Comparative Evaluation of General PI Controller and Fuzzy Logic Based PI Controller for Harmonics Reduction

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Abstract: **In Present-Day scenario in the distribution system harmonics is created by nonlinear load and unbalanced current. Applications are mostly based on power electronics loads like printers, Fax Machines, computers and other switching based devices which is mostly fed by three phase four wire System, this increases harmonics in ac mains current. This paper purposes harmonic current reduction in three phase four wire system using fuzzy logic based PI controller with PLL based shunt active filter. The appliance paper comprises of fuzzy logic controller technique for dc link voltage regulation, hysteresis current controller scheme for three phase four leg voltage source inverter. As in PI controller the proportional and integral gains are needed fine tuning for each load setting here fuzzy logic based PI controller gives reliable operation. For the proposed auto tuned shunt active power filter, the THD reduces within IEEE-519 standards. THD calculation of current based on FFT analysis. The main objective of this work is to develop PI and Fuzzy logic based PI controllers to analyze the performance of Shunt Active Filter for mitigating current harmonics under balanced sinusoidal source voltage conditions for normal load . The relevance model is made in MATLAB/SIMULINK and successfully reduces harmonic in the source current.**

Keyword: **PI Controller, Fuzzy logic based PI controller, THD, PLL, Hysteresis current controller, shunt active power filter, FFT analysis, MATLAB/SIMULINK.**

I. INTRODUCTION

As power electronic converter based devices proliferate in power systems, harmonics becomes a greater matter of concern.it is also come to in concern that in current scenario mostly equipment is fitted with power electronics devices which comes under nonlinear load, and nonlinear load cause harmonics. So researchers have attention on the power quality and customize power in distribution and transmission system because of widely use nonlinear loads. The fuzzy logic based PI controller is used to maintain dc link voltage at desired level and error obtained by fuzzy logic based PI controller is used for reference current generator. Instantaneous reactive power (PQ) theory is used to produce reference current. According to this theory the three phase quantity can be converted into two phase quantity for a system of active and reactive component. The method hysteresis current control has one of the highest rates of quick current controllability, unconditional stability, better current tracking accuracy and easy implementation. After generation of reference current it is compared with actual current in hysteresis current controller, where tracking of actual current is done on behalf of reference current. The current error is obtained by subtracting the actual filter current from reference current. This error current in conjunction with actual current and reference current gives gate pulse for voltage source inverter .The operation of voltage source inverter based shunt active filter depends on the sequence of pulse generated by controller. Shunt active filter injects a current equal in magnitude but in phase opposition to generated harmonic current to achieve a purely sinusoidal current wave in phase with the supply voltage. The schematic diagram of proposed paper is shown in fig.1. For fixed load fixed compensation is required and it is fulfilled by passive filter. In this paper as it deals with nonlinear varying load so shunt active filter is proposed to control the compensating current to mitigate harmonic current. For controlling techniques to be efficient author is dealing with fast acting fuzzy logic based PI controller and hysteresis current controller. This paper recommend a new method that consist of four leg current controlled voltage source inverter that is efficient to compensating problem like power factor, current unbalanced and current harmonics.

II. SYSTEM CONFIGURATION

For generating gate pulse for voltage source inverter, which is actually used here to control compensating current, various controlling techniques implemented. . The basic building block of proposed controlling techniques for generating gate signal for voltage source inverter is shown in fig.2.

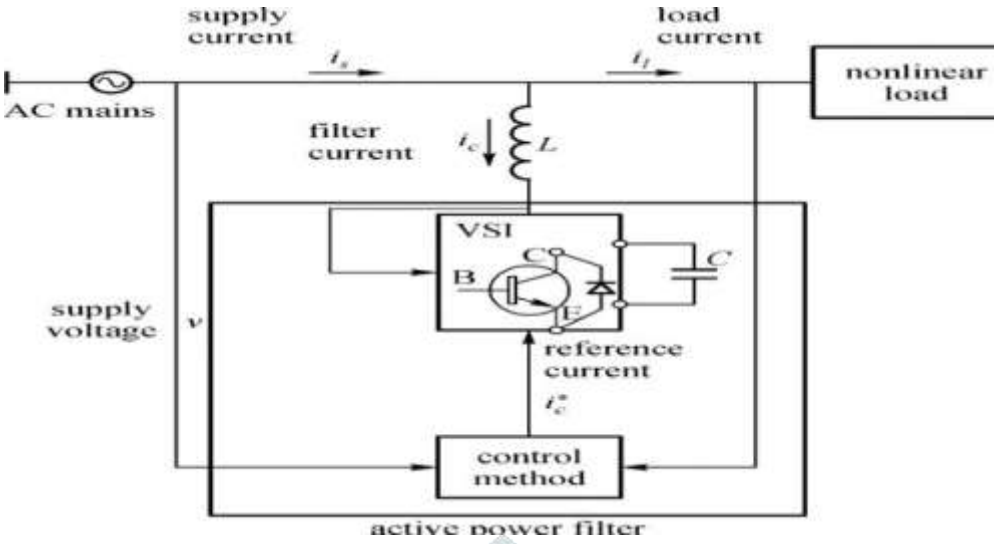

Fig.1 Block diagram of three phase four wire system with shunt active filter

The dc capacitor has two functions. First it maintains a dc voltage with a small ripple in steady state by the help of fuzzy logic based PI controller and the second one is that it serves as an energy storage element to supply the real power difference between load and source during transient period. The dc link capacitor voltage is compared with reference voltage, which is the desired voltage for voltage source inverter, and the error signal generated by comparing of dc link voltage with reference voltage. This error signal is input for fuzzy logic based PI controller. Fuzzy logic based PI controller gives proper output as per the rules. And fuzzy logic output is used for generating reference current. Reference currents are the sinusoidal wave with frequency as the source voltage and magnitude as the output of the controller. Then this reference current compared with the actual currents and the error is process in the hysteresis controller. Hysteresis current controller generates gate pulse by comparing actual current and reference current.

III. CONTROL SYSTEM

The control algorithm for the whole mitigation process is follows as to determine reference current for tracking actual current, to control dc link voltage, generate switching algorithm for IGBTs of voltage source inverter. Fuzzy logic based PI controller gives the signal to reference current generator where with the help of PLL and small drive circuit reference current is generated. Reference current generation is based on pq theory. this generated reference current is then compared with the actual current in hysteresis band current controller where on behalf of error signal gate pulse is generated which is fed to the voltage source inverter . Voltage source inverter works according to gate pulse to injects current in same magnitude but opposite in phase to mitigate harmonic current of supply current.

PLL based reference current generator is basically a electronic circuit which give ease to generate reference current whose phase is related to the phase of an input signal. Phase locked loop can generate a frequency that is multiple of the input frequency. It can track input frequency. In shunt active power filter we need multiple of fundamental frequency to mitigate harmonics current which is in the higher order of frequency range. The basic controlling circuit is shown in fig.2.

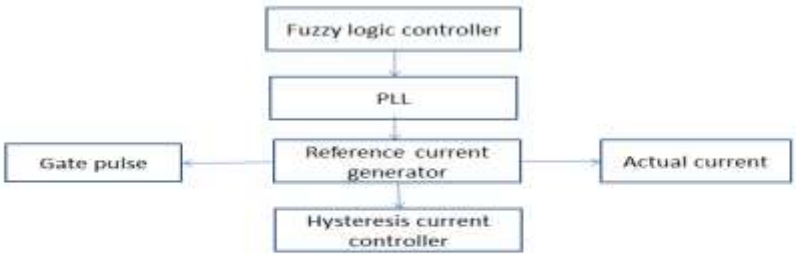

Fig.2 controlling circuit for compensating current generation

IV. PI CONTROLLER

The control scheme consists of PI controller, limiter and three phase sine wave generator for reference current generation and generation of switching signals . It is known that the real power of the system changes and that is compensated by the DC link capacitor voltage. The new capacitor voltage is now compared with a reference voltage and a difference signal or error signal is given to the PI controller. The error signal is then processed through a PI controller, which contributes to zero steady error in tracking the reference current signal. The output of the PI controller is considered as peak value of the supply current (Imax), which is composed of two components: (a) fundamental active power component of load current and (b) loss component of APF; to maintain the average capacitor voltage to a constant value. This peak value of the current (Imax) so obtained, is multiplied with the respective source voltages to obtain the reference compensating currents. These estimated reference currents(I*sa, I*sb, I*sc) and sensed actual currents (Isa, Isb, Isc) are compared at a hysteresis band, which gives the error signal .Fig. 5 shows how the error signal is generated by comparing the two currents.

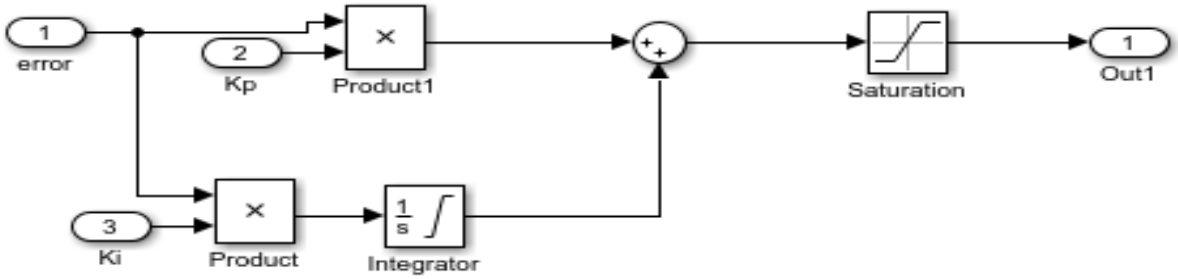

Fig.3 PI controller

V. FUZZY LOGIC BASED PI CONTROLLER

In conventional controllers like PI and PID have control gains in the combination of numerical values but in case of fuzzy logic based PI controller linguistic variables are used in which error (e) and change in errors (ce) are the inputs and gives output according to rules. The basic Simulink model of fuzzy logic based PI controller is shown in fig.4.

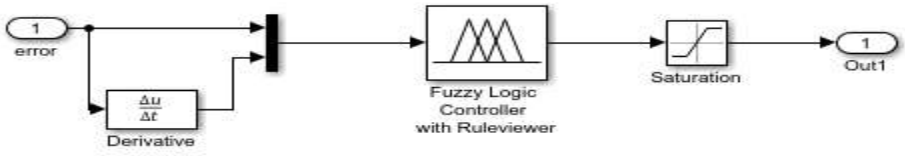

Fig.4 Fuzzy logic based PI controller

The main concern of fuzzy logic is to map an input space to an output space and it is based on the list of if then statement called rules. All rules are evaluated in parallel and the order of rules is not in concern as it evaluates in parallel. The fuzzy logic starts with the concept of fuzzy set. Fuzzy set is a clearly defined boundary which can contains only a partial degree of membership. The fuzzy logic control can be investigated with different membership functions like

1. Triangular membership function
2. Trapezoidal membership function
3. Generalized bell shaped membership function
4. Gaussian membership function

The shapes of membership functions can be plotted by taking the different values of variables. Here mamdani method of fuzzy inference is used. Fuzzy inference is a method that interprets the values in the input vector and based on some sets of rules assigns values to the output. Basic block of membership function is shown in fig.5.

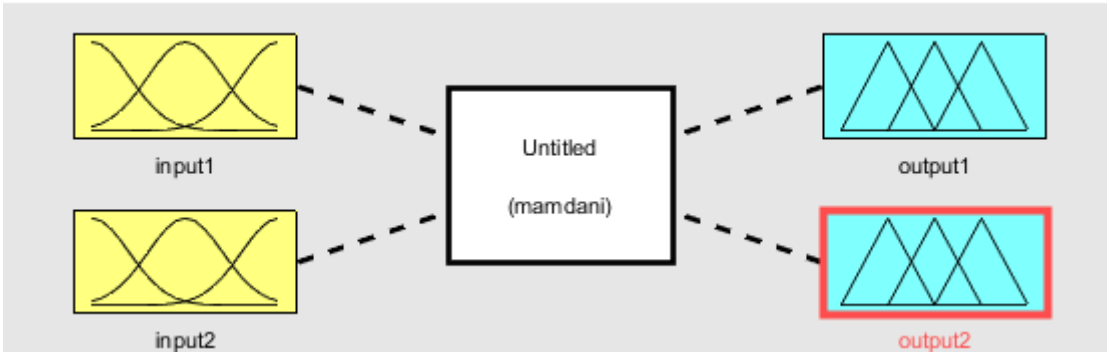

Fig.5 Membership function for input and output

VI. HYSTERESIS CURRENT CONTROLLER

For generation of pulse in current controlled VSI, hysteresis band current control technique is used, as because it gives instant response and fine accuracy. For tracking the reference current, voltage source inverter needs proper gate pulse which is given by the current controller. The actual current is sense instantaneously, and then compared to reference current which is generated by proposed algorithm. Error current is generated by subtracting the actual current from the reference current, which is used in current control algorithm. The schematic diagram of hysteresis current controller is shown in fig.7.

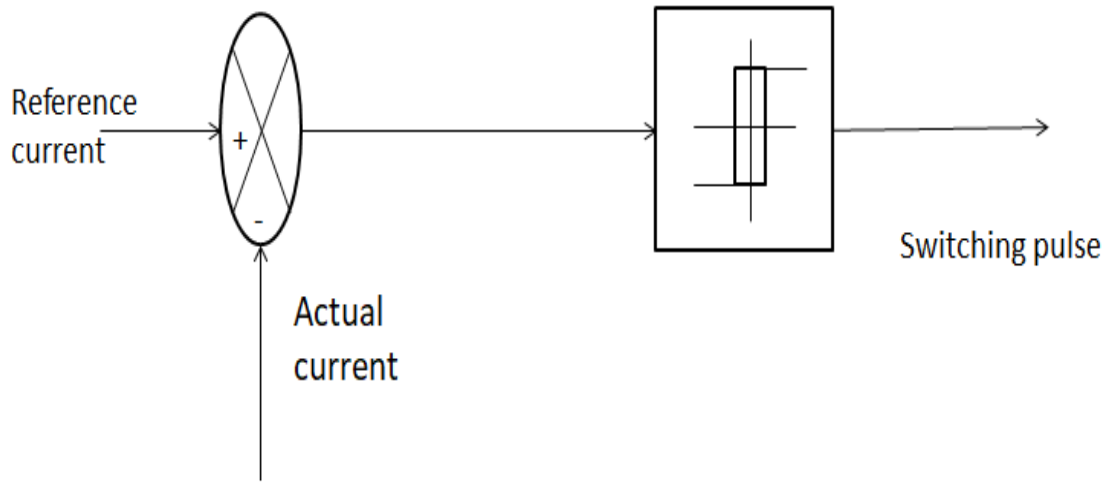

Fig.6 schematic of hysteresis current controller

VII. SIMULATION RESULTS AND ANALYSIS

Simulation of proposed model for a designed parameter in Simulink is clearly shown by the waveform. The three-phase three-wire system with a non-linear load is equipped with shunt active filter for mitigating the current harmonics. PI controller and FLC are used to control the shunt active filter under balanced and unbalanced source voltage condition for normal load as well as increase load. As before the use of shunt active filter THD is much more after the using shunt filter. The waveform of current before using shunt active power filter is shown in fig.7. After using shunt active power filter the current waveform is shown as in fig.8. The waveform of Compensating current is shown in fig.9. The simulation of model shows that the distorted waveform is come to the sinusoidal shape after using shunt active power filter. The THD is shown on behalf of FFT analysis. FFT analysis shows the THD of waveform before and after the using of sapf (shunt active power filter). The THD spectrum of current without using shunt active filter is shown in fig.10 the THD spectrum of current with shunt active filter of PI controller and the THD spectrum of current with shunt active power filter of fuzzy logic based PI controller is shown in fig.12.

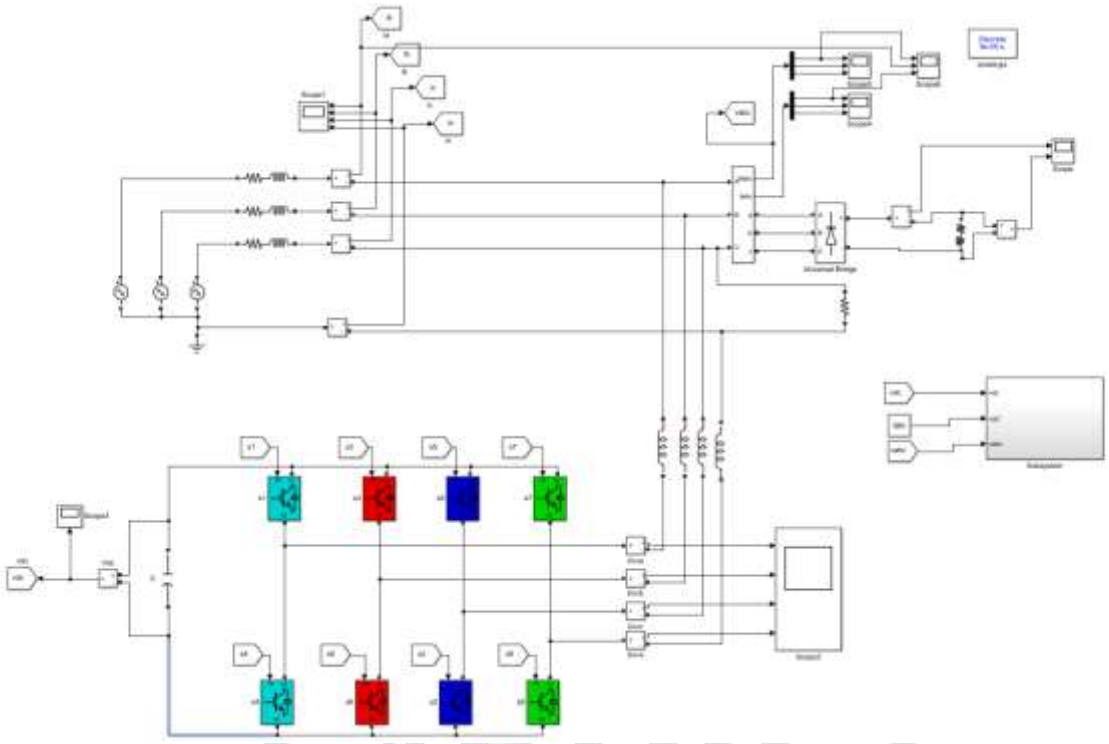

Fig.7 schematic diagram of three phase four wire system with shunt active power filter

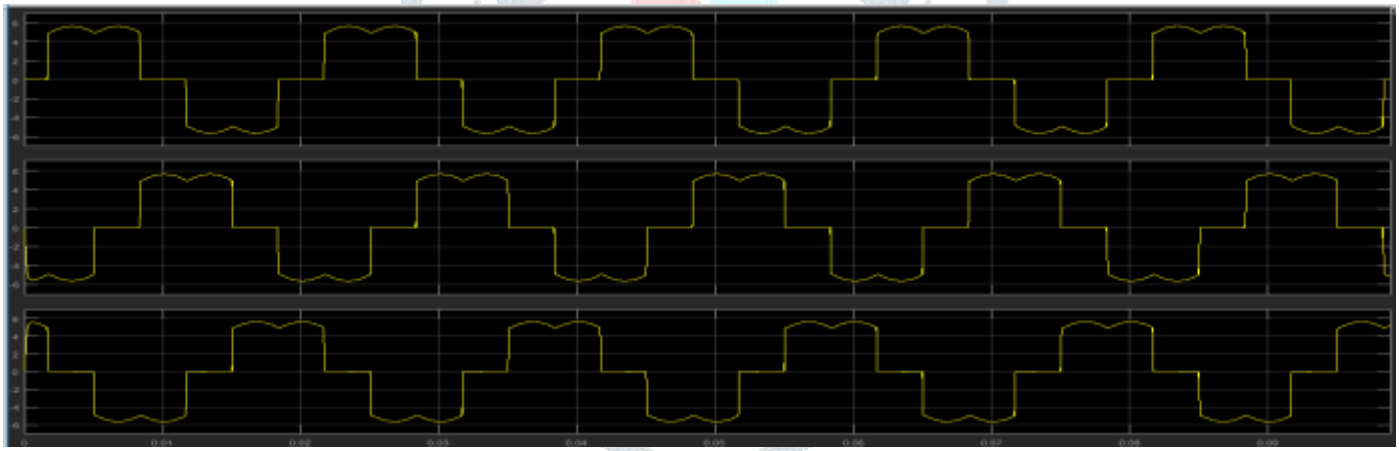

Fig.8 Source current when active filter is not connected

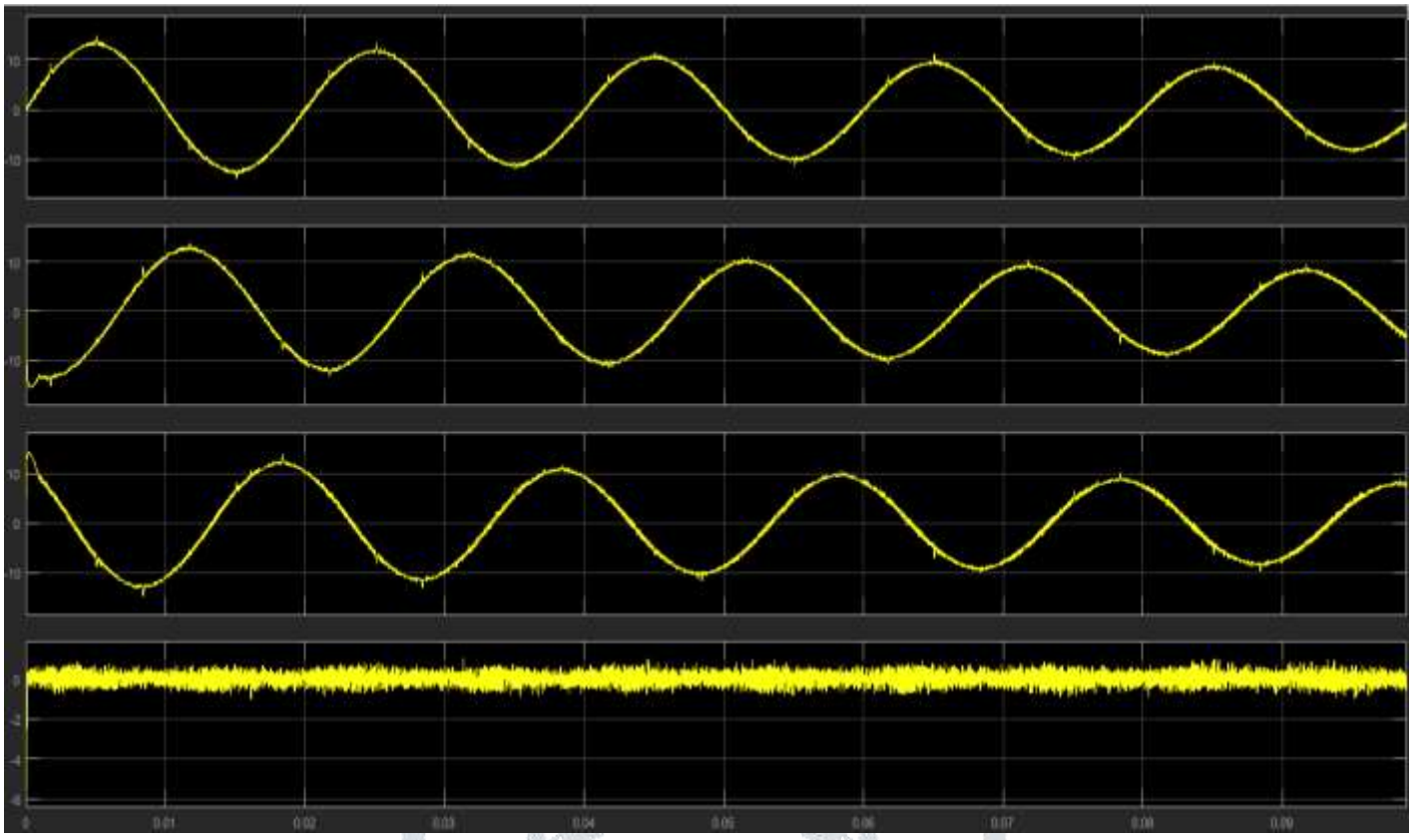

Fig.9 Source current when shunt active filter is connected

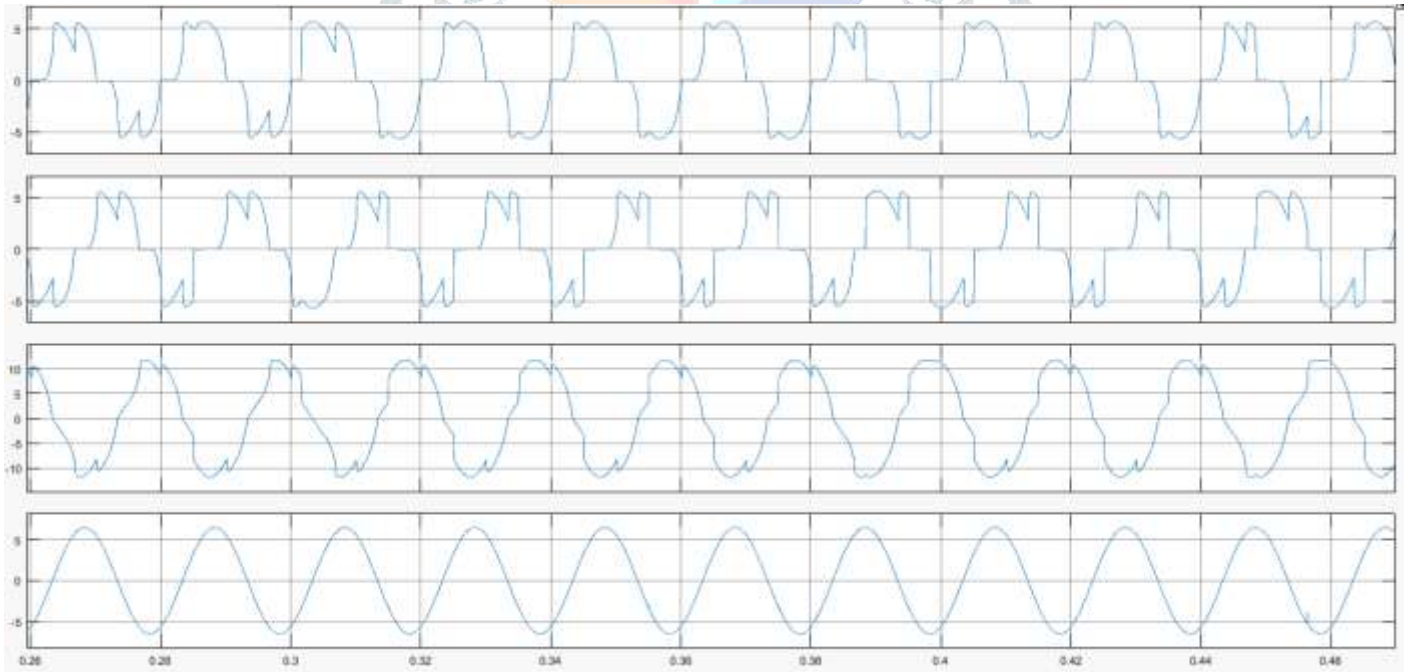

Fig.10 Compensating current waveform

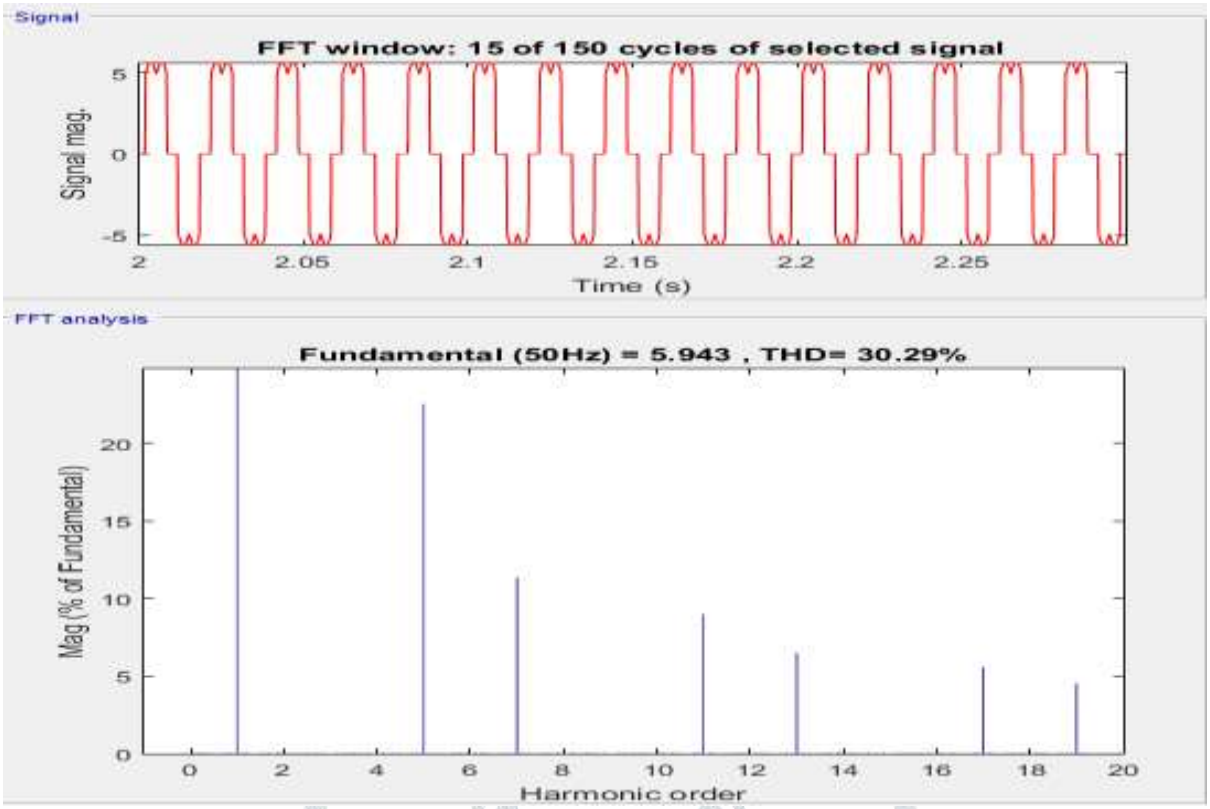

Fig.11 THD spectrum when filter is not connected

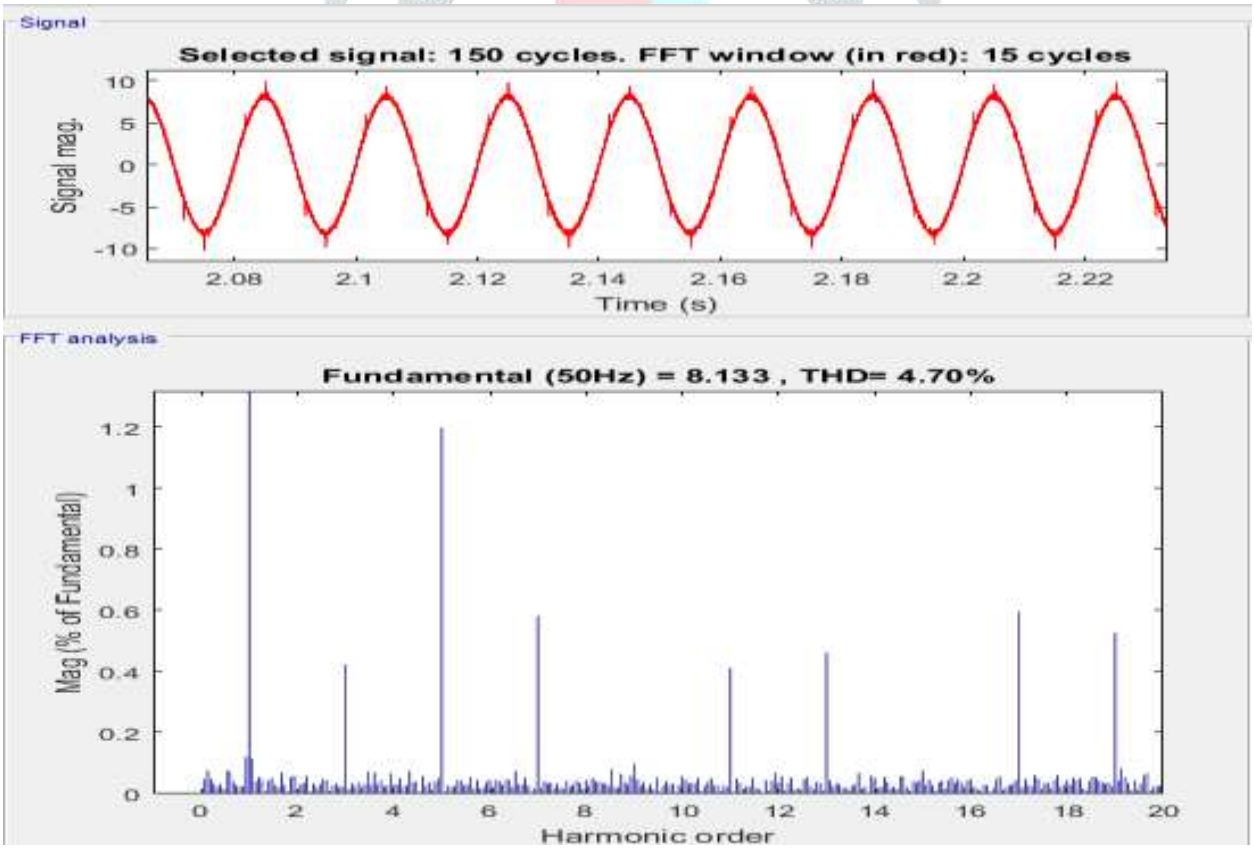

Fig.12 THD spectrum when filter is connected of PI controller

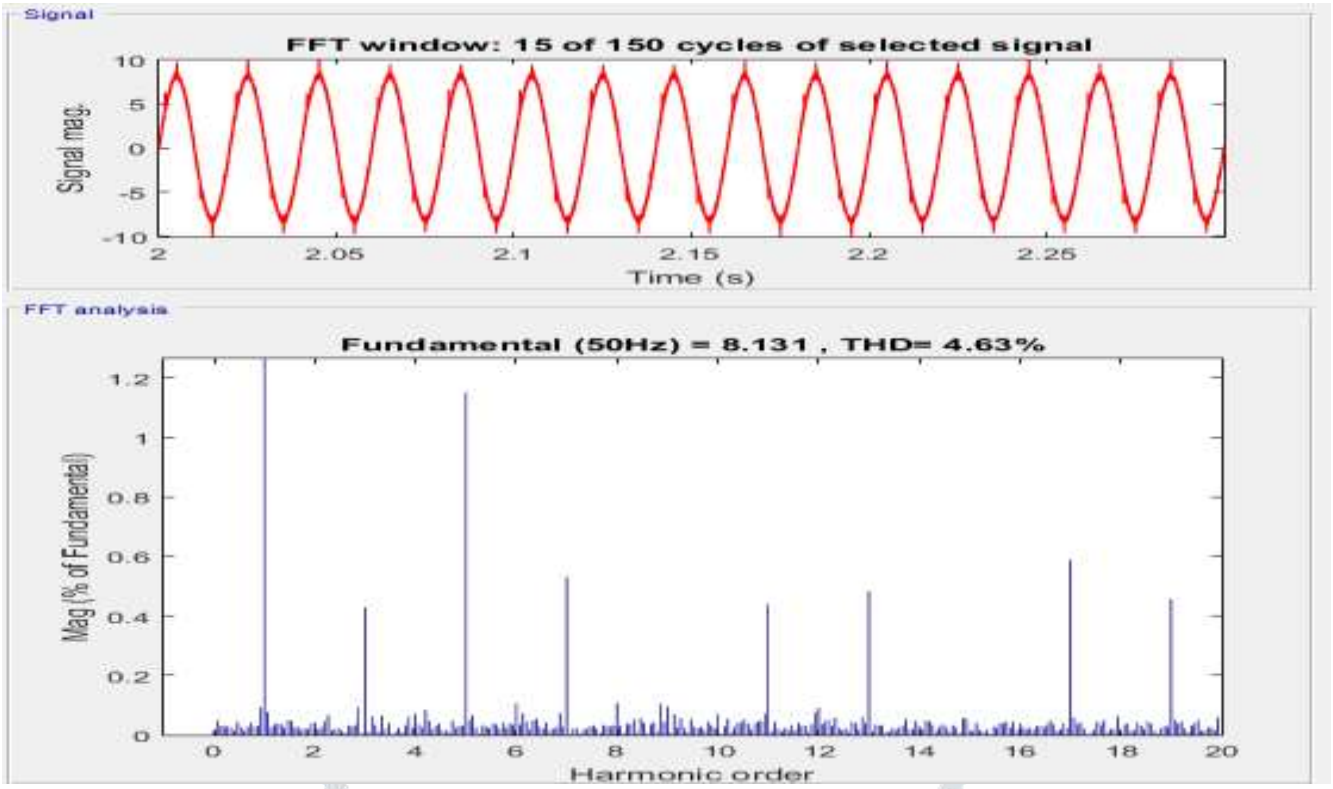

Fig.13 THD spectrum when filter is connected of Fuzzy logic based PI controller

VIII. CONCLUSION

The shunt active power filter based on fuzzy logic based PI controller compare to PI controller for three phase four wire system gives the less THD when it is implemented in the three phase four wire system. Three phase four leg current controlled voltage source is used for the injection of compensating current in three phase four wire system. Before using shunt active power filter the THD of current is 30.29% and after using the shunt active power filter for PI controller the current THD comes to the 4.70% and after using the shunt active power filter for fuzzy logic based PI controller the current THD comes to the 4.63%, which is within the limit of IEEE-519 standards.

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