qquad (x)$$

$$I_{nerr} = I_n^* - I_n \qquad (xi)$$

These errors are given to hysteresis current controller then generate the switching pulses for six IGBTs of the grid interfacing inverter.

D.HYSTERESIS CURRENT CONTROL

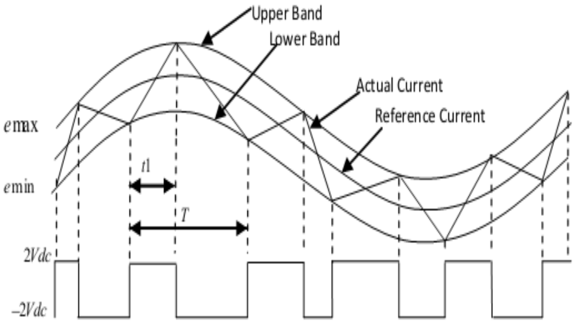


Fig.3 waveform of hysteresis current controller

In Fig. 3, waveforms for a closed loop control system with a hysteresis current controller are shown. A voltage source inverter's switches are controlled by an error signal. The disparity between the desired current and the current that the inverter is injecting causes this problem. The upper switch of the inverter arm is turned off and the lower switch is switched on if the error is greater than the hysteresis band's upper limit. The current then begins to decrease as a result. The lower switch of the inverter arm is turned off, and the higher switch is turned on, if the error exceeds the lower limit of the hysteresis band. As a result, the current enters the hysteresis band once more.The minimum and maximum values of the error signal are e_{min} and e_{max} respectively. The range of the error signal $e_{max} - e_{min}$ directly controls the amount of ripple in the output current from the VSI.

E.SIMULATION MODEL OF HYSTERESIS CURRENT CONTROLLER AND PI CONTROLLER

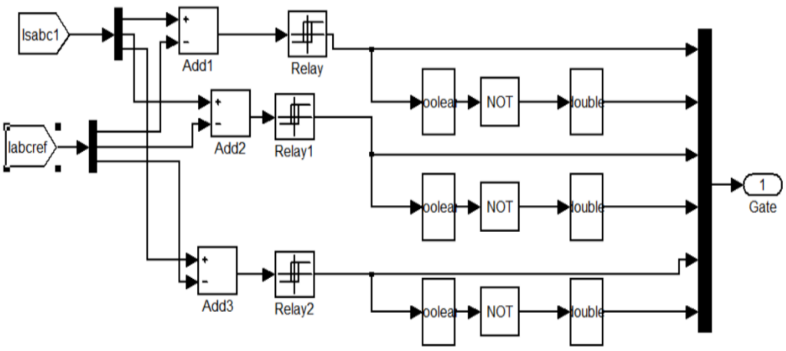


Fig.4 Simulink Model of Hysteresis Current Control

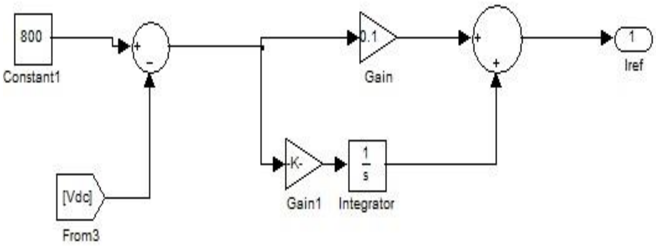


Fig.5 Simulink model of PI control

F.LOADS

1. NON LINEAR LOAD: A three phase four leg diode rectifier feeding an RL load is considered as a non-linear load. The load is modeled in Simulink by using diodes.

2. BALANCED LOAD: The three impedance values are connected to the three phases of the source. The load is modeled in Simulink by using resistors.

3. UNBALANCED LOAD: The three different impedance of value is connected to the three phases of the source. The load is modeled in Simulink by using resistors and inductors.

4. THREE PHASE SUPPLY: Three phase supply is modeled in MATLAB /Simulink using, the three Voltage Sources.

IV.ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks are computational models and inspire by the human brain[15]. A neural network is a group of algorithms that certify the underlying relationship in a set of data similar to the human brain. The neural network helps to change the input so that the network gives the best result without redesigning the output procedure. In this thesis, a feedforward network is developed consisting of an Input layer, Hidden layer and an Output layer.

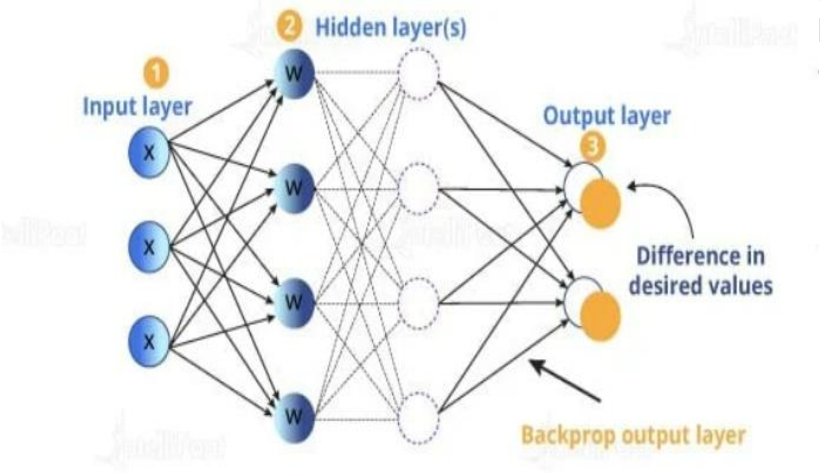


Fig.6 Artificial Neural Network

The inputs are the error which are multiplied by the weights and added with the bias and the desired output is also provided. Due to this Supervised learning, the training data is input to the network, and the desired output is known, weights are adjusted until production yields desired value. Here, the sigmoidal transfer function is used to approximate the output from the net input. In this, a Multi layer neural network is used which processes the inputs and compares its resulting outputs against the desired outputs. Errors are then propagated back through the system, causing the system to adjust the weights until the output is converged.

V.MATLAB/SIMULINK MODEL OF THE PROPOSED SYSTEM

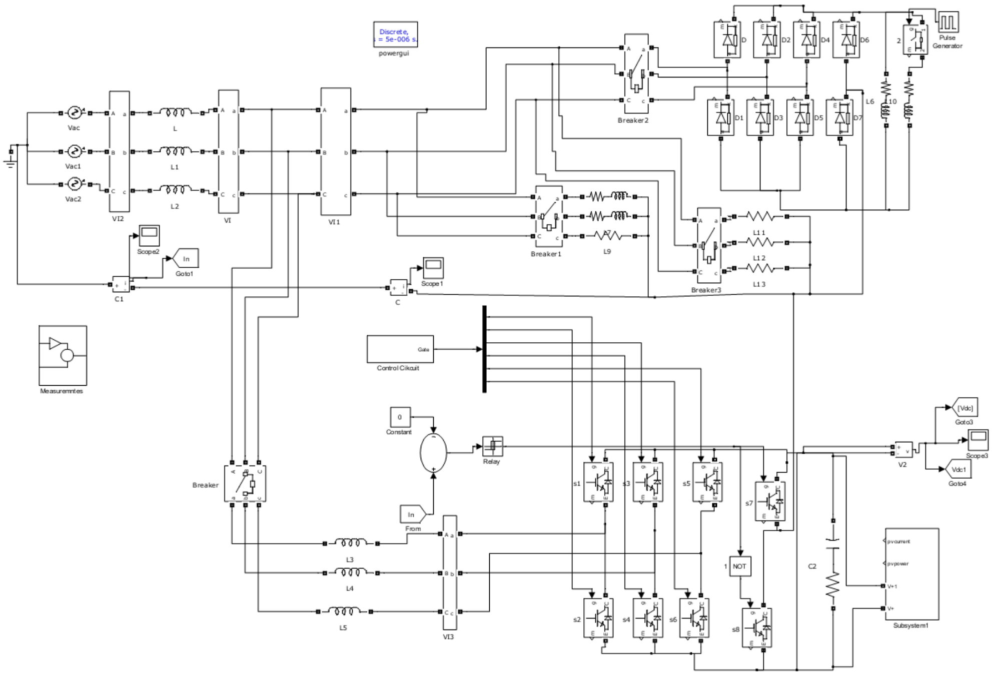


Fig.7 MATLAB Simulink model of the proposed system

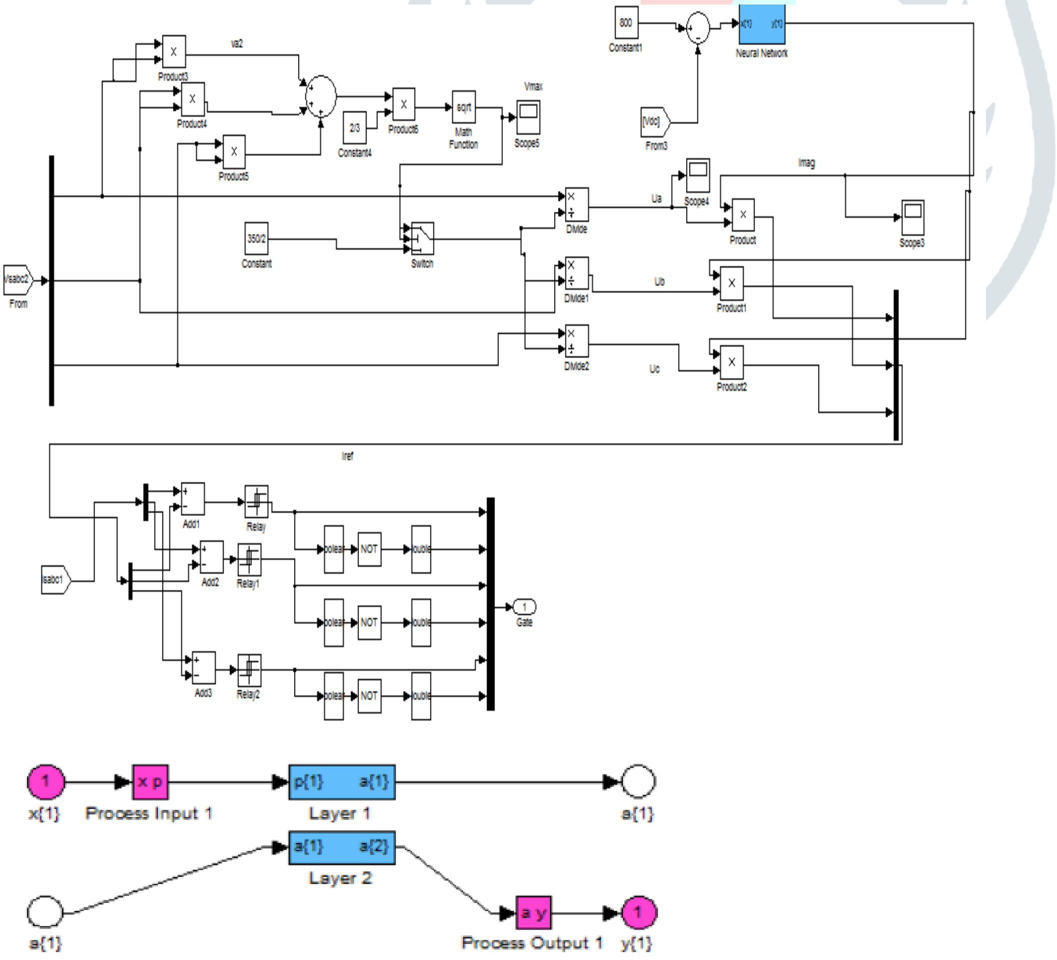
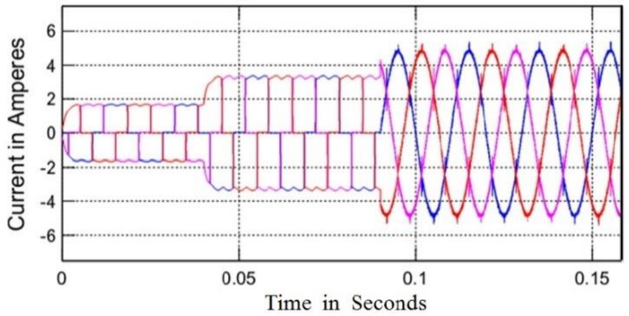


Fig.8 THD Inverter current control using ANN

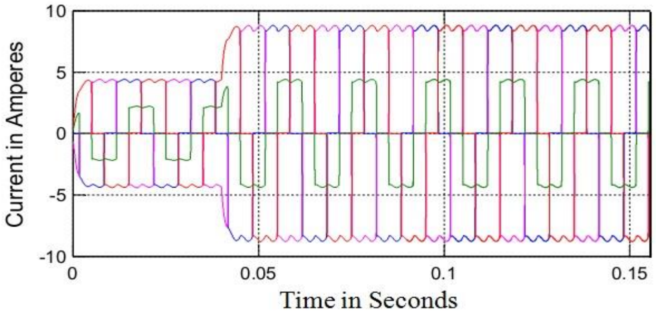
VI.SIMULATION RESULTS

Here Simulation results are presented for four cases.
Case 1: Non Linear Load.
Case 2: Balanced Non-Linear Load.
Case 3: Unbalanced Non-Linear Load.
Case 4: THD Analysis for different combination of loads using ANN

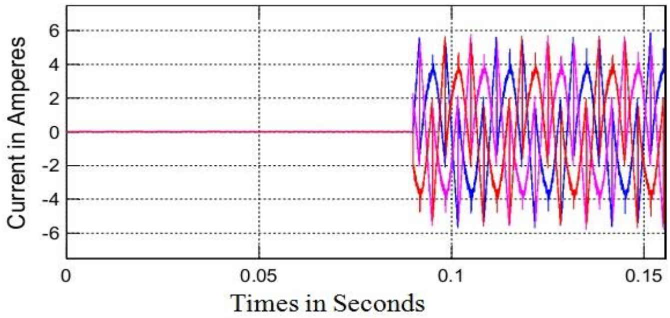
A.Case 1: Non Linear Load.



(a)



(b)



(c)

Fig.9 Simulation results of Non-Linear Load (b) Source Current (c) Load Current (d) Inverter Current.

Fig.9 shows the source current, load current, inverter compensating current respectively. The inverter is turned on at 0.09 seconds. Fig.9 (a): it clearly indicates the source current from 0 to 0.09 sec represents the non-sinusoidal nature due to the presence of nonlinear load .At 0.09 seconds the nature of waveform is almost sinusoidal this represents the inverter compensated the non-sinusoidal wave to balanced sinusoidal wave. The load current waveform is shown in Fig.9 (b). The inverter supplies the compensating current that is shown in Fig .9(c).

- **THD ANALYSIS FOR NON-LINEAR LOAD**
- **THD OF SOURCE CURRENT BEFORE COMPENSATION**

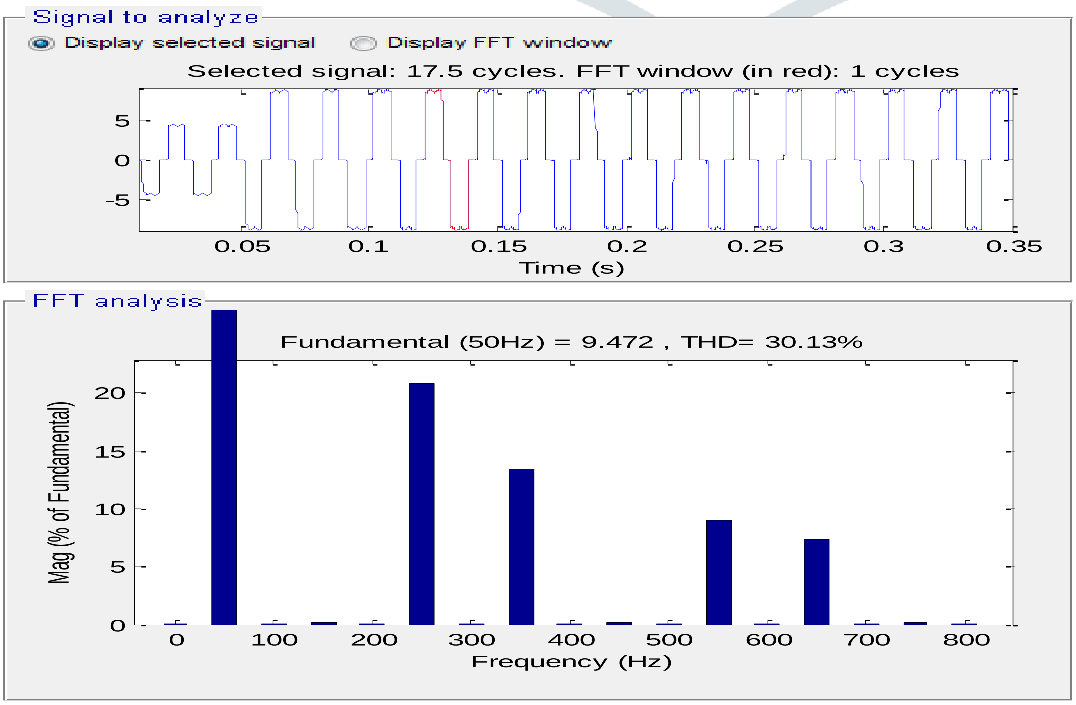


Fig.10 THD of Source Current before Compensation

Total Harmonic Distortion of Source Current before Compensation = 30.13%

- **THD OF SOURCE CURRENT AFTER COMPENSATION**

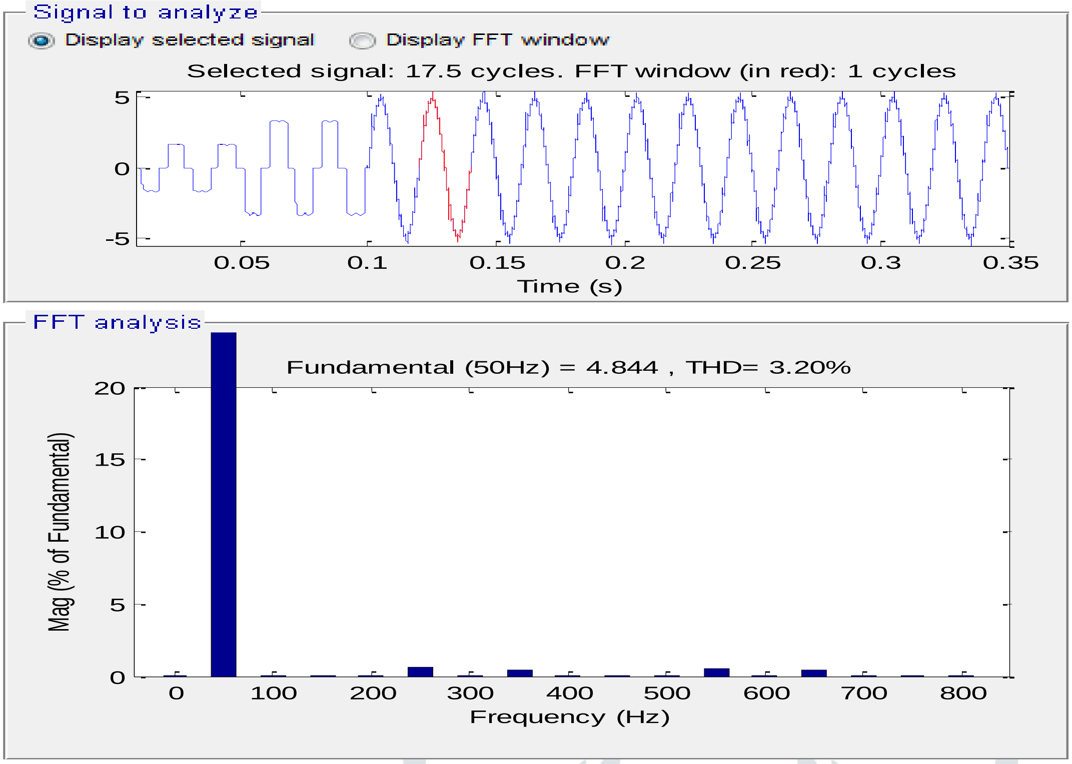
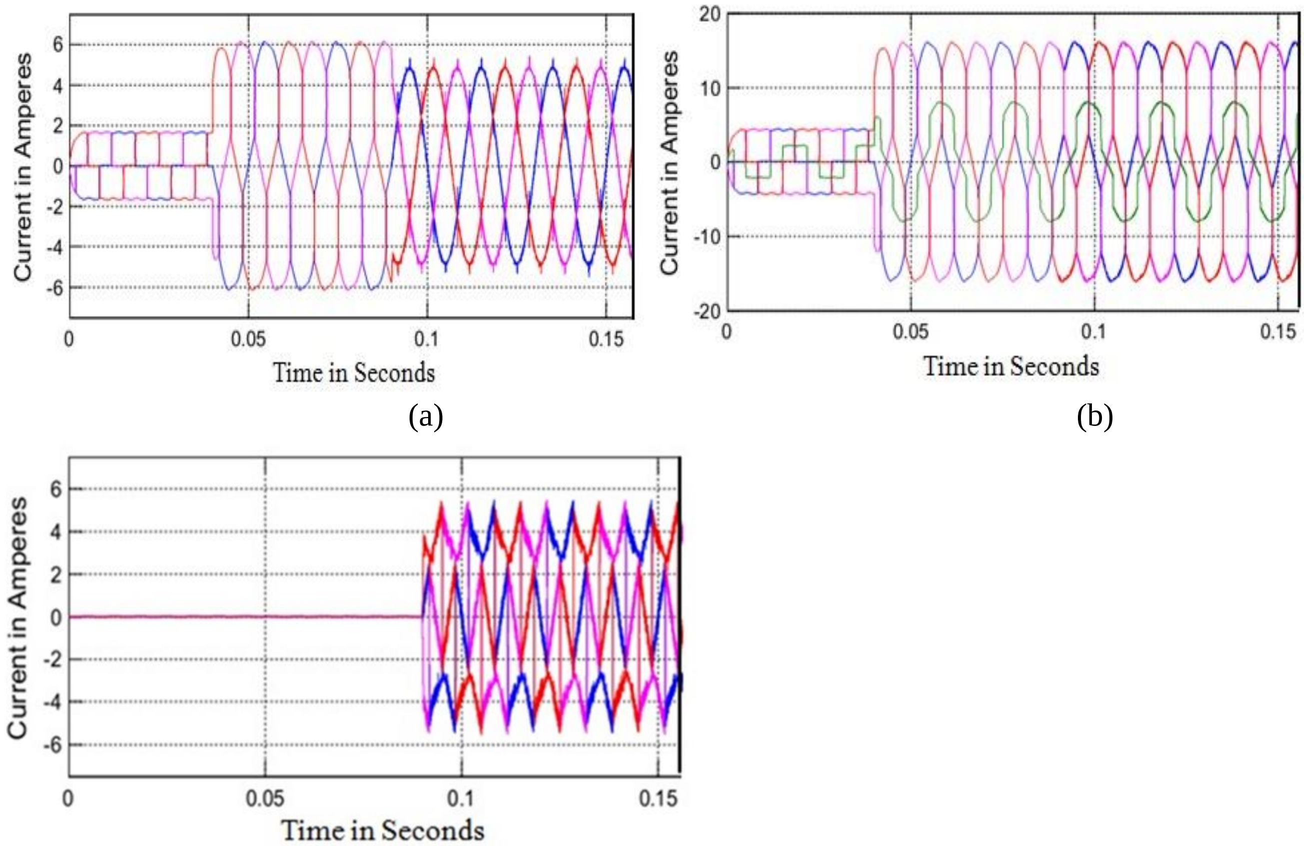


Fig.11 THD of Source Current after Compensation

Total Harmonic Distortion of Source Current after Compensation = 3.20%

Fig.10, Fig.11 gives the simulation result of three phase four wire shunt active power filter under nonlinear load condition. After compensation, THD of the source is reduced from 30.13% to 3.20% which is well below the recommended 5% limit.

B.CASE 2: BALANCED NON-LINEAR LOAD



(a) (b)

(c)

Fig.12 Simulation results Balanced Non-Linear Load (b) Source Current (c) Load Current (d) Inverter Current

Fig.12 shows the source current, load current, inverter compensating current respectively. The inverter is turned on at 0.1 seconds. Fig.12 (a): it clearly indicates the source current from 0 to 0.1 sec represents the balance nonlinear nature due to the presence of balance nonlinear load. At 0.1 seconds the nature of waveform is almost sinusoidal this represents the inverter compensated the balanced nonlinear wave to balanced sinusoidal wave. The load current waveform is shown in Fig.12(b) .The inverter supplies the compensating current that is shown in Fig.12(c).

- **THD ANALYSIS OF BALANCED NON-LINEAR LOAD**

➢ **THD OF SOURCE CURRENT BEFORE COMPENSATION**

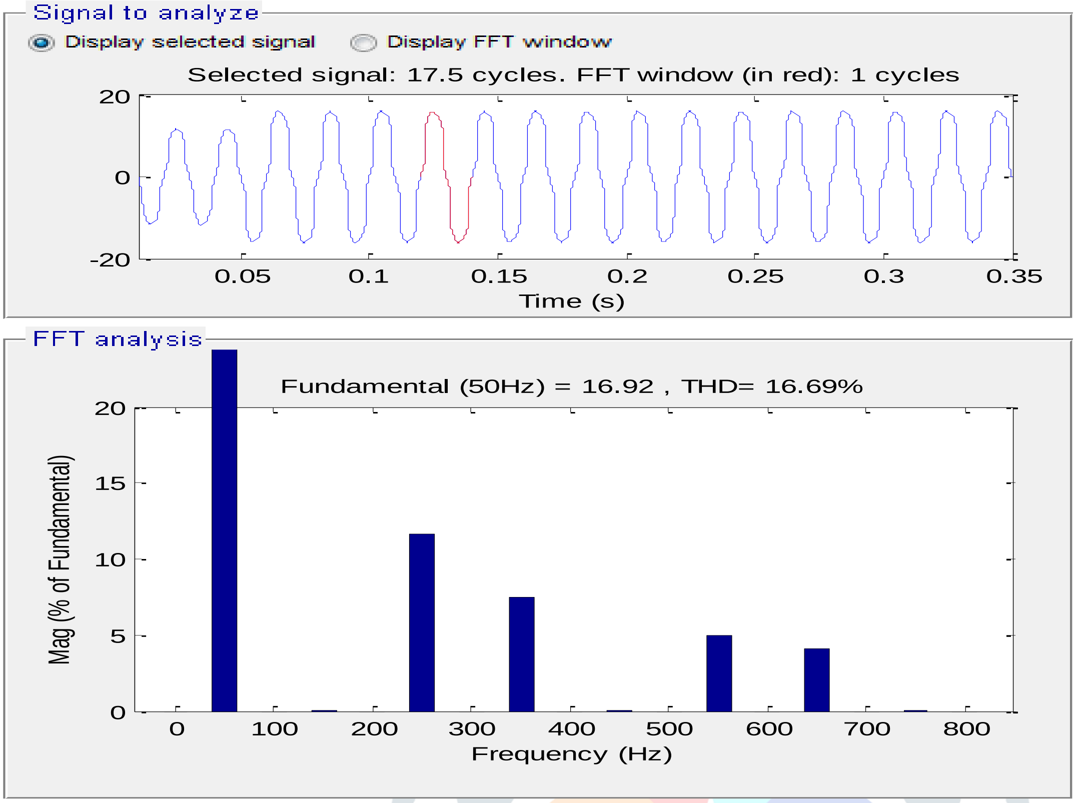


Fig.13 THD of Source Current before Compensation

Total Harmonic Distortion of Source Current before Compensation =16.69%

➢ **THD OF SOURCE CURRENT AFTER COMPENSATION**

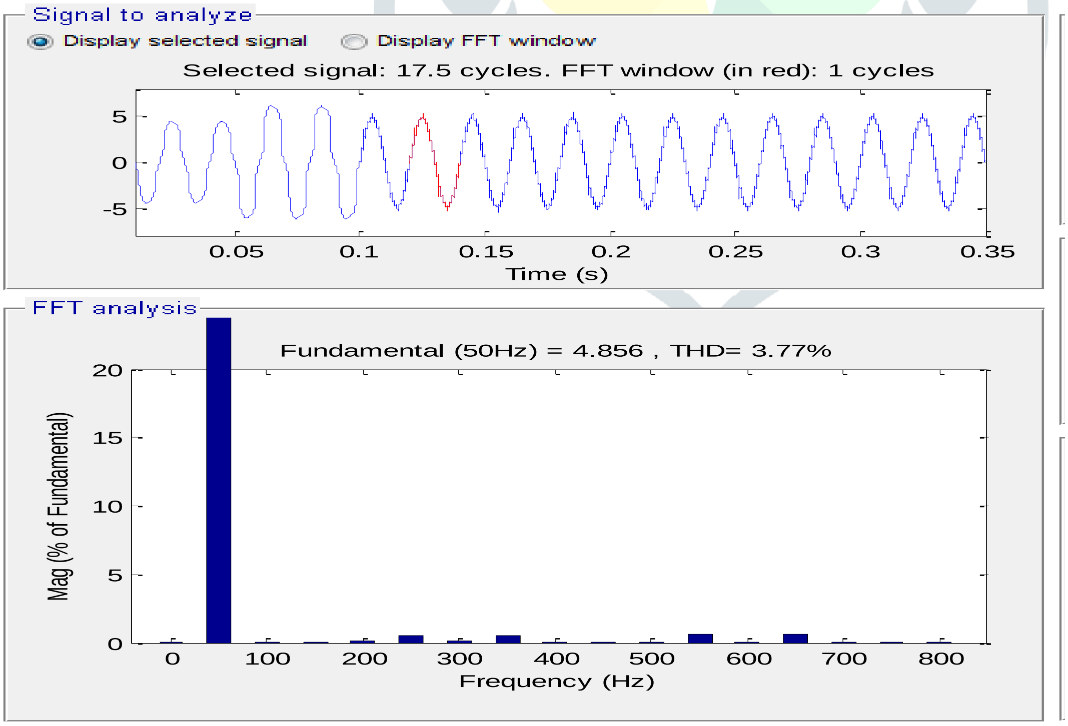
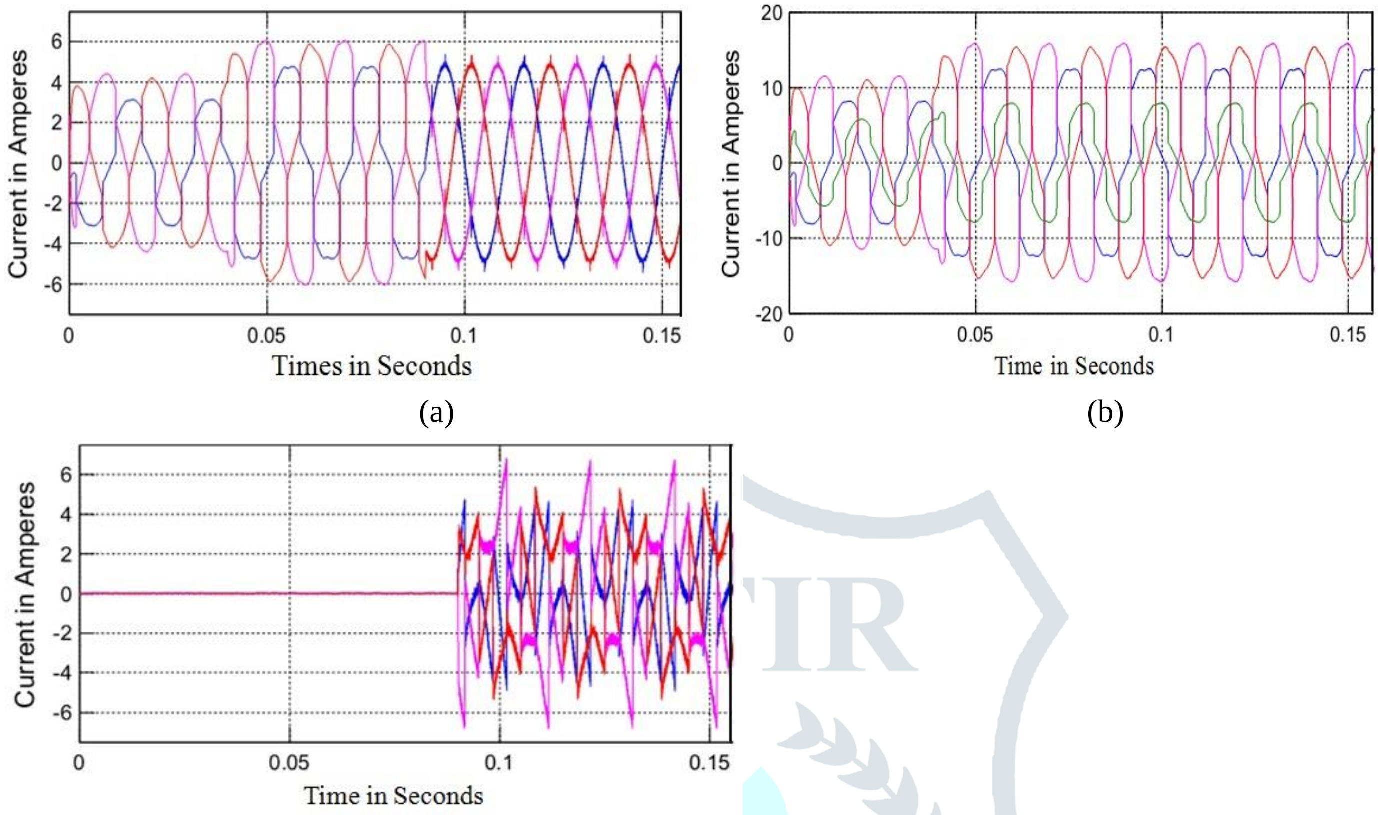


Fig.14 THD of Source Current after Compensation

Total Harmonic Distortion of Source Current after Compensation =3.77%

Fig.13, Fig.14 gives the simulation result of three phase four wire shunt active power filter under Balanced Nonlinear Load condition. After compensation, THD of the source is reduced from 14.6% to 3.77% which is well below the recommended 5% limit.

C.CASE 3: UNBALANCED NON-LINEAR LOAD



(a) (b) (c)

Fig.15 Simulation results Unbalanced Non-Linear Load (a) Source Current (b) Load Current (c) Inverter Current.

Fig.15: shows the source current, load current, inverter compensating current respectively. The inverter is turned on at 0.1 seconds. Fig.15 (a): it clearly indicates the source current from 0 to 0.1 sec represents the unbalance and non-sinusoidal nature due to the presence of unbalance nonlinear load. At 0.1 seconds the nature of waveform is sinusoidal this represents the inverter compensated the both unbalance and non-sinusoidal wave to balanced sinusoidal wave. The load current waveform is shown in Fig.15 (b) .The inverter supplies the compensating current that is shown in Fig.15 (c).

- **THD ANALYSIS OF UNBALANCED NON-LINEAR LOAD**
  - **THD OF SOURCE CURRENT BEFORE COMPENSATION**

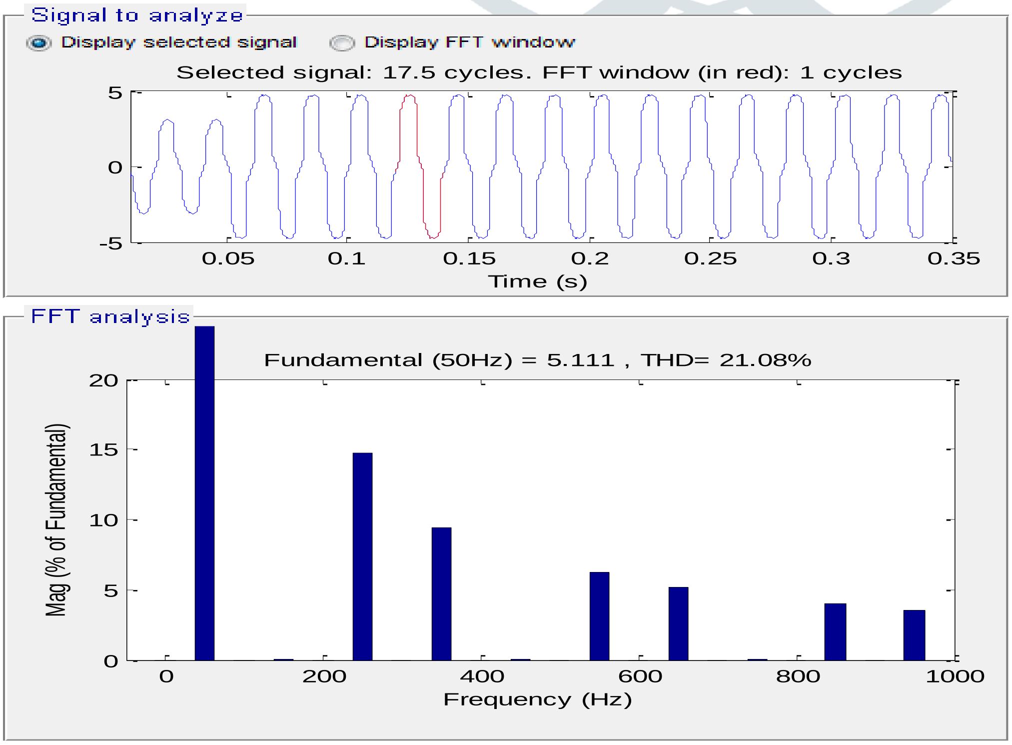


Fig.16 THD of Source Current before Compensation

Total Harmonic Distortion of Source Current before Compensation =21.08%

- **THD OF SOURCE CURRENT AFTER COMPENSATION**

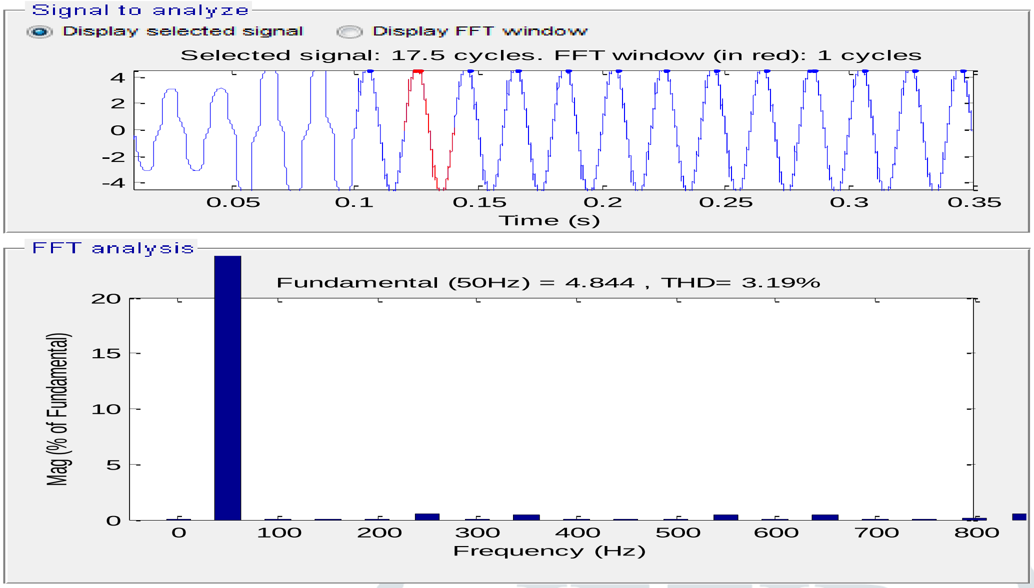


Fig.17 THD of Source Current after Compensation

Total Harmonic Distortion of Source Current after Compensation = 3.19%

Fig.17 gives the simulation result of three phase four wire shunt active power filter under Unbalanced Nonlinear Load condition. After compensation, THD of the source is reduced from 21.08% to 3.19% which is well below the recommended 5% limit.

D.CASE 4: THD ANALYSIS FOR DIFFERENT COMBINATION OF LOADS USING ANN:

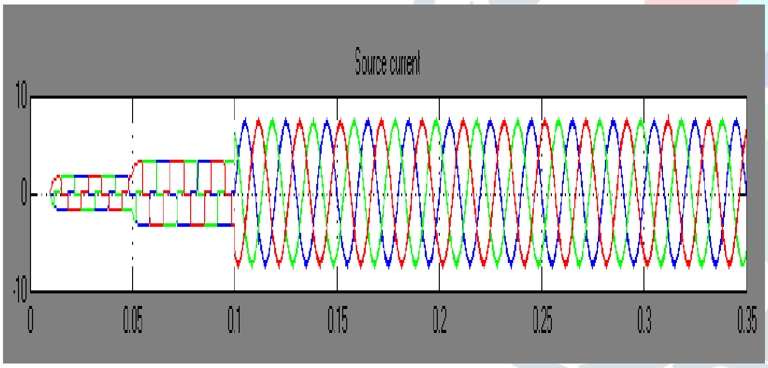


Fig.18 Source Current after Compensation USING ANN

Fig.18 shows the source current waveform. The inverter is turned on at 0.1 seconds. It clearly indicates the source current from 0 to 0.1 sec represents the non-sinusoidal nature due to the presence of nonlinear load .At 0.1 second the nature of waveform is sinusoidal this represents the inverter compensated the non-sinusoidal wave to balanced sinusoidal wave.

- **THD ANALYSIS OF NONLINEAR LOAD AFTER COMPENSATION USING ANN**

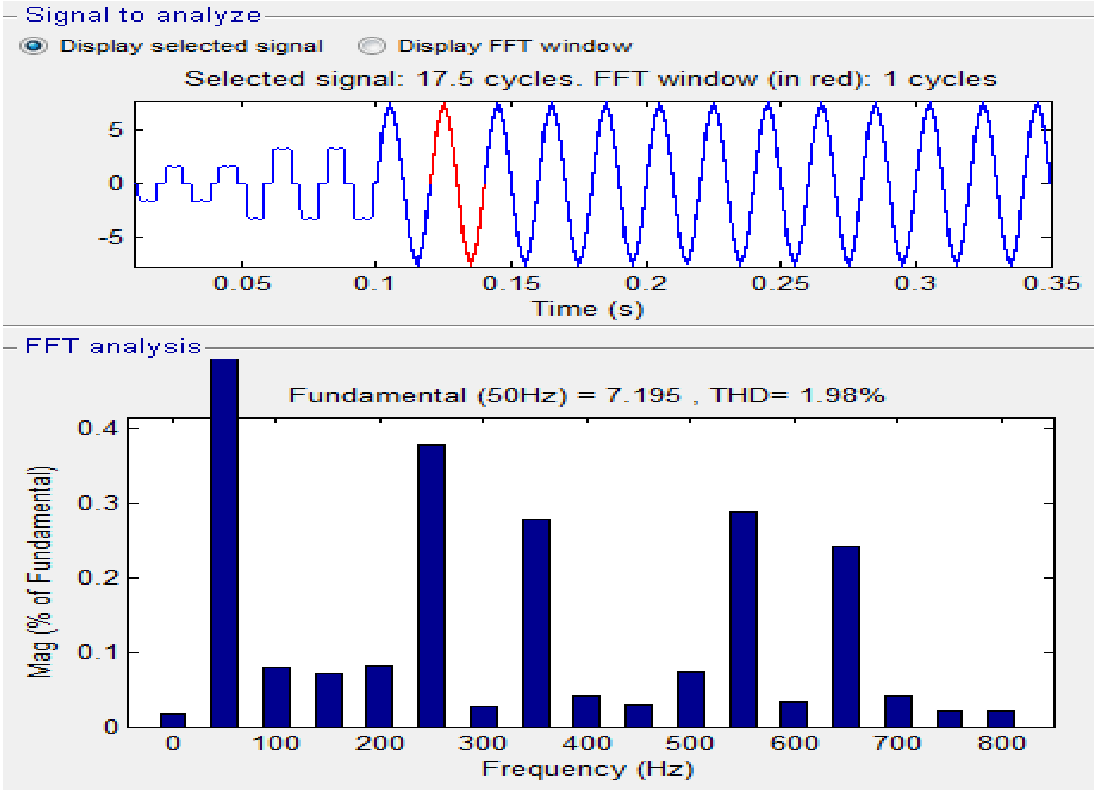


Fig.19 THD of source current with non-linear load after compensation using ANN

After compensation using ANN, THD of the source current is reduced from 3.20% to 1.98% which is well below the recommended 5% limit.

- **THD ANALYSIS OF UNBALANCED NONLINEAR LOAD AFTER COMPENSATION USING ANN**

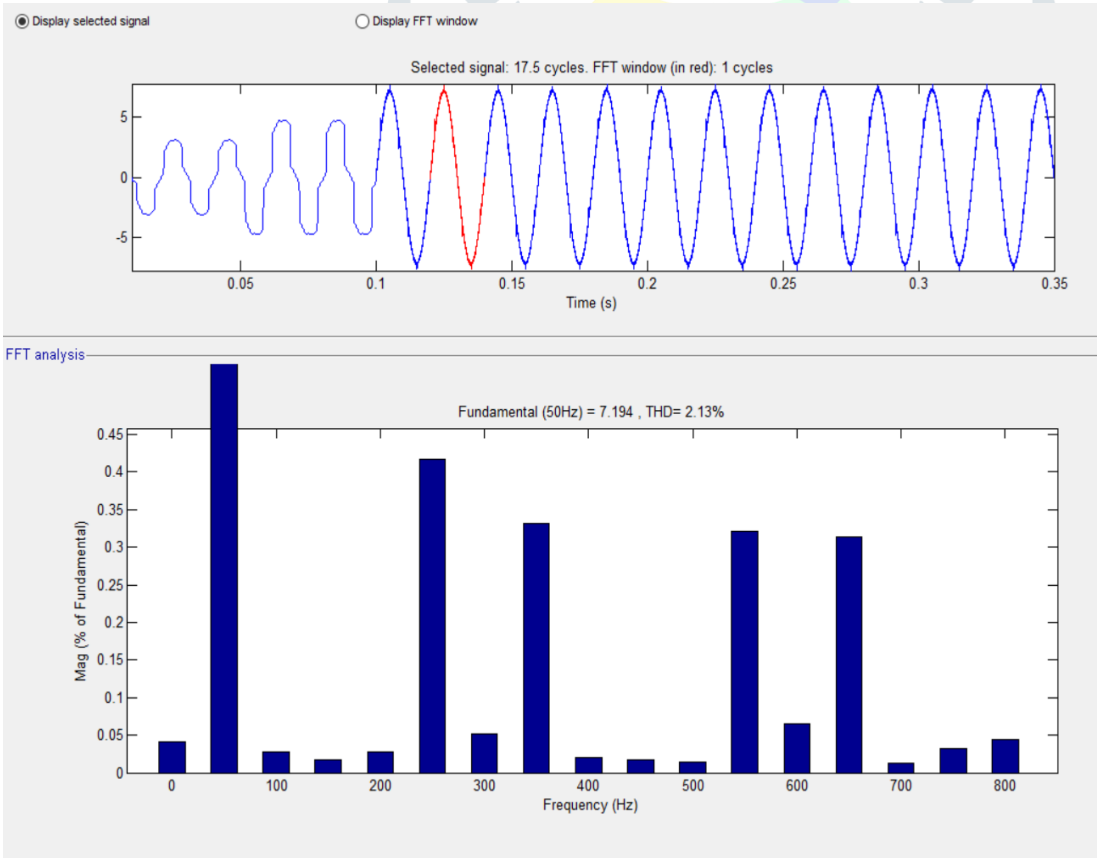


Fig.5.20 THD of source current with unbalanced non-linear load after compensation using ANN

After compensation using ANN, THD of the source current is reduced from 3.19% to 2.13% which is well below the recommended 5% limit.

- **THD ANALYSIS OF BALANCED NONLINEAR LOAD AFTER COMPENSATION USING ANN**

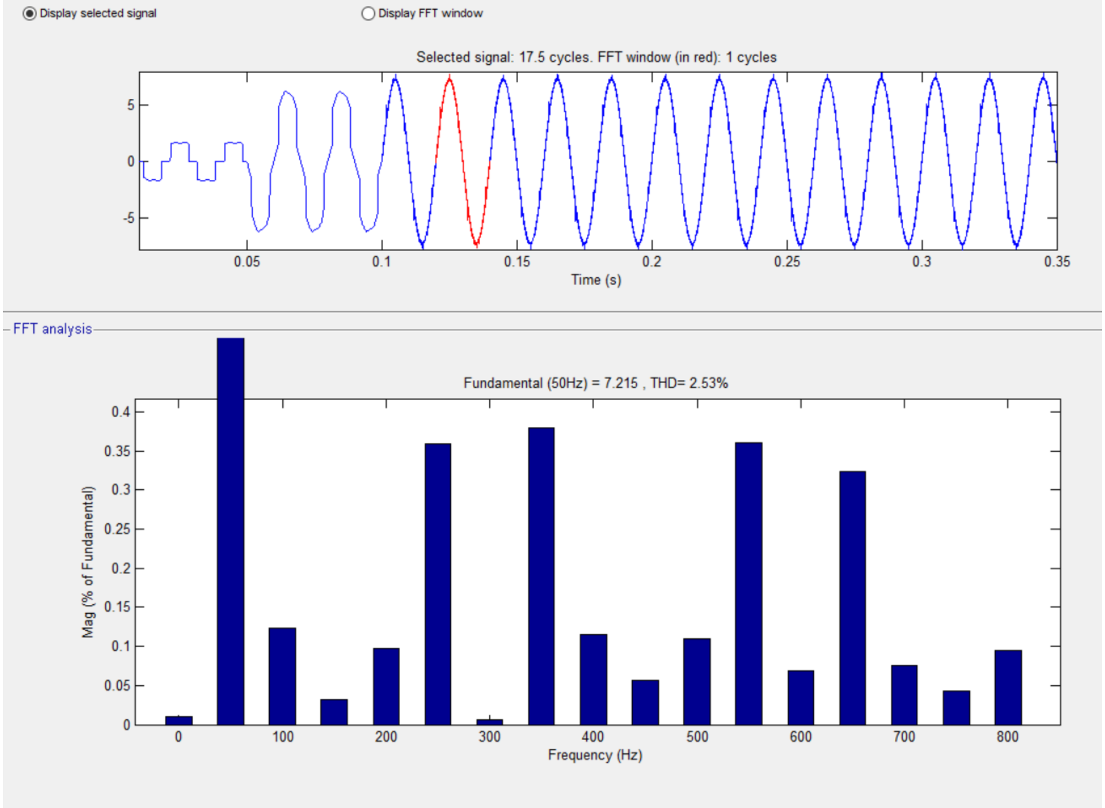


Fig.21 THD of Source Current with balanced non-linear load after Compensation using ANN

After compensation using ANN, THD of the source current is reduced from 3.77% to 2.53% which is well below the recommended 5% limit.

S.NO	Combination of loads	THD before compensation	THD using PI Controller	THD using ANN
1.	NL load	30.13%	3.20%	1.98%
2.	NL+UB load	21.08%	3.19%	2.13%
3.	B+NL load	16.69%	3.77%	2.53%

NL= Non-Linear B= Balanced UB= UnBalanced

Table:1 THD Analysis for different combination of loads

VII.CONCLUSIONS AND FUTURE SCOPE

A.CONCLUSIONS

1. Shunt active power filter is modeled and connected to three phase four wire distribution system through an inverter.
2. It can be concluded that the grid interfacing inverter is functioning as a conventional inverter as well as an Active Power Filter.
3. From the results, it can also be concluded that the grid interfacing inverter is maintaining sinusoidal source current with reduced THD under various load conditions.
4. PI controller and ANN controllers are used to mitigate the harmonics. ANN controller helps to reduce the THD of source current to a greater extent compared to PI controller.

B.SCOPE FOR FUTURE WORK

In this thesis, the inverter is utilized to work as shunt active power filter as well as conventional inverter by using PI control with hysteresis current control technique.

This work can be extended

i. By changing control scheme like fuzzy network, PID control techniques.
ii. By using load side control technique like PQ theory.

VIII.REFERENCES

[1] J. M. Guerrero, L. G. de Vicuna, J. Matas, M. Castilla, and J. Miret, "A wireless controller to enhance dynamic performance of parallel inverters in distributed generation systems," IEEE Trans. Power Electron.,vol. 19, no. 5, pp. 1205–1213, Sep. 2003.

[2] Janakrani Wadhawan, Updesh Pandey, Mala Yadav, Amit Kumar Kesarwani, 2020, A Review on Power Quality Problems and Improvement Techniques, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) ENCADEMS – 2020 (Volume 8 – Issue 10),

[3] POWER QUA.LITY: A UTILITY AND INDUSTRY PERSPECTIVE Jeff G. Dougherty, Member Duke Power Company P. 0. Box 1006 Charlotte, NC 28201-1006 Wayne L. Stebbins, Senior Member Hoechst Celanese Corporation 2850 Cherry Road Rock Hill, SC 29730-8998

[4]Singh.B, Chandra.A, Al-Haddad.K, "A review of active filters for power quality improvement," IEEE Trans. Industrial Electronics, Vol. 46, pp. 960-971, Oct. 1999

[5]J. H. R. Enslin and P. J. M. Heskes, "Harmonic interaction between a large number of distributed power inverters and the distribution network,"IEEE Trans. Power Electron., vol. 19, no. 6, pp. 1586–1593,Nov. 2004

[6]Ron A. Adams, Power Quality: A Utility Perspective, AEE Technical Conference Paper, October, 1996 Special Feature: Power quality Solutions to the power quality problem by Prof. Ray Arnold

[7] L. Gyugi and E. C. Strycula, "Active AC Power Filters", IEEE-IAS Annual Meeting Record, 1976, pp. 529-535.

[8] V. Khadkikar, A. Chandra, A. O. Barry, and T. D. Nguyen, "Application of UPQC to protect a sensitive load on a polluted distribution network," in Proc. Annu. Conf. IEEE Power Eng. Soc. Gen. Meeting, 2006, pp. 867–872.

[9] Khadkikar V, Agarwal P, Chandra A, Barry A O and Nguyen T.D, "A simple new control technique for unified power quality conditioner (UPQC)", Harmonics and Quality of Power, 2003. 11th International Conference on 12- 15 Sept. 2004, pp. 289 – 293

[10] Hirofumi Akagi, Akira Nabae, Satoshi Atoh, "Control Strategy of Active Power filters using multiple filters using multiple voltage source PWM converters",IEEE transactions on Industry Applications, Vol 1A-22, No 3, May/June 1986

[11] Munk-Nielsen S., Vaerens M., Sundvall J., "Three level MV converter using serial connected IGBT's," European Conference on Power Electronics and Applications, 2009,pp.1-7.

[12] D. B. Nelson, M. H. Nehrir, and C. Wang, ―Unit Sizing and Cost Analysis of Stand-Alone Hybrid Wind/PV/Fuel Cell Power Generation Systems,‖ Renewable Energy, pp. 1641-1656, Aug. 2004.

[13] Francisco M. González-Longatt ,"Model of Photovoltaic Module in Matlab™"

[14] Mukhtiar Singh, Student Member, IEEE, VinodKhadkikar, Member, IEEE, Ambrish Chandra, Senior Member, IEEE and Rajiv K. Varma, Senior Member,IEEE "Grid Interconnection of Renewable Energy Sources at the Distribution Level With Power-Quality Improvement Features."IEEE Transactions On Power.

[15] M. Karthikeyan, K. Sharmilee, P.M. Balasubramaniam, N.B. Prakash, M. Rajesh Babu, V. Subramaniyaswamy, S.Sudhakar,Design and implementation of ANN-based SAPF approach for current harmonics mitigation in industrial power systems,Microprocessors and Microsystems, Volume 77, 2020, 103194, ISSN 0141-9331.