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Performance Analysis of Fuzzy Logic Based PI Controller

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Abstract: ***Tuning in the performance of a controller is very important in system performance. Power quality problem is the most sensitive problem in the power system. The objective of the work is to reduce one of the power quality issue called "harmonics" using compensation technique. Shunt Active Power Filter (SAPF) is used to eliminate harmonic current and also it compensates reactive power. In this work, Fuzzy Logic based PI Controller based three-phase shunt active filter is employed for a three-phase four wire systems. The advantage of fuzzy control is that it provides linguistic values such as low, medium, high that are useful in case where the probability of the event to occur is needed. It does not require an accurate mathematical model of the system. A MATLAB/SIMULINK has been used to perform the simulation. Simulink model is developed for three phase four wire system under balanced source condition. The performance of balanced source is done by using Fuzzy Logic based PI controller. Simulation results are obtained and compared by applying different rules i.e. 9, 25, 49 and 81.***

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

I. INTRODUCTION

Harmonics are usually defined as periodic steady state distortions or deterioration of original voltage and/or current waveforms in power systems where frequency of harmonic wave is an integral multiple of fundamental frequency. Major sources of voltage and current harmonic generation in power system are controlling action of power electronic devices such as chopper, inverter etc. cause imbalance in power system leading to harmonic generation. Non-linear load like UPS, SMPS, battery charger.

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.

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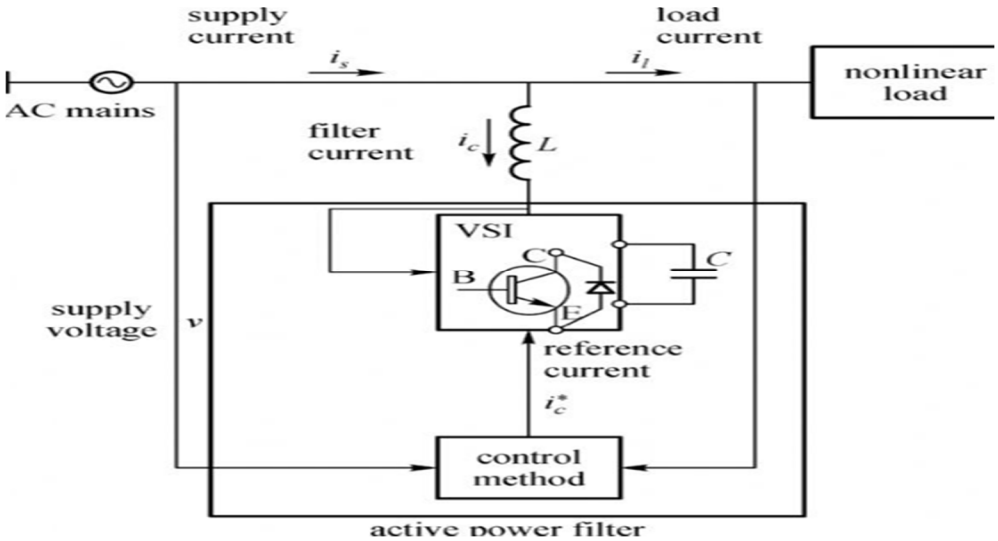

Fig.1 Block diagram of three phase four wire system with shunt active filter

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.

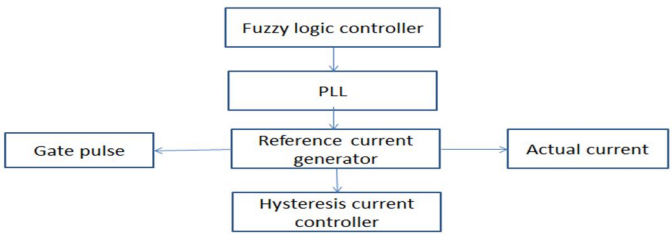

Fig.2 controlling circuit for compensating current generation

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IV. 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.

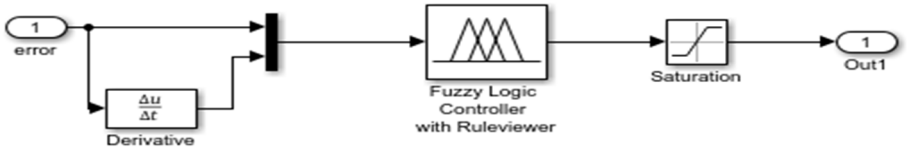

Fig.4 Fuzzy logic based PI controller

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.

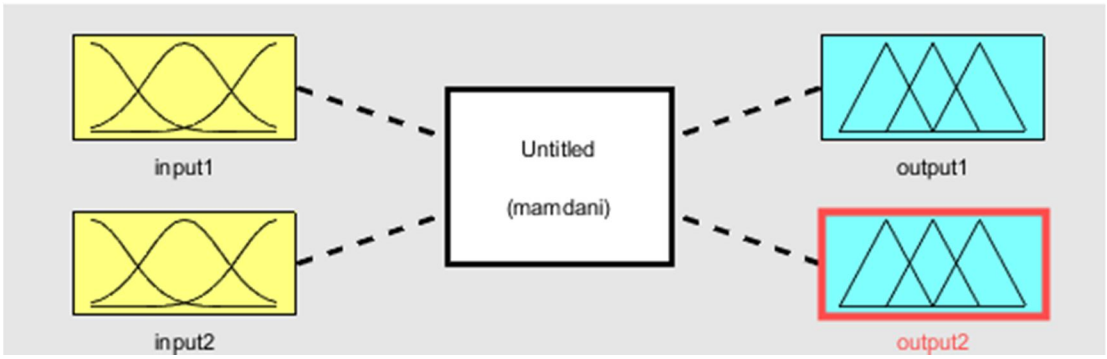

Fig.5 Membership function for input and output

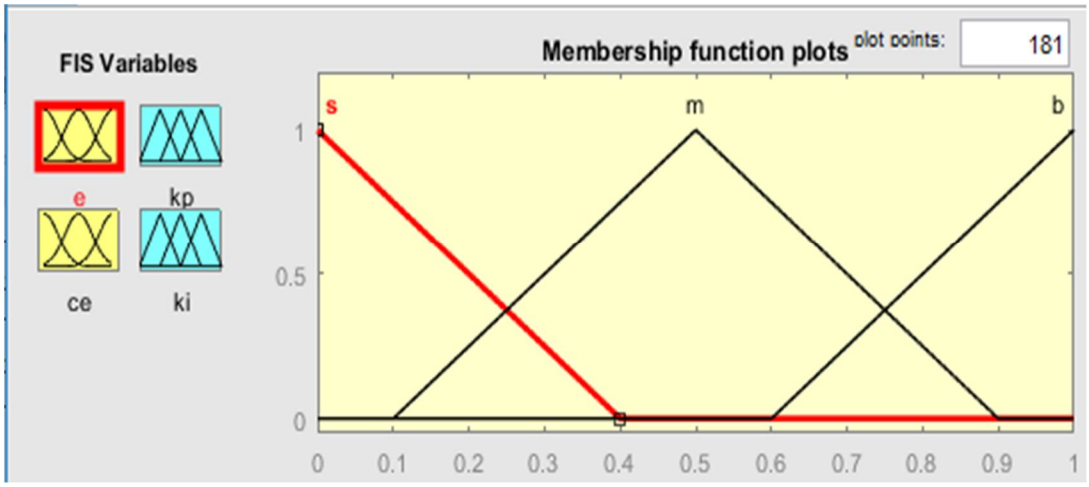

Fig.6 Membership function of 3*3 rule

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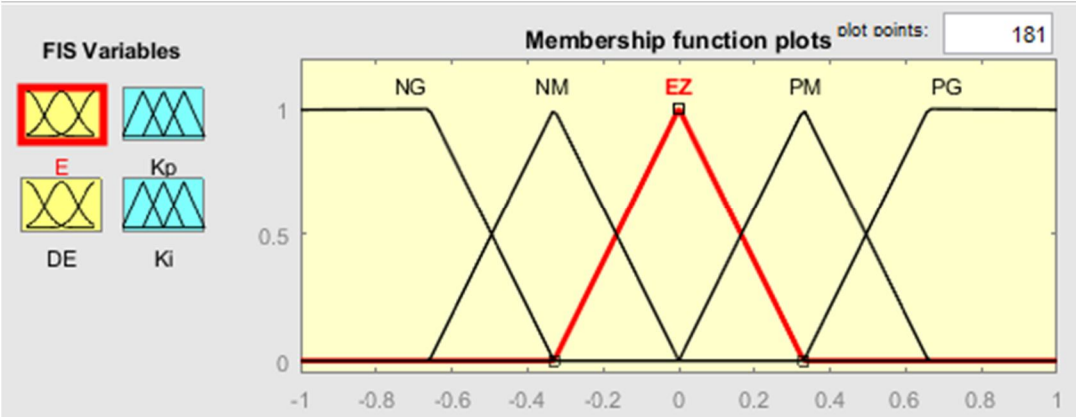

Fig.7 Membership function of 5*5 rule

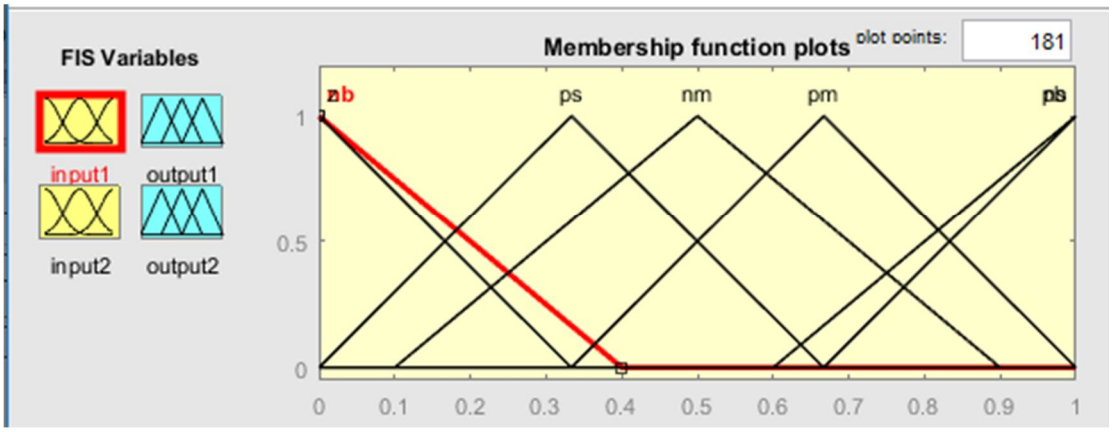

Fig.8 Membership function of 7*7 rule

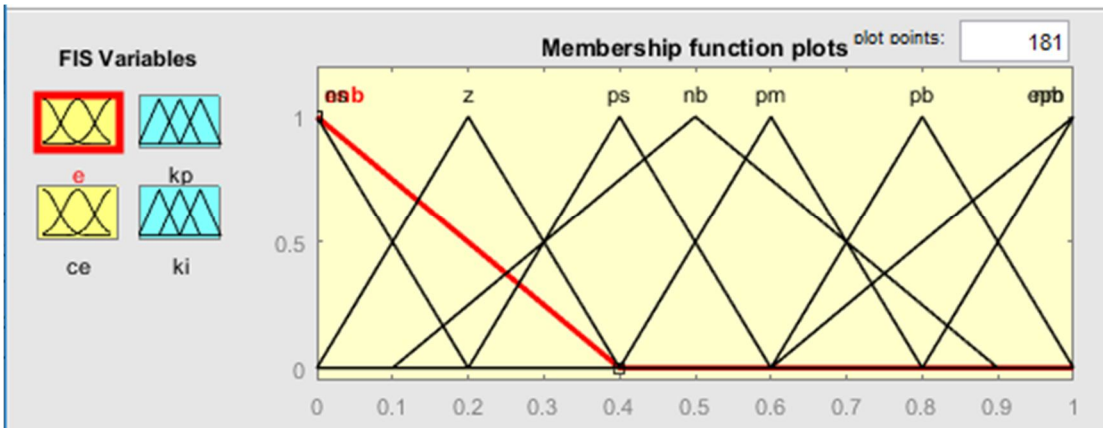

Fig.9 Membership function of 9*9 rule

V. 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.

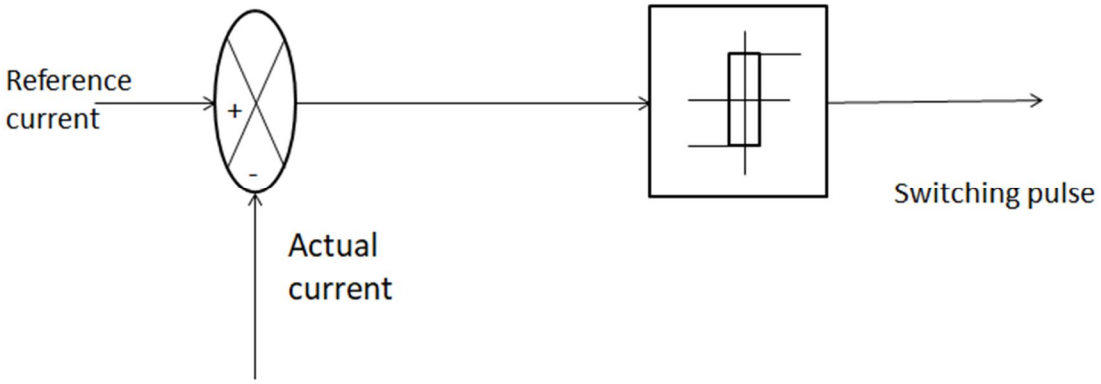

Fig.10 schematic of hysteresis current controller

VI. SIMULATION RESULTS AND ANALYSIS

Simulation of proposed model for a designed parameter in Simulink is clearly shown by the waveform. The three-phase four-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 using shunt active power filter is shown in fig.12. The waveform of Compensating current is shown in fig.13. 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 with using sapf (shunt active power filter) and fuzzy logic based PI controller. The THD spectrum of current with using shunt active filter is shown in fig.14 the THD spectrum of current with fuzzy logic based PI controller in different rule i.e. 9, 25, 49, 81 are FFT analysis shown in fig simultaneously 17, 18, 19 and 20.

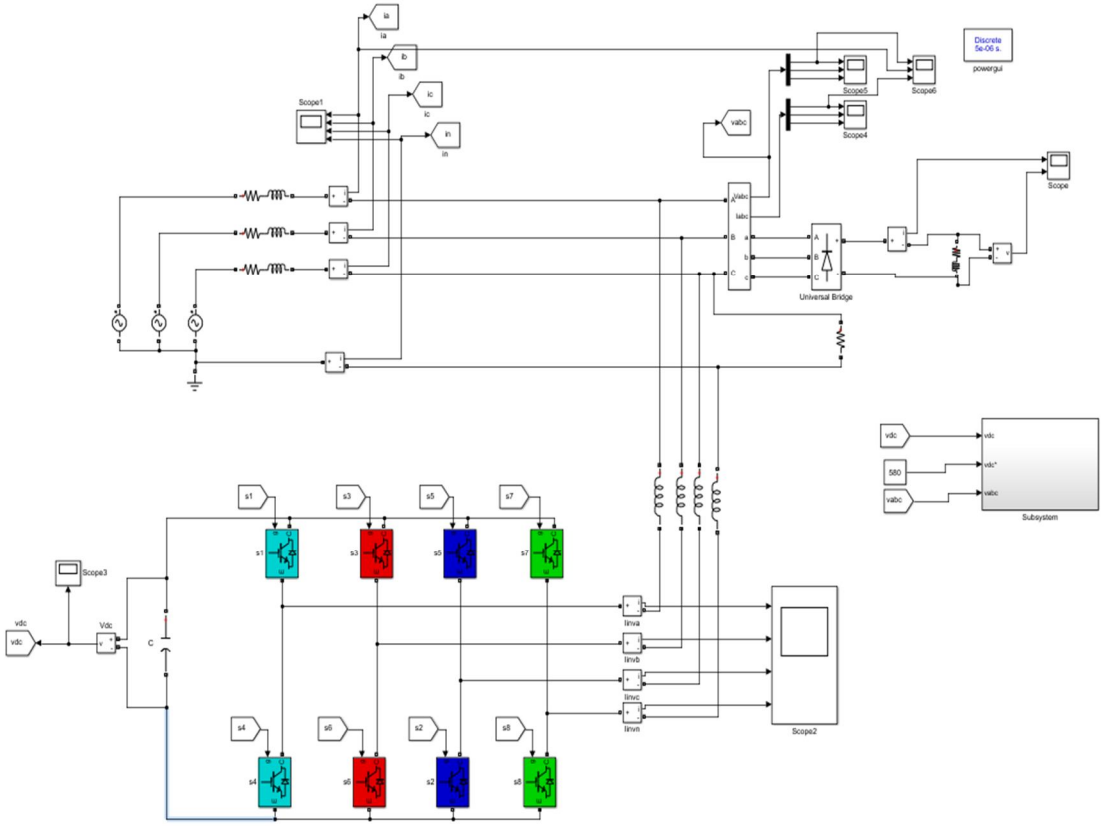

Fig.11 schematic diagram of three phase four wire system with shunt active power filter

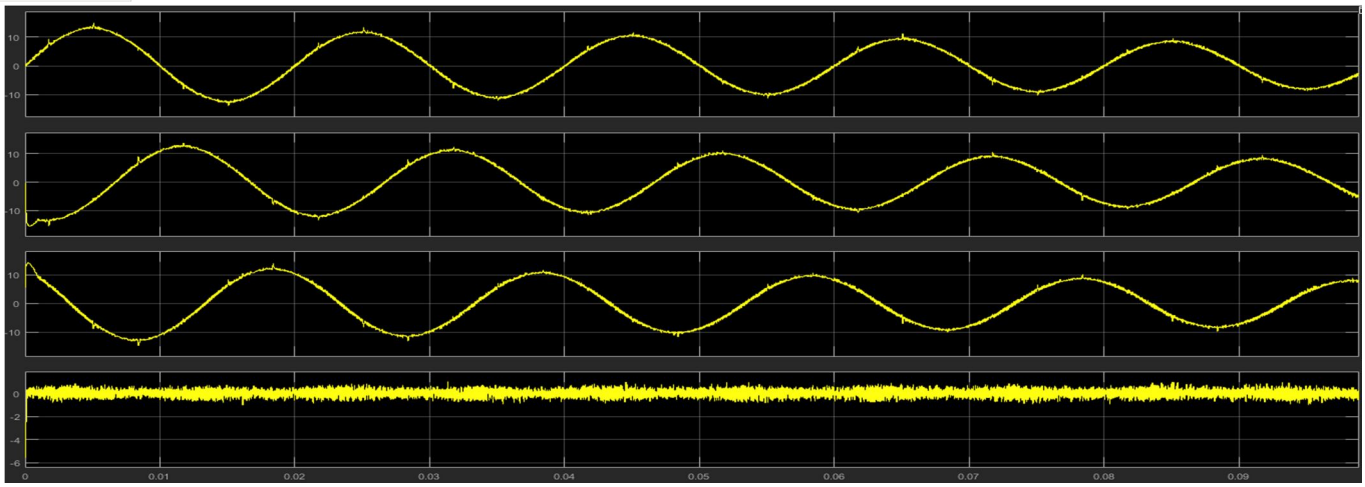

Fig.12 Source current when shunt active filter is connected

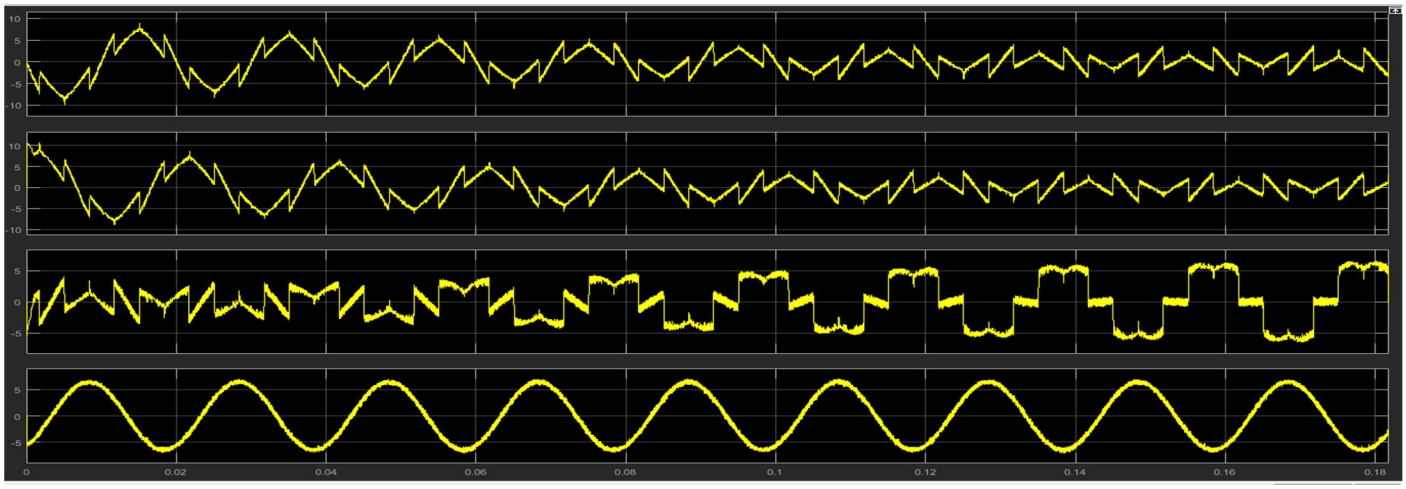

Fig.13 compensating current waveform

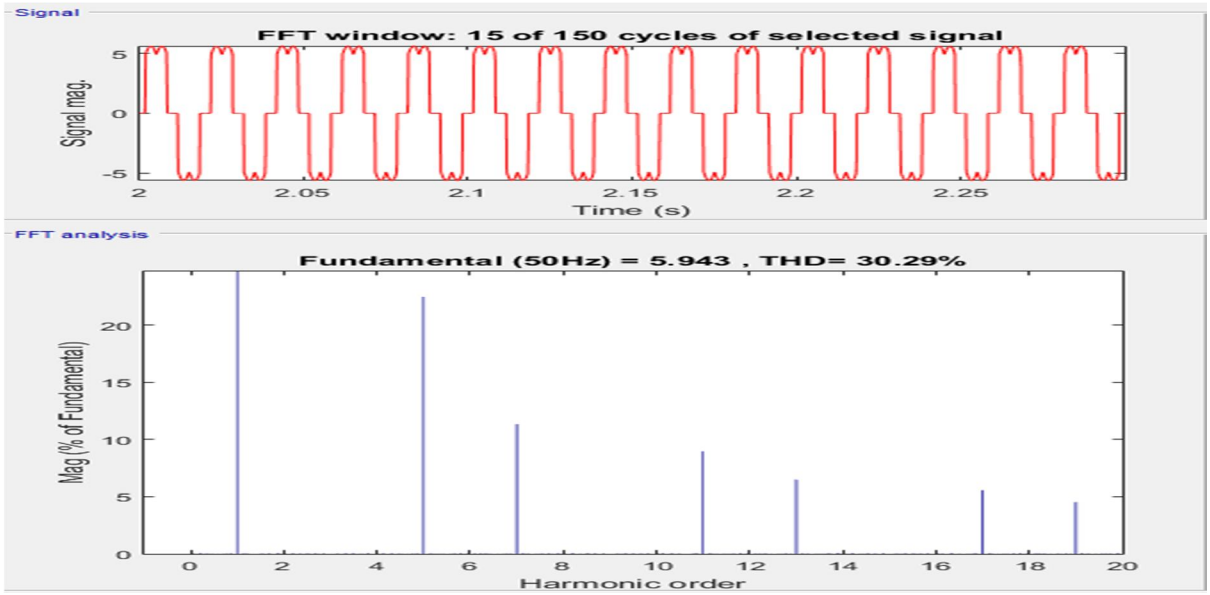

Fig.14 THD spectrum when filter is not connected

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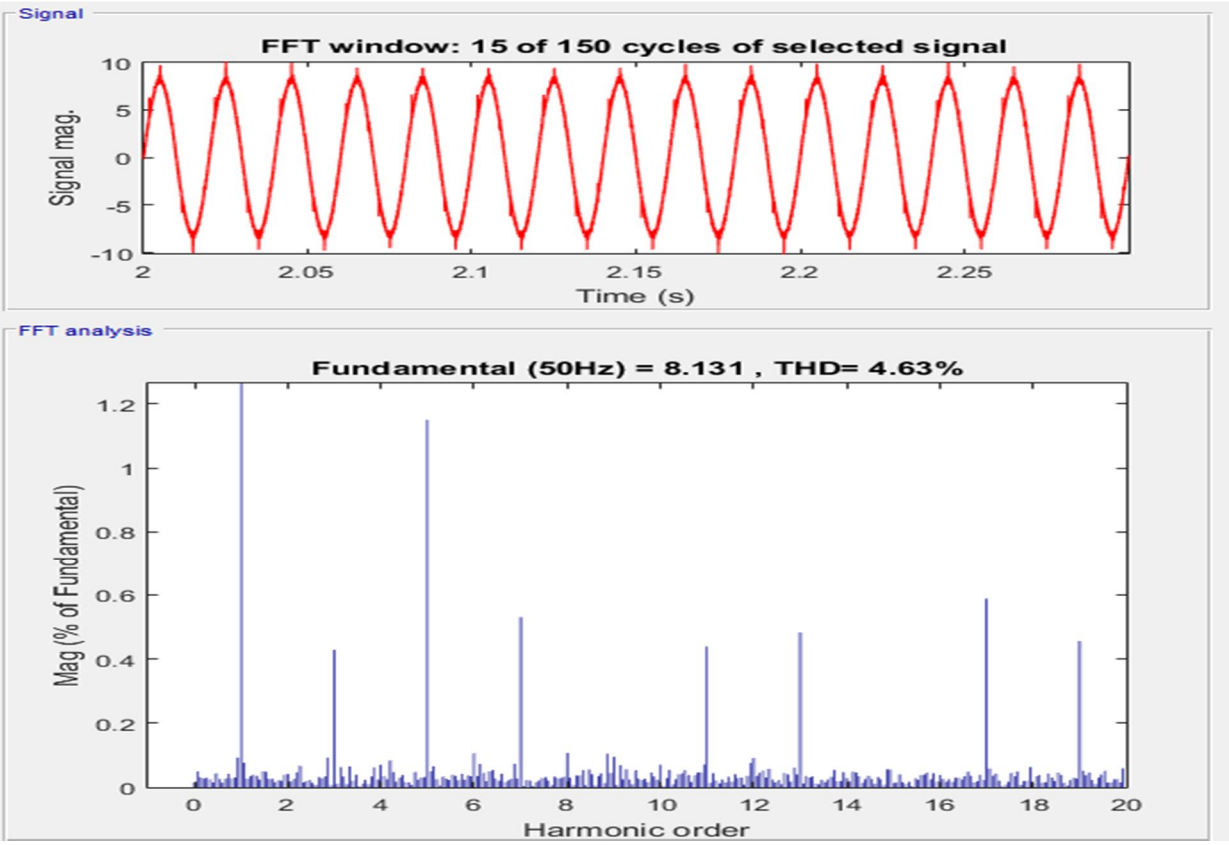

Fig.15 THD spectrum when filter is connected using Fuzzy logic based PI controller

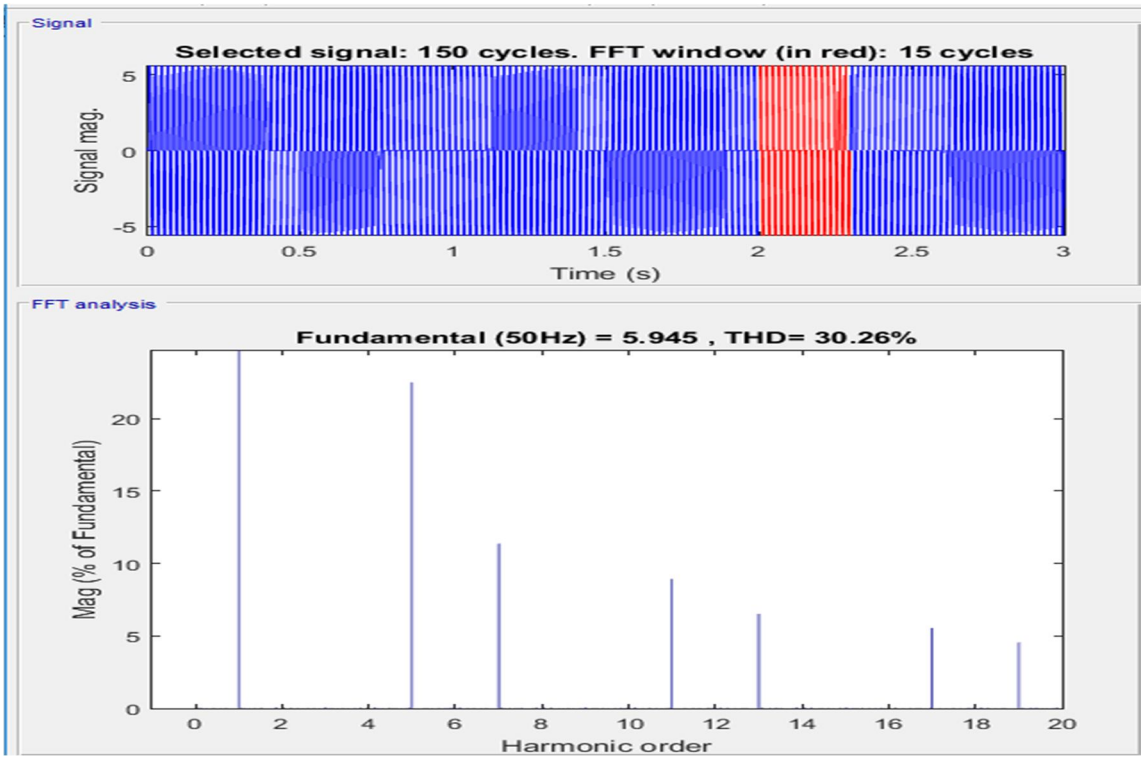

Fig.16 FFT Analysis of current THD in load side

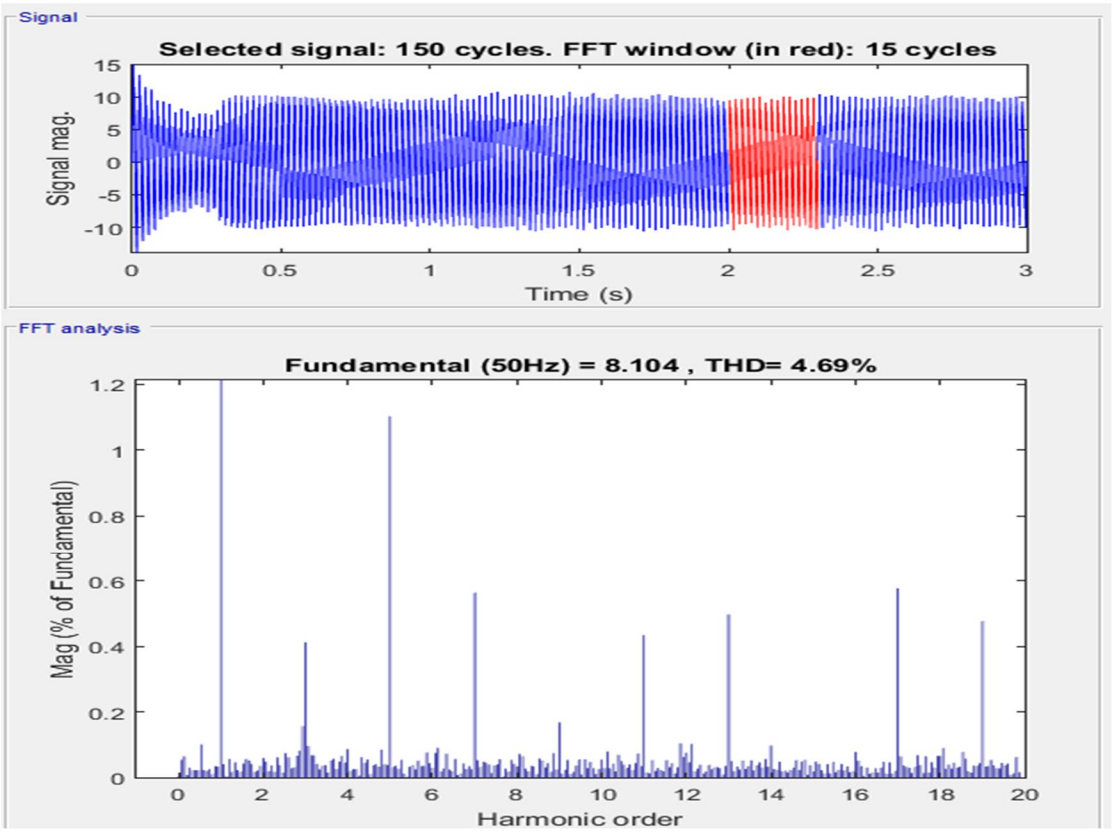

Fig.17 FFT Analysis of current THD in source side by 3*3 rule base fuzzy logic based PI controller

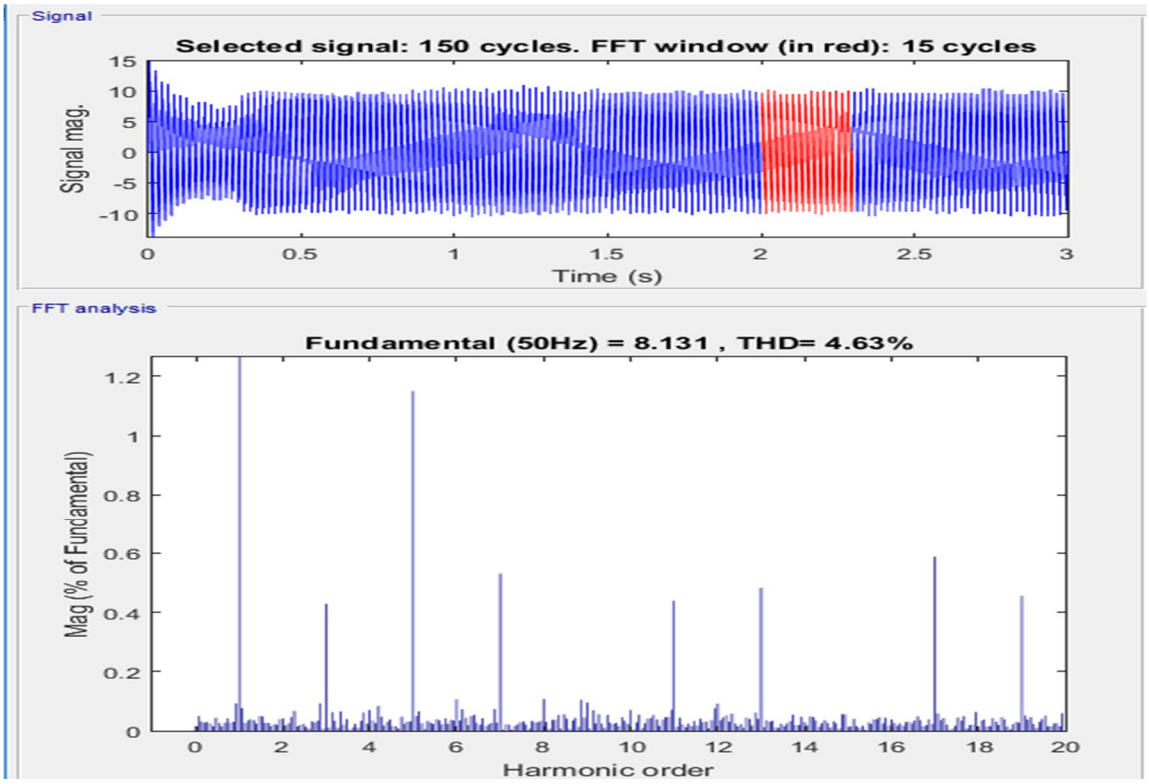

Fig.18 FFT Analysis of current THD in source side by 5*5 rule base fuzzy logic based PI controller

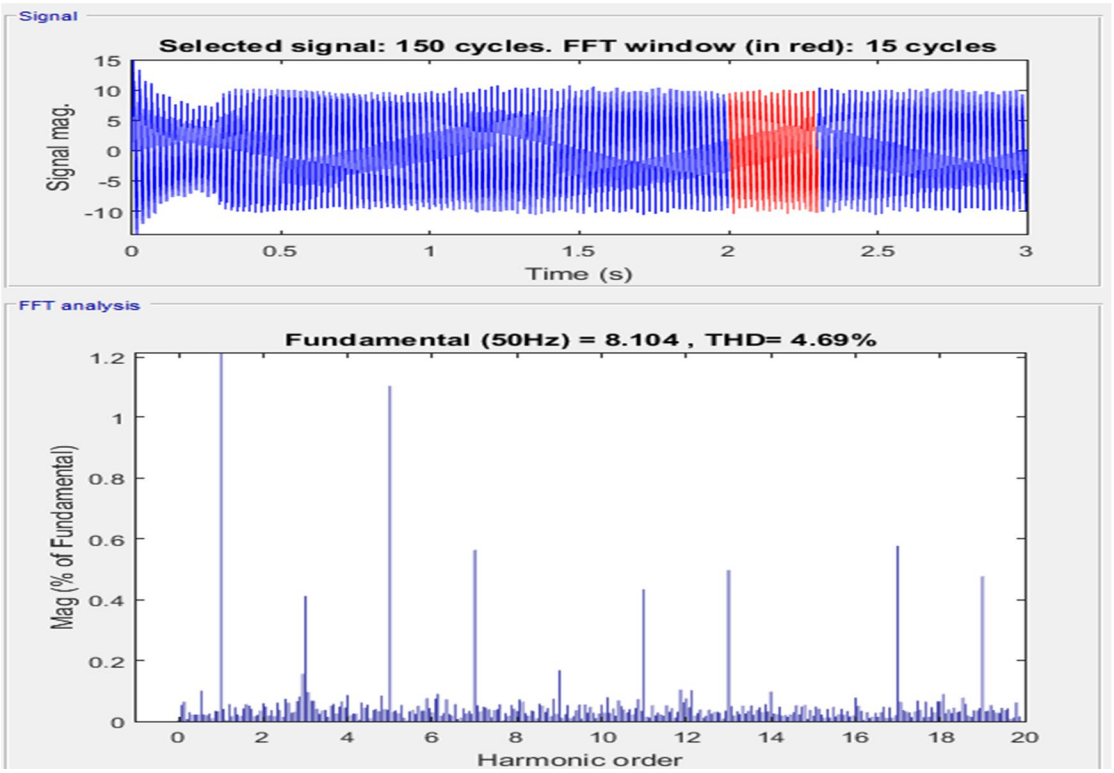

Fig.19 FFT Analysis of current THD in source side by 7*7 rule base fuzzy logic based PI controller

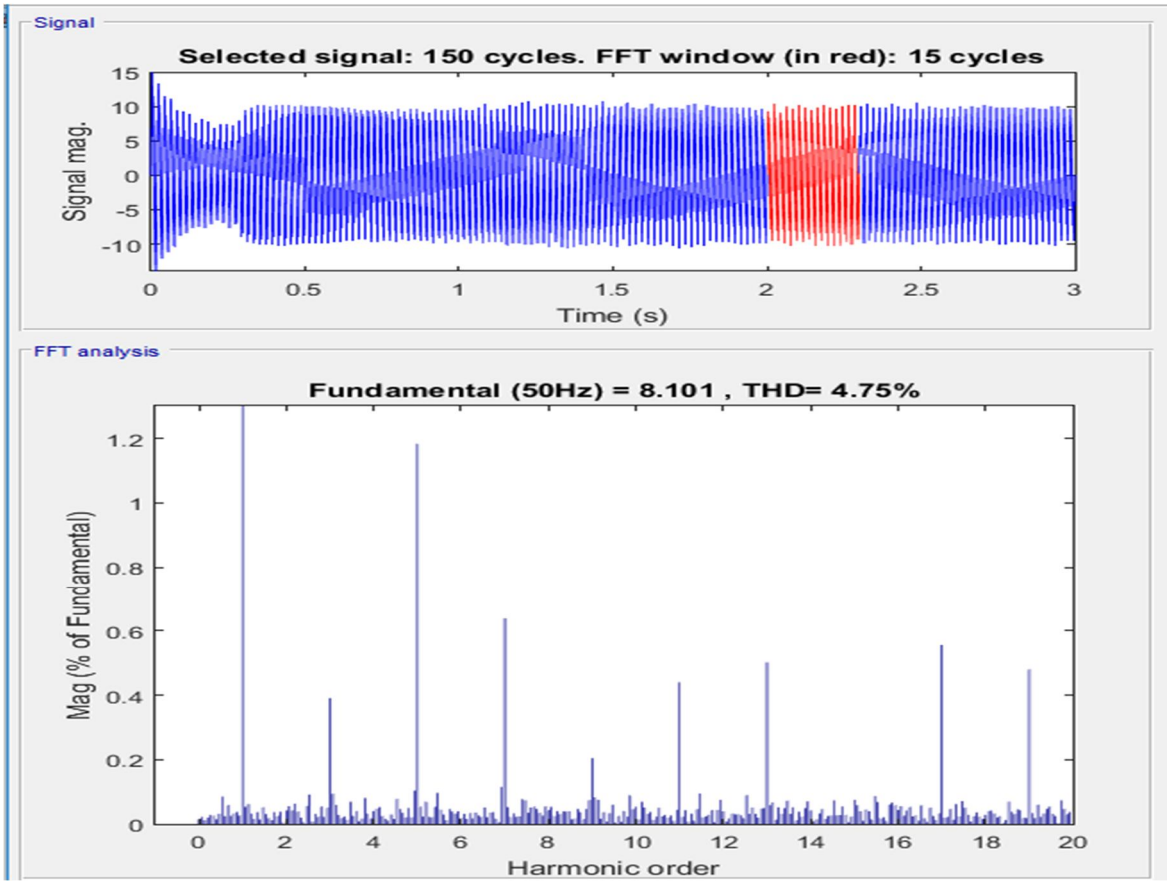

Fig.20 FFT Analysis of current THD in source side by 9*9 rule base fuzzy logic based PI controller

VII. CONCLUSION

In this paper the performance of current harmonics controlled technique with proposed FLC for harmonics reduction has been presented for four different FLC rule bases namely 81, 49, 25 and 9 rules. The dynamic model of the three phase four wire system has been developed in Simulink/MATLAB. The drive performance has been evaluated for reference harmonics reduction, disturbance rejection control capability. It has been observed that the performance of the three phase four wire system using larger FLC rule base has been found excellent as far as performance indices have been concerned in comparison with the performance with lesser rules but at the cost of large computational resources. Before using shunt active power filter the THD of current is 30.29% and after using the shunt active power filter for fuzzy logic based PI controller for different rule 9, 25, 49 and 81 the current THD comes to the 4.69%,4.63%,4.69% and 4.75%, which is decreasing then increasing in order, within the limit of IEEE-519 standards.

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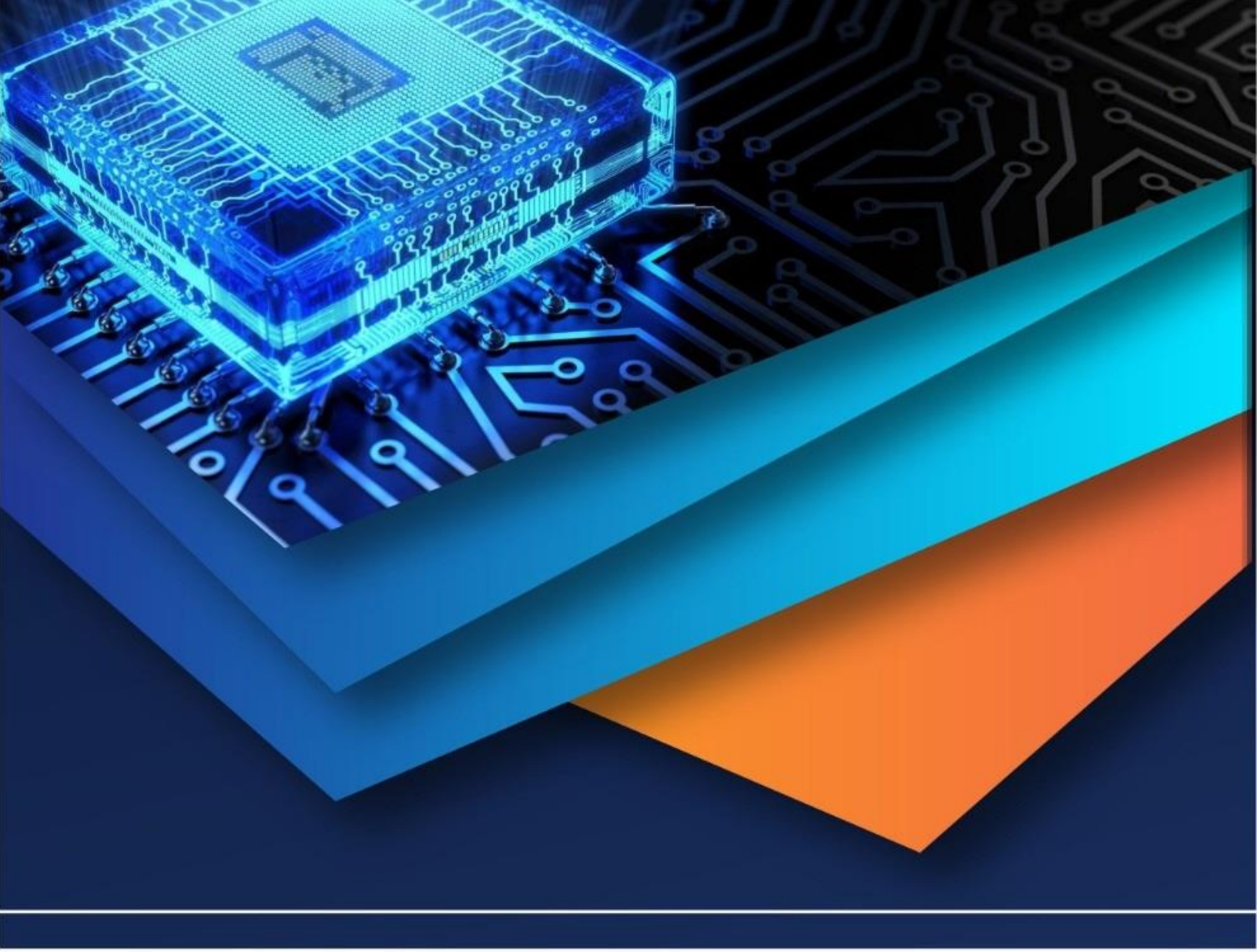

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