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Power Quality Improvement Using Artificial Neural Networks with Renewable Energy Sources

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***Abstract* – Renewable energy resources (RES) are being increasingly connected in distribution systems utilizing power electronic converters. This project presents a novel control strategy for achieving maximum benefits from these grid-interfacing inverters when installed in 3-phase 4-wire distribution systems. The inverter is controlled to perform as a multi-function device by incorporating active power filter functionality. The inverter can thus beutilized as: 1) power converter to inject power generated from RES to the grid, and 2) shunt APF to compensate load current harmonics. All of these functions may be accomplished either individually or simultaneously. With such a control, the combination of grid-interfacing inverter and the 3-phase 4-wire linear/non-linear unbalanced load at point of common coupling appears as balanced linear load to the grid. This new control concept is demonstrated with extensive MATLAB/Simulink simulation studies.**

***Keywords:* photovoltaic cell (PV cell); Active power filter (APF); Hysteresis current control (HCC); Renewable Energy Sources (RES), ANN.**

I. INTRODUCTION

Now a days, issues like air pollution, global warming concerns, decreasing fossil fuels and their increasing cost have made it to look towards the alternative sources like renewable sources as a future energy solution. Among them Photovoltaic cell energy got much attention. After generation, we need to integrate it with already existing power system by using power electronic devices. The extensive use of electronics devices causes harmonic injection into the system which is undesirable [1], [2]. Because of the harmonics some of the problems are equipment overheating, damage devices, EMI related problems etc. For compensating these harmonics and load disturbances Active power filters (APF) [3] are used, which causes extra hard ware cost. There are certain controlling techniques like p-q theory [4], to make these interfacing inverters to work as power quality compensating devices. In this work a control technique is proposed to the PV based inverter to acts like shunt APF to compensate these current harmonics and current unbalancing problems apart from basic power conversion function. Here this PV based inverter connected in shunt with the load at point of common coupling. Thus with the help of this Hysteresis current control technique, the inverter will keep the supply current balanced.

II. SYSTEM UNDER CONSIDERATION

The system consists of a PV cell as a RES connected to a current controlled voltage source inverter with a dc capacitor link as shown in Fig. 1.

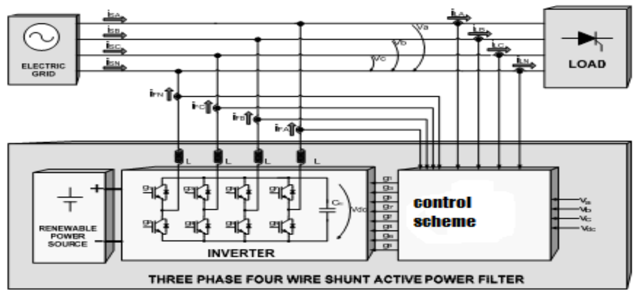

Fig.1. System under consideration

A. Photovoltaic energy panel

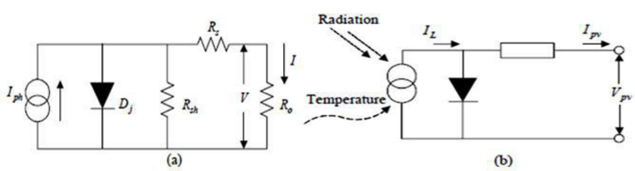

Fig. 2. solar cell (a) equivalent circuit (b) Simplified circuit

PV cell is a energy conversion device, which uses solar energy to generate electric energy and amount of production of electric energy depends upon the solar irradiation, temperature and incident photon wave length.

B. DC link capacitor

The power generated by this PV cell is variable in nature as it depends on sun light. To transfer this variable power to the system, a dc-link capacitor plays important role. The output of this capacitor carries the information regarding the power transfer between RES to the system. This power flow is represented in Fig. 3.

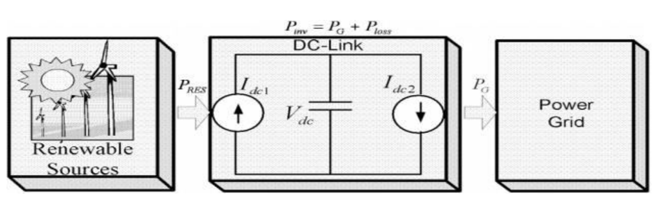

Fig. 3. DC-Link equivalent diagram.

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C. Voltage Sources Current Controlled Interfacing Inverter

A voltage sources current inverter is a power electronic converter which is connected in parallel with the system. The basic function of this converter is to convert the dc voltage into a balanced three phase ac voltage. It can also able to deliver or absorb the reactive power to/from the grid system. If the inverter output voltage is greater than the existing system voltage then the inverter acts in capacitive mode. The switching devices used in this VSCC inverter is an IGBT in anti-parallel with a diode.

D. Control technique used for interfacing inverter to act as shunt APF

The turn On and turn Off instants of inverter switches should be such that the load and the connected RES could be appeared as a balanced load to the system. For this kind of control, we need to monitor the output of dc link capacitor continuously and is compared with reference voltage $Vdc*$, after passing through a LPF. The difference between these voltages will go through a voltage regulator, whose final out put gives an active component Im. By multiplying this peak value (Im) with the three-unit sine vectors (Ua , Ub and Uc) ,which are in phase with the three source voltages will generate the reference current templates (Ia*,Ib*,and Ic*).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. The grid synchronizing angle (θ) obtained from phase locked loop (PLL) [7] is used to generate unity vector template as

$$U_a = Sin\Theta \quad (1)$$

$$U_a = Sin(\Theta-2\prod/3) \quad (2)$$

$$U_a = Sin(\Theta+2\prod/3) \quad (3)$$

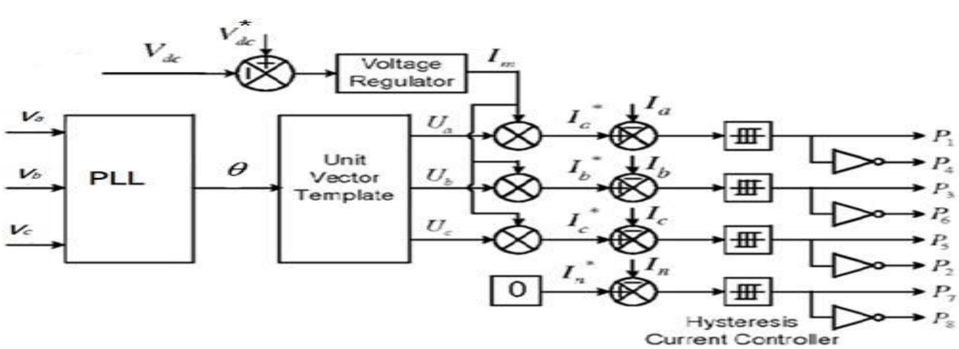

Fig. 4. Block diagram representation of grid-interfacing inverter control

Artificial Neural Networks

Numerous advances have been made in developing intelligent systems, some inspired by biological neural networks. Researchers from many scientific disciplines are designing artificial neural networks to solve a variety of problems in pattern recognition, prediction, optimization, associative memory, and control. Conventional approaches have been proposed for solving these problems. Although successful applications can be found in certain well-constrained environments, none is flexible enough to perform well outside its domain. ANNs provide exciting alternatives, and many applications could benefit from using them. This article is for those readers with little or no knowledge of ANNs to help them understand the other articles in this issue of Computer.

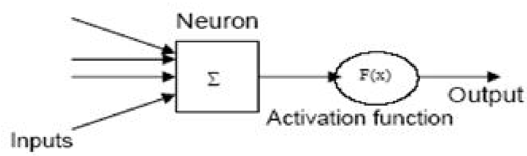

Fig. 5 Simple Artificial Neuron

The long course of evolution has given the human brain many desirable characteristics not present Invon Neumann or modern parallel computers. These include massive parallelism,distributed representation and computation, learning ability,Generalization ability

III. Simulation Results

The simulation of the proposed work has been carried out in MATLAB/SIMULINK Software. The performance of the proposed system under different load conditions is studied as follows.

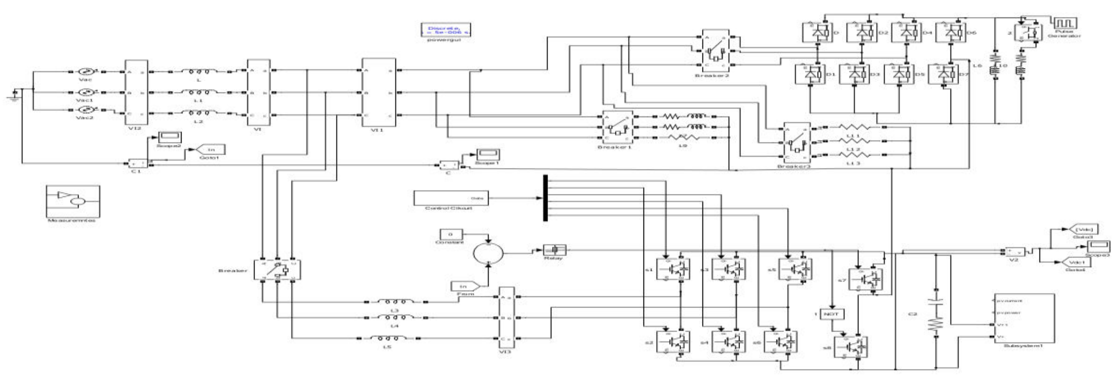

Fig .6: MATLAB Simulink model of the proposed system

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A. Nonlinear Load

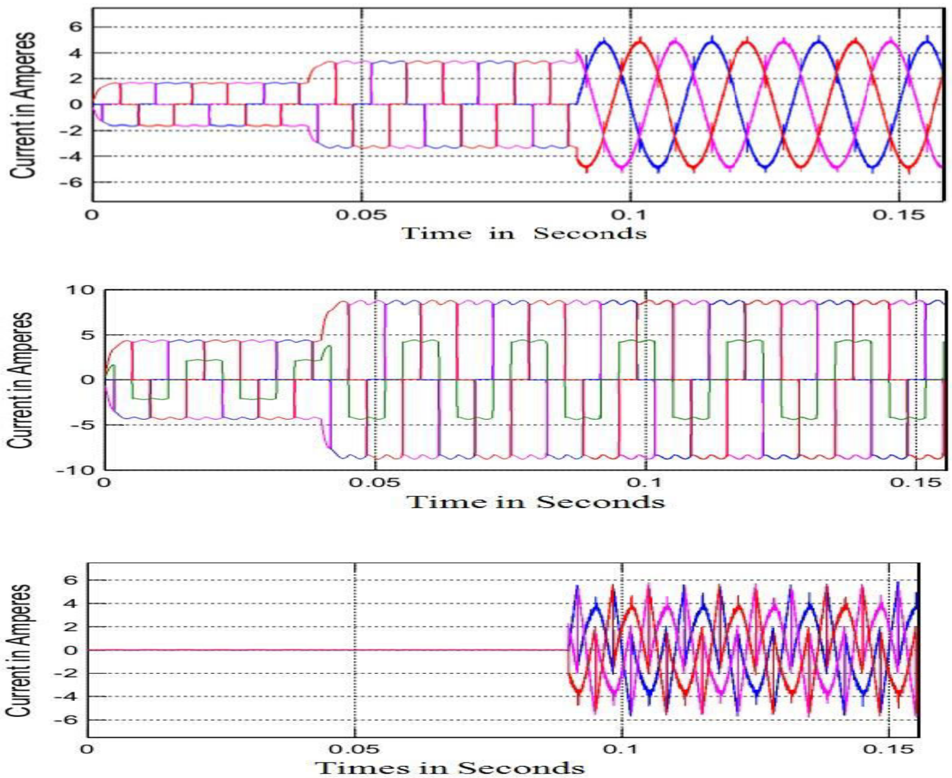

Fig. 7. Simulation results of Non- Linear Load (a) Source Current (b) Load Current (c) Inverter Current

It can be observed from Fig. 7 that from 0 to 0.09sec the waveform of source current is non sinusoidal due to nonlinear load. At 0.09 sec, when the inverter is turned On it starts compensating the non-sinusoidal current and make it sinusoidal. The load current and inverter compensating current is shown in Fig. 7. FFT analysis of Non Linear Load for before compensation and after compensation is shown in Fig. 8 and Fig. 9 respectively.

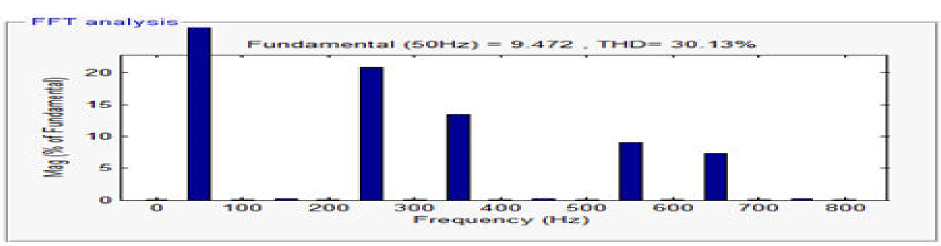

Fig. 8. THD of Source Current before Compensation

From FFT analysis THD of Source Current before Compensation is 30.13%.

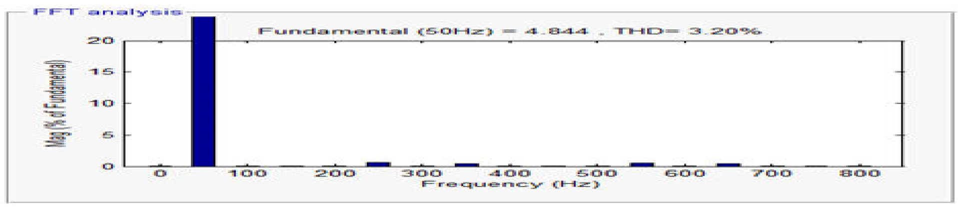

Fig. 9. THD of Source Current After Compensation

THD of Source Current after Compensation has been measured as 3.20%, it gets reduced from 30.13% to 3.2%.

B. Unbalanced Load

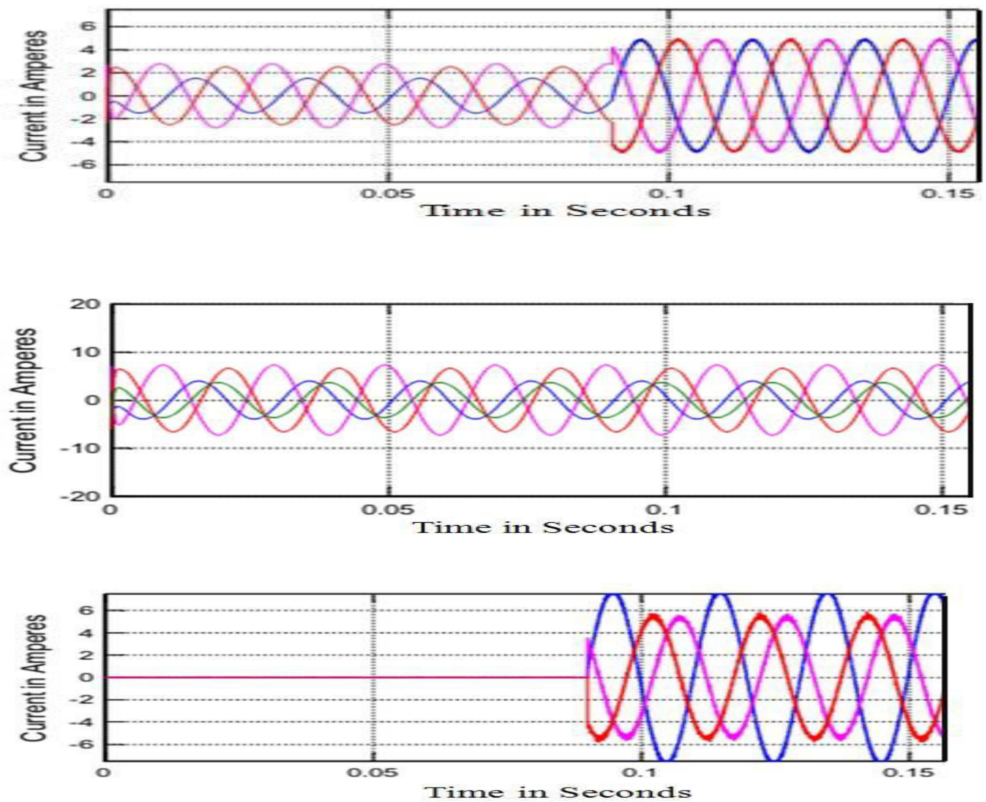

Fig. 10. Simulation results Unbalance Load (a) Source Current (b) Load Current (c) Inverter Current

It can be observed from Fig. 10(a) that from 0 to 0.09sec the waveform of source current is non sinusoidal due to unbalanced load. At 0.09 sec, when the inverter is turned it starts compensating the unbalanced sinusoidal current and make it balanced sinusoidal. The load current and inverter compensating current is shown in Fig. 10

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C. Balanced Nonlinear Load

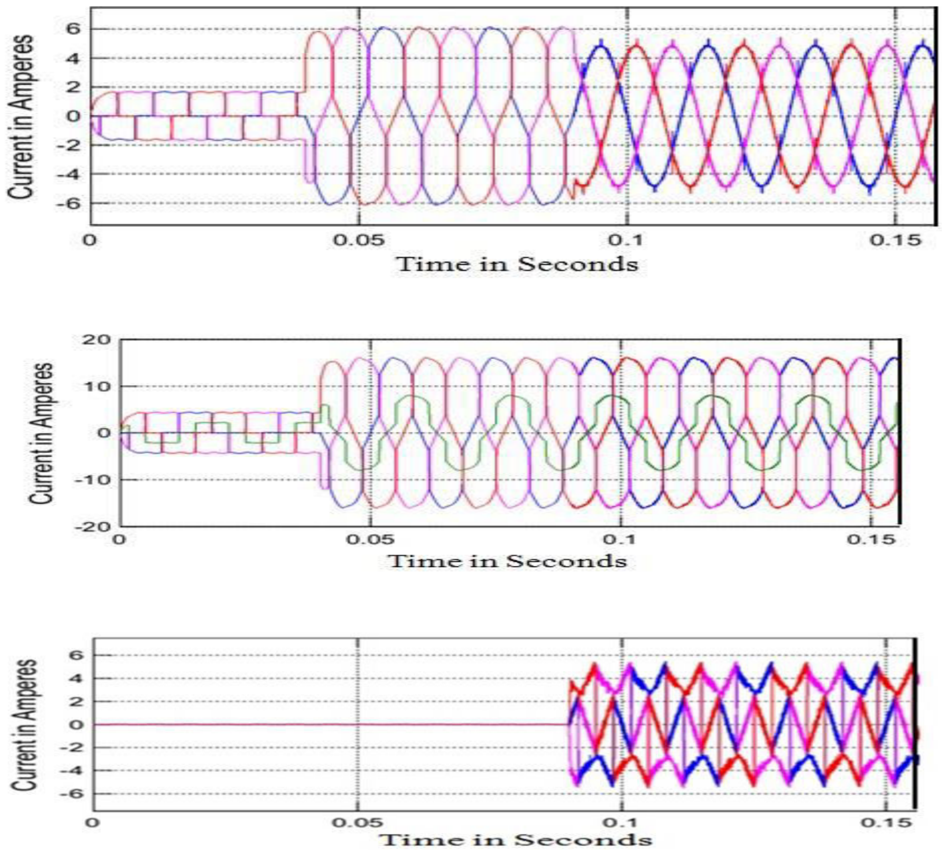


Fig. 11. Simulation results Balanced Nonlinear Load (a) Source Current (b) Load Current (c) Inverter Current

It can be observed from Fig. 11(a) that from 0 to 0.09sec the waveform of source current is non sinusoidal due to balanced nonlinear load. At 0.09 sec, when the inverter is turned it starts compensating the non sinusoidal current and make it balanced sinusoidal. The load current and inverter compensating current is shown in Fig. 11(b) and Fig. 11(c).

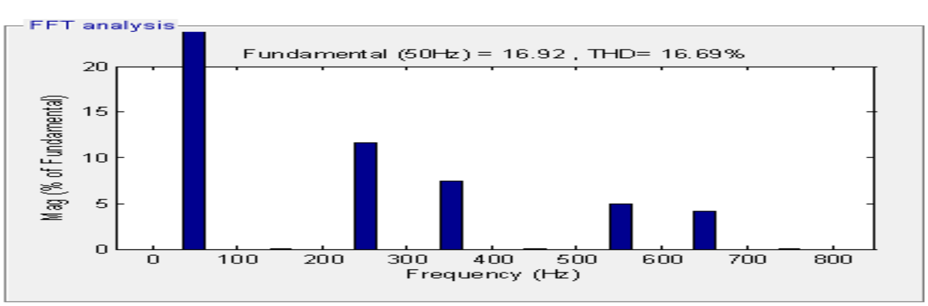


Fig. 12. THD of Source Current Before Compensation

From FFT analysis THD of Source Current Before Compensation is 16.69%.

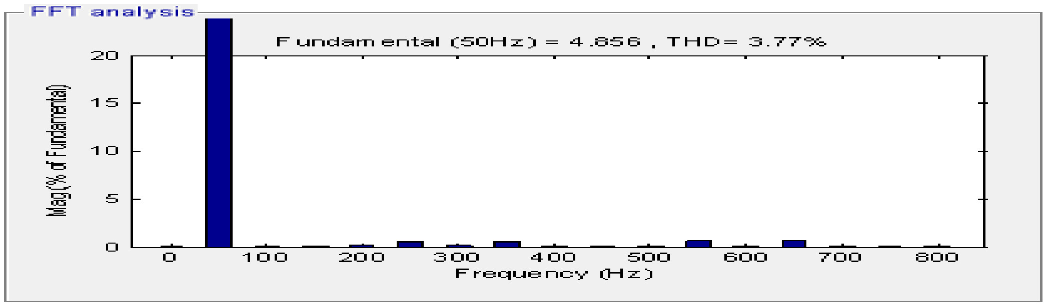
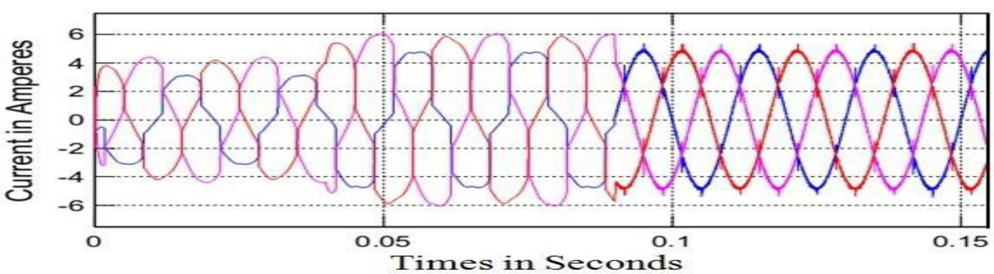
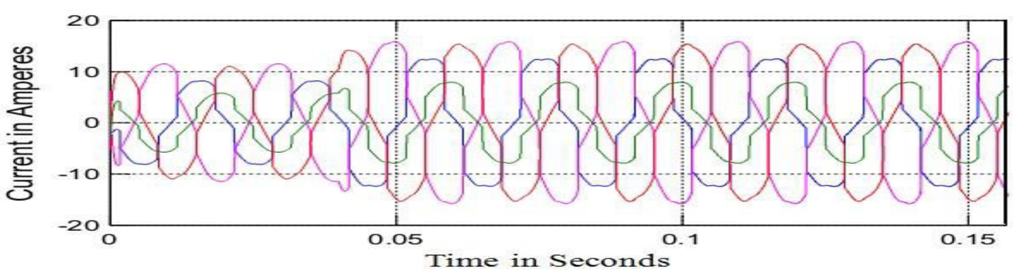


Fig. 13. THD of Source Current After Compensation

THD of Source Current after Compensation has been measured as 3.77%, it gets reduced from 16.69% to 3.77%.

D. Unbalanced Nonlinear Load





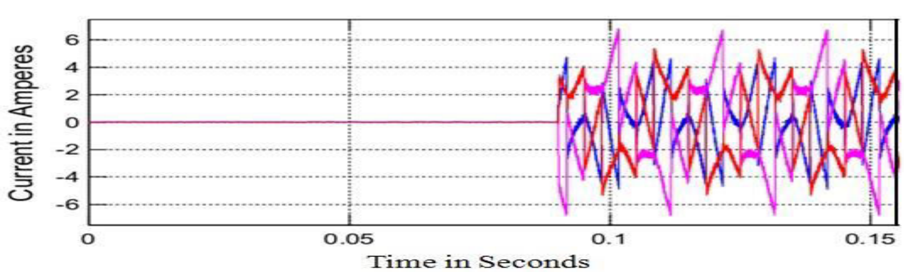


Fig. 14. Simulation results Unbalanced Nonlinear Load (a) Source Current (b) Load Current (c) Inverter Current
Load Current (c) Inverter Current

It can be observed from Fig. 14(a) that from 0 to 0.09sec the waveform of source current is unbalanced and non-sinusoidal due to unbalanced nonlinear load. At 0.09 sec, when the inverter is turned it starts compensating the unbalanced and non-sinusoidal current and make it balanced sinusoidal. The load current and inverter compensating current is shown in Fig. 14(b) and Fig. 14(c).

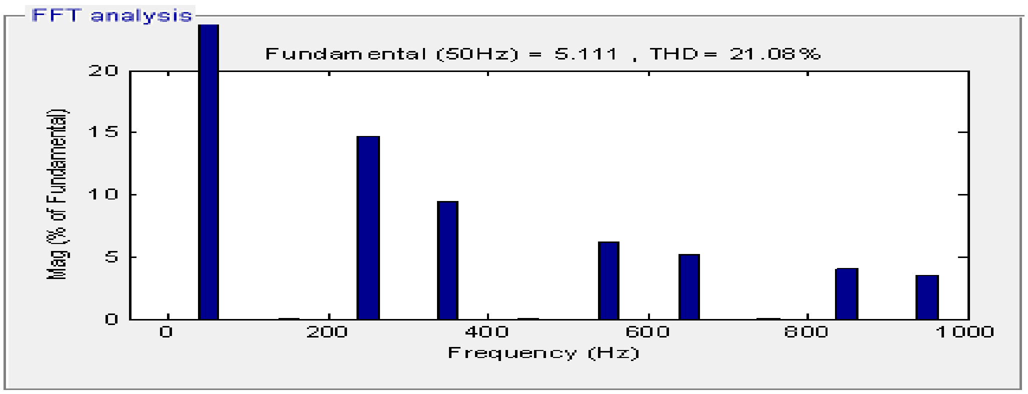


Fig. 15. THD of Source Current Before Compensation

From FFT analysis THD of Source Current Before Compensation is 21.08%.

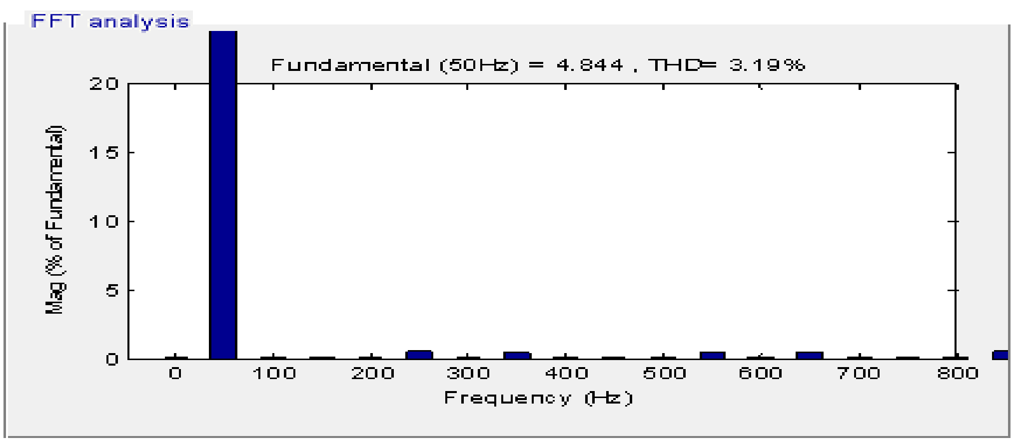


Fig. 16. THD of Source Current After Compensation

THD of Source Current after Compensation has been measured as 3.19%, it gets reduced from 21.08% to 3.19%.

E. THD Analysis for Different Hysteresis Bands

TABLE I. THD ANALYSIS FOR DIFFERENT HYSTERESIS BANDS

S.NO	**Hysteresis Band**	**Source Current THD Without Inverter**	**Source Current THD With Inverter**
1	0.05	21.08	3.24
2	0.1	21.08	2.98
3	0.15	21.08	3.10
4	0.2	21.08	3.65
5	0.25	21.08	3.68
6	0.3	21.08	3.41
7	0.35	21.08	3.50
8	0.4	21.08	3.54
9	0.45	21.08	3.58
10	0.5	21.08	3.57
11	0.55	21.08	3.78
12	0.6	21.08	3.82
13	0.65	21.08	4.12
14	0.7	21.08	3.98
15	0.75	21.08	4.15
16	0.8	21.08	3.65
17	0.85	21.08	3.64
18	0.9	21.08	3.54
19	0.95	21.08	3.77
20	1.0	21.08	3.66
21	1.5	21.08	4.09
22	2	21.08	4.53
23	2.5	21.08	5.05

From the Table I it can be observed that as the hysteresis bands increase the THD valves of source current increased.

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F. THD Analysis for Different Percentage Of Unbalanced Nonlinear Load

TABLE II. THD ANALYSIS FOR DIFFERENT PERCENTAGE OF UNBALANCED NONLINEAR LOAD

S.NO.	Percentage of Unbalanced Nonlinear Load	Source Current THD Without Inverter	Source Current THD With Inverter
1	10	28.63	3.18
2	20	27.54	3.21
3	30	26.53	3.53
4	40	25.59	3.11
5	50	24.71	3.22
6	60	23.89	3.52
7	70	23.12	3.19
8	80	22.40	2.95
9	90	21.72	3.20

From the above Table II it is observed that for different percentage of Unbalanced Nonlinear load to eliminate harmonics for various loads.

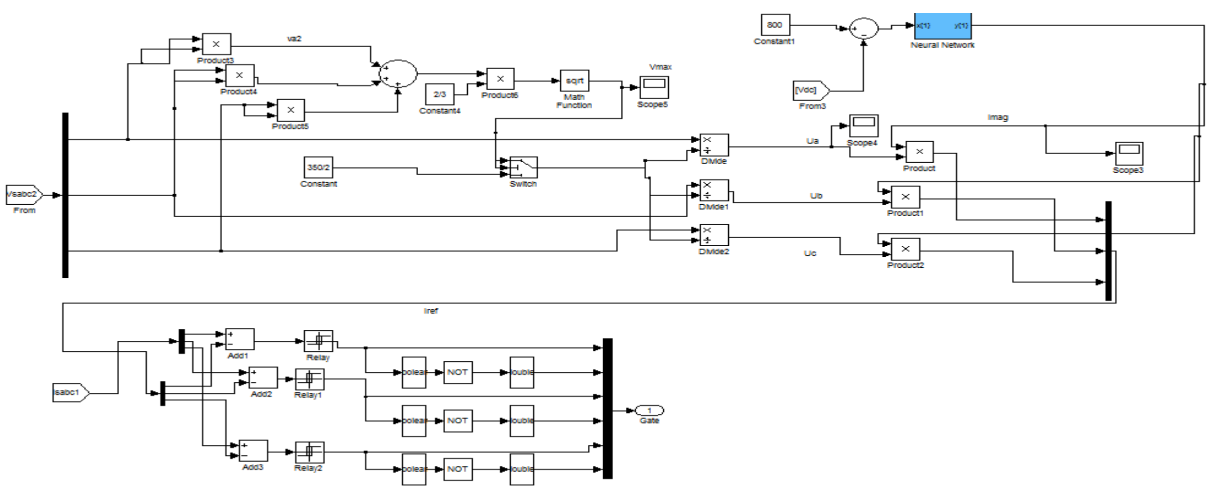

Fig.17 THD Inverter current control using ANN

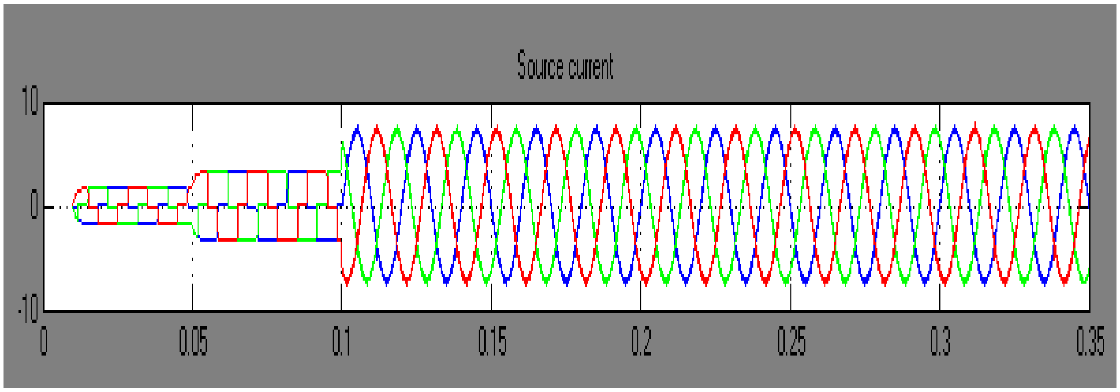

Fig.18 Source Current after Compensation USING ANN

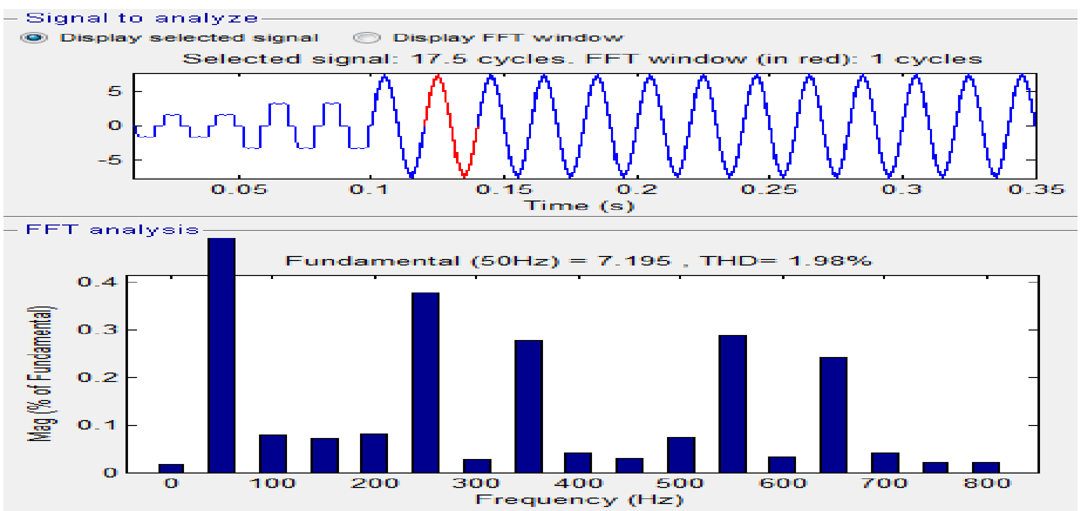

Fig.19 THD of Source Current after Compensation USING ANN

IV. Conclusion

The photovoltaic panel is modeled and connected to three phase four wire distribution system through an inverter. From the results, it can be concluded that the grid interfacing inverter is functioning as a conventional inverter as well as an Active Power Filter. It can also be concluded that the grid interfacing inverter is maintaining sinusoidal source current by reducing THD in supply under various load conditions. Pi controller and ANN controllers are used for Inverter current control. It is better to use ANN controller by replacing pi controller.

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