DC Voltage Feedback Control to Active Power Filter for Harmonic Reduction

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Abstract
This paper presents an active harmonic filter for non linear loads using feedback control loop technology. Due to non linear loading the input ac current wave gets distorted which leads to aging effect. Inorder to reduce the effect an active power filter is used to proved the harmonic current to the source with 180 degrees phase shift. Dc voltage feedback control is used to track the harmonic percentage and to develop a pulse sequence to the inverters. The model results are carried out using matlab simulation software.
Keywords: converter, rectifier, active power filter, harmonics

1. Introduction
Fossil fuels are our main source of energy and they are depleting. Fossil fuels are non renewable and environmentally damaging. Due to increasing air pollution, global warming concerns, diminishing fossil fuels and their increasing cost have made it necessary to look towards renewable sources as a future energy solution. There are many Renewable Energy Sources (RES) such as wind, solar, tidal power, biomass etc. Solar energy has great potential to supply energy with minimum impact on the environment, since it is clean and pollution free. In finding solutions to overcome a global energy crisis, the Photo Voltaic (PV) system has attracted significant attention in recent years. The government is providing incentives for further increasing the use of grid-connected PV systems. Conventionally, grid connected Photo Voltaic energy conversion systems are composed of an inverter. Renewable Energy Sources are increasingly integrated at the distribution level due to increase in load demand which utilize power electronic converters. There is a disturbance in the electrical network due to the extensive use of these power electronic devices. The disturbances are due to the use of non-linear devices. These will introduce harmonics in the power system thereby causing equipment overheating ,damage devices ,EMI related problems etc[1],[2]. Harmonics is considered as one of the most essential problems in electrical power systems. Harmonics in power distribution system are current or voltage that are integer multiples of fundamental frequency. For example if the fundamental frequency 50Hz, then 3rd is 150Hz, 5th is 250Hz. Ideally, voltage and current waveforms are perfect sinusoids. However, because of the increased popularity of electronic and non linear loads, these waveforms become distorted. This deviation from a perfect sine wave can be represented by harmonic components having a frequency that is an integral multiple of the fundamental frequency. Thus a pure voltage or current sine wave has no distortion and no harmonics and a non sinusoidal wave has distortion and harmonics. Several methods are described in various papers to solve these problems.

2. RENEWABLE BASED DISTRIBUTED GENERATION SYSTEM
The proposed system is Three Phase Four wire which consists of Photovoltaic system connected to the dc-link of a grid-interfacing inverter as shown in Fig.4.1. 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 Photovoltaic system 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.

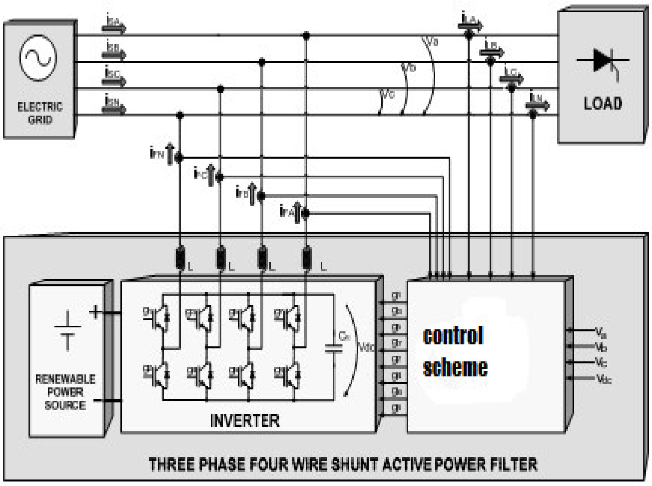

Fig .1: Proposed Three Phase Four Wire System

2.1 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.

Voltage source converters are preferred over current source converter because it is higher in efficiency and lower initial cost than the current source converters. They can be readily expanded in parallel to increase their combined rating and their switching rate can be increased if they are carefully controlled so that their individual switching times do not coincide. Therefore, higher-order harmonics can be eliminated by using converters without increasing individual converter switching rates.

2.2 CONTROL TECHNIQUE USED FOR INTERFACING

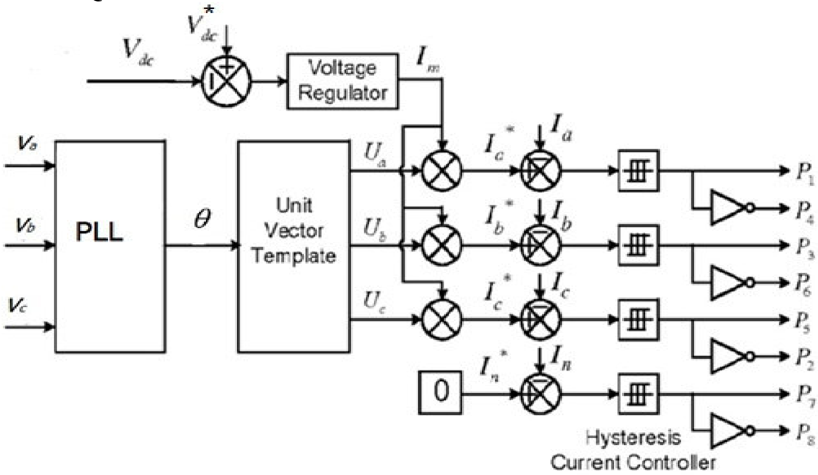

Fig 2: Control scheme

The turn on and turn off instants of inverter switches should be such that the load and the connected RES could appear as balanced load to the system. 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 (Ө) obtained from phase locked loop (PLL) is used to generate unity vector template as

2.3 HYSTERESIS CURRENT CONTROL

The hysteresis current control (HCC) is the easiest control method to implement; it was developed by Brod and Novotny in 1985. The shunt APF is implemented with three phase current controlled VSI and is connected to the ac mains for compensating the current harmonics. The VSI gate control signals are brought out from hysteresis band current controller

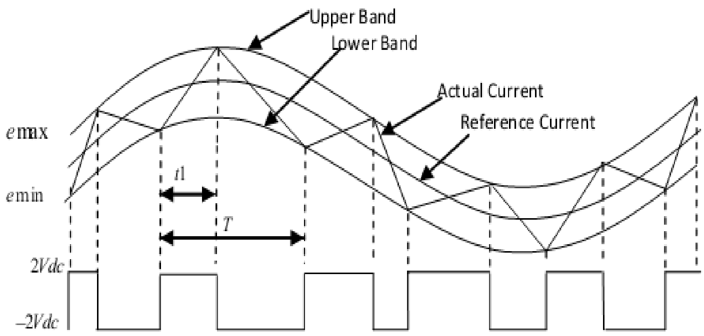

Fig:3 Waveform of Hysteresis current controller

A hysteresis current controller is implemented with a closed loop control system and waveforms are shown in Fig 4.4. An error signal exceeds the upper limit of the hysteresis band, the upper switch of the inverter arm is turned off and the lower switch is turned on. As a result, the current starts decaying. If the error crosses the lower limit of the hysteresis band, the lower switch of the inverter arm is turned off and the upper switch is turned on. As a result, the current gets back into the hysteresis band. 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.

2.4 SIMULINK MODEL OF HYSTERESIS CURRENT CONTROL

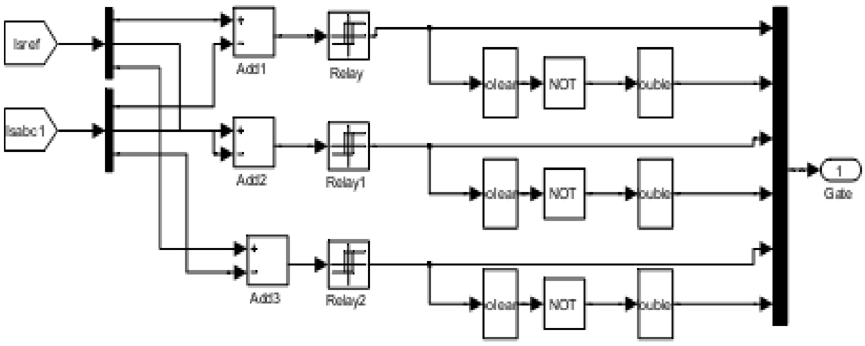

Fig. 4: Simulink Model of Hysteresis Current Control

2.5 MATLAB /SIMULINK MODEL OF PI CONTROL

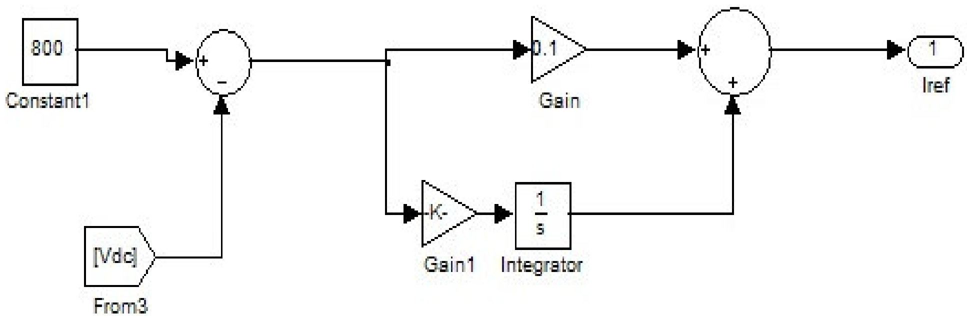

Fig.5: MATLAB Simulink model of PI control

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3.FUZZY SYSTEM

The fuzzy interface system Fuzzy system basically consists of a formulation of the mapping from a given input set to an output set using Fuzzy logic. The mapping process provides the basis from which the interference or conclusion can be made.

A Fuzzy interface process consists of following steps

Step 1: Fuzzification of input variables.
Step 2: Application of Fuzzy operator.(AND, OR, NOT) In the IF (antecedent) part of the rule.
Step 3: Implication from the antecedent to the consequent (Then part of the rule).
Step 4: Aggregation of the consequents across the rules.
Step 5: Defuzzification.

Generally there will be a matrix of rules similar tot eh ES rule matrix for Ex: There are 7MF for input variables 'x' and MF for input variable 'y' then there will be all together35 rules.

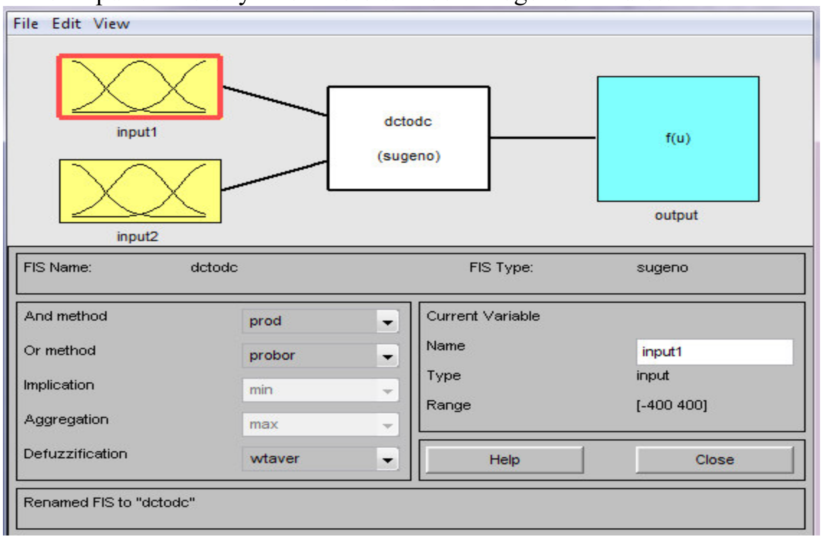

Fig3.1 Fuzzy controller

4.SIMULATION DESIGN

A simulation design open loop system as shown in **Fig.** is implemented in MATLAB SIMULINK

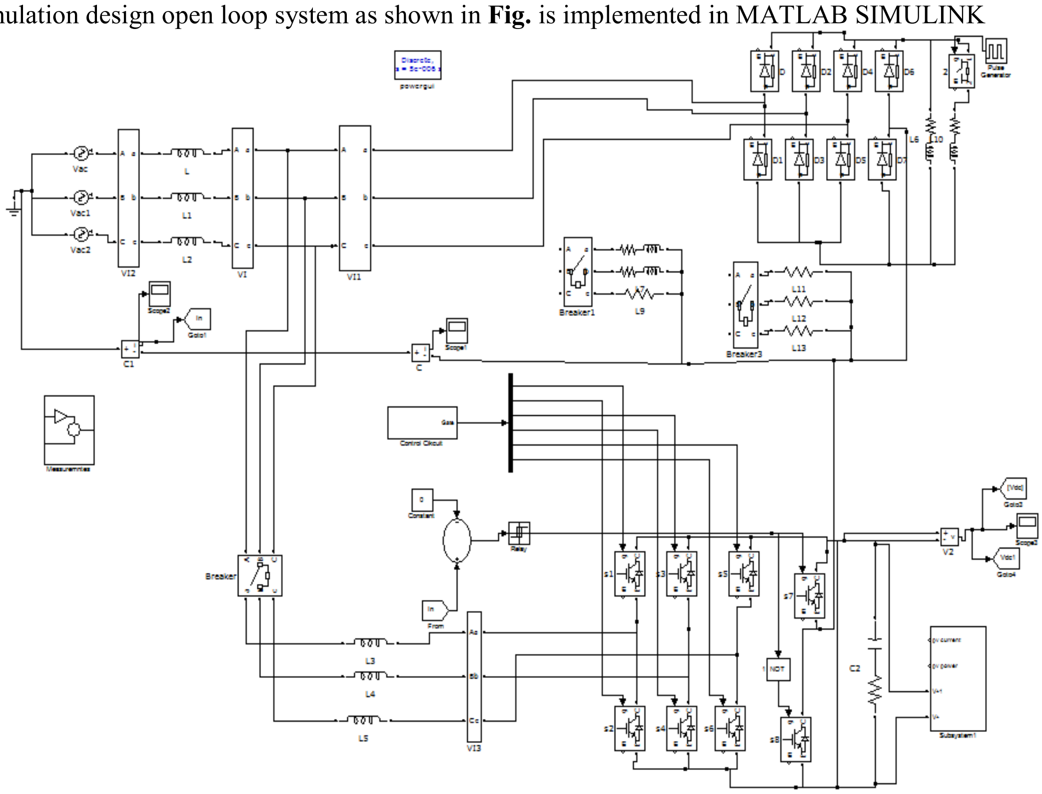

Fig 4.1. Matlab Implementation

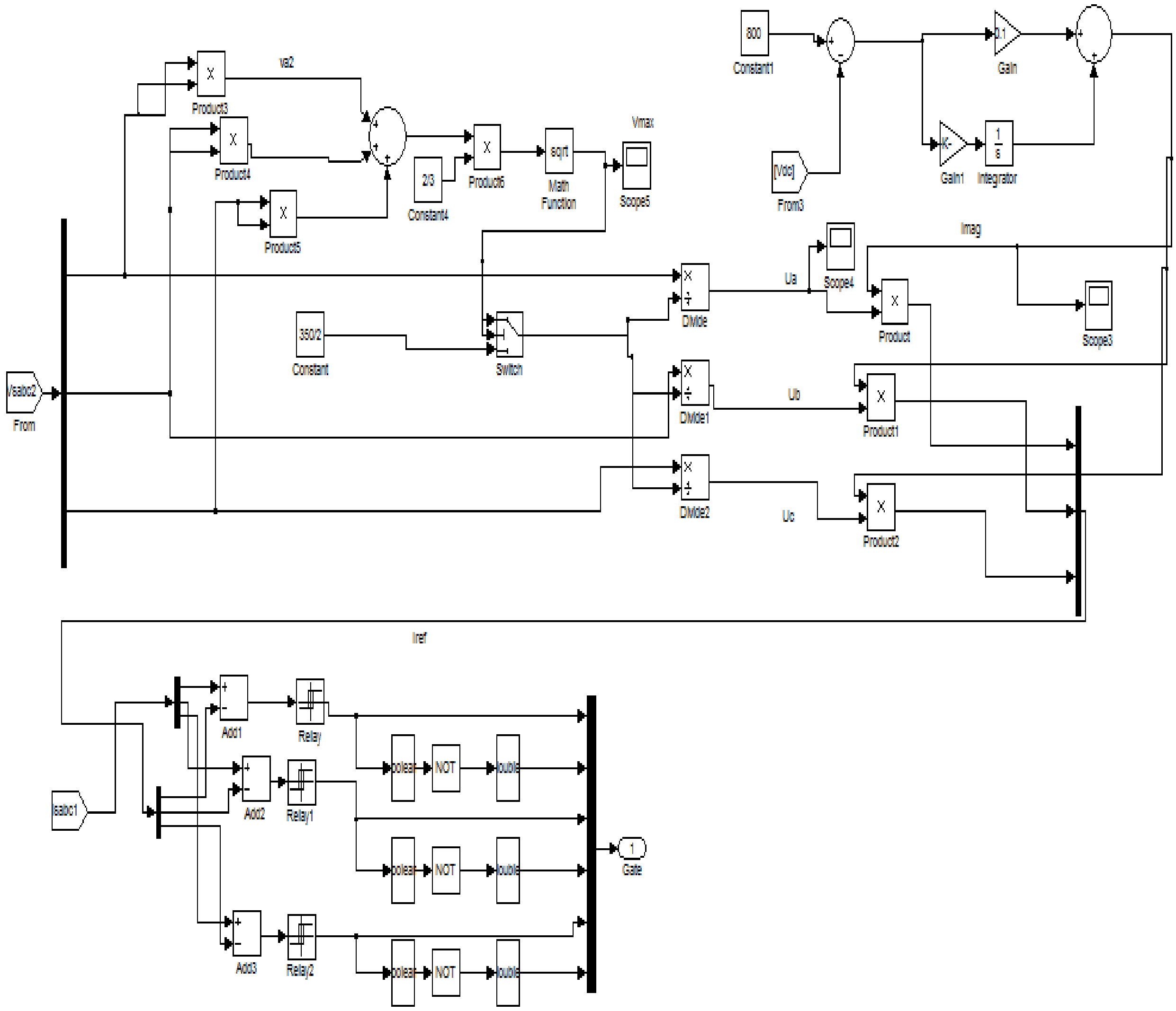

Fig 4.2. Hysteresis With Pi Controller

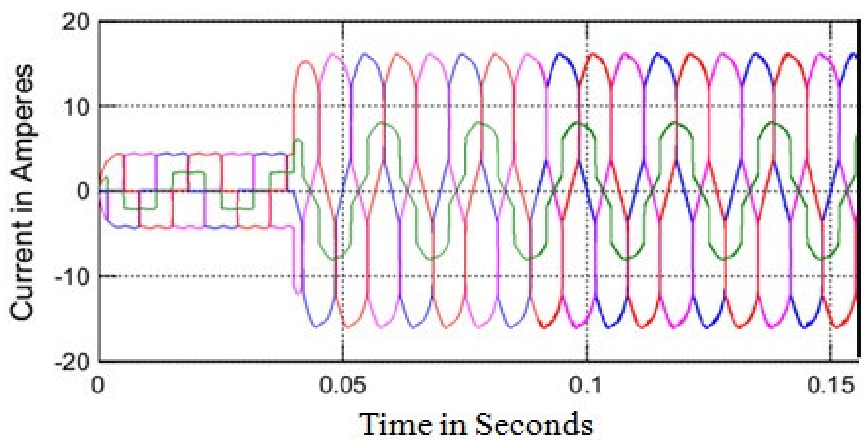

Fig 4.3. Source Current Due To Non Linear Load

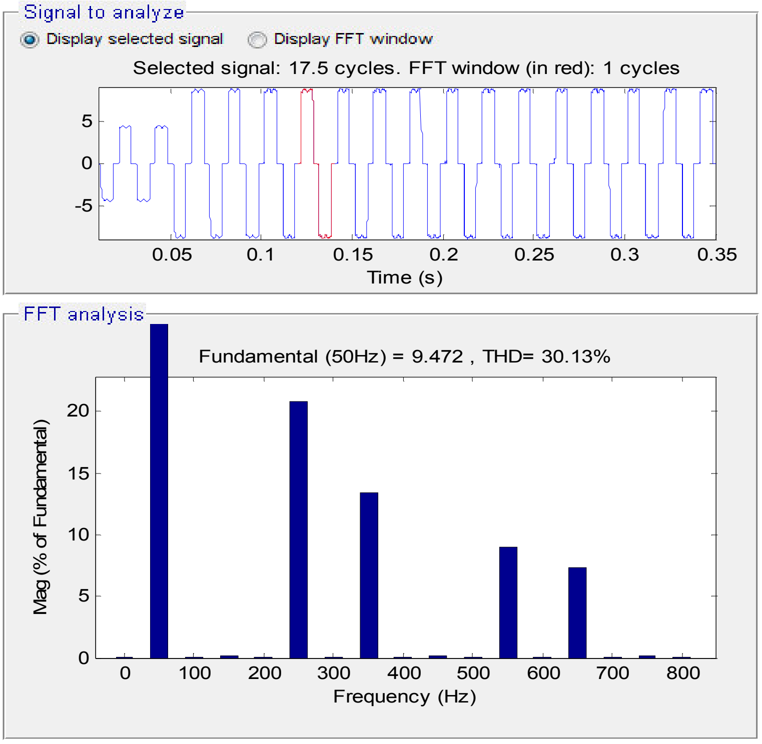

Fig 4.4. THD Of Source Current Before Compensation

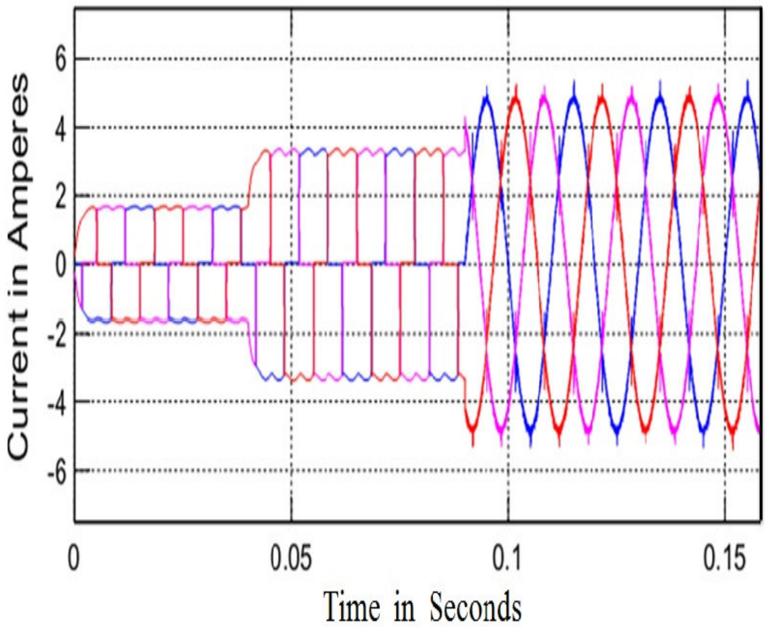

Fig 4.5. Source Current With Filter

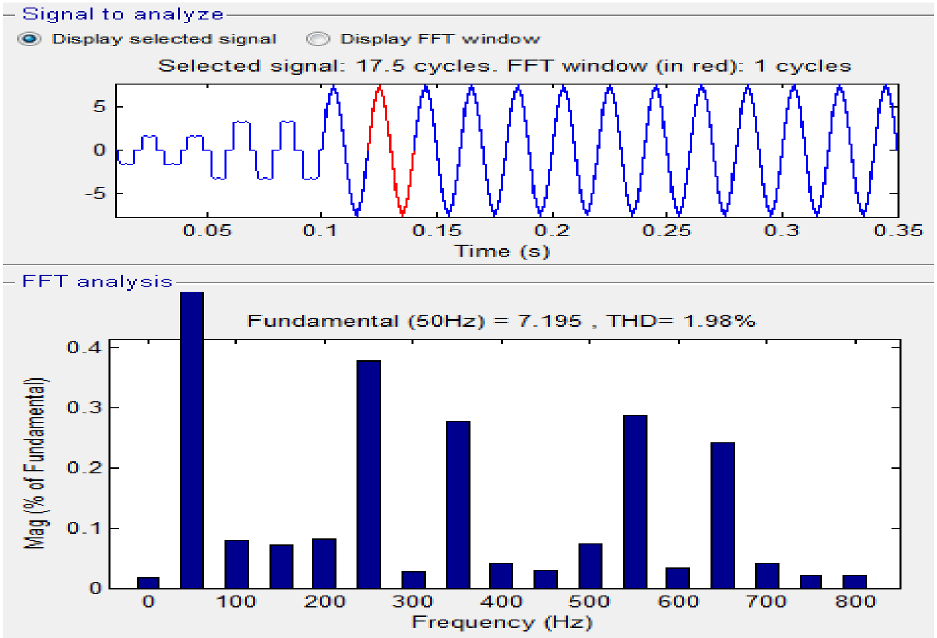

Fig 4.6 THD Of Source Current With fuzzy

5. 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 fuzzy controller is used for Inverter current control. It is better to use fuzzy controller by replacing pi controller.

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