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Developing an Improved Model for THD Reduction using Hybrid Active Power Filter for 12-Pulse Rectifier Circuit Load

KM Jyoti[1], Dr. Manish Kumar Srivastava[2]
[1]PG Scholar, [2]Head, Department of Electrical Engineering, SIET, SHUATS, ALLAHABD

Abstract: ***This paper deals with harmonics that occurs due to nonlinear nature of rectifier circuit. The harmonics generated are very harmful within an electrical system and can have serious consequences. This degrades power quality of an electrical system. Harmonic mitigation is important to minimise the presence of harmonics in an electrical system and can achieve great cost saving. The simulation model is established in the environment of MATLAB/Simulink. We have designed a fuzzy based HAPF(hybrid active power filter) for 12 –pulse rectifier circuit load. The simulation result analysed the THD% using FFT analysis of input current. The simulation result shows that hybrid filter using fuzzy controller gives an improved THD.***
Keywords: **Harmonics, 12-Pulse rectifier, THD analysis, fuzzy controller, FFT, HAPF (hybrid active power filter)**

I. INTRODUCTION

Voltage and current harmonics become a serious issue in transmission and distribution of system in modern era of development. With the increase in development of the Power distribution systems and power equipments, the need to maintain the power quality has been a challenge. With the increase of the complexity of load and power distribution, the load nature can't be precisely assumed. Power quality is a set of electrical boundaries that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy. All the electrical devices are prove to failure when exposed to one or more power quality problem but our aim is to maintain the Quality of Services (QOS) to ensure right power quality distribution. Due to nature of the generation and then transmission equipments, the supply is AC in nature and supplied in sinusoidal form. The signals that are supplied are low pass in nature and thus are prone to the high frequency components. In such cases, the problem of the high order harmonics arises and need to mitigate in order to ensure the good quality of power distribution. However, the main problem of the harmonics arises due to the non-linear nature of loads like diodes, non-linear electrical components. They tend to add higher order harmonics to degrade the quality of power. Rectifiers are considered as basic element in power conversion to ensure supply of appropriate form of energy to the load. Various topologies are there, like 6-pulse, 12-pulse etc. Since, inputs harmonics are found to be more efficient since they have lesser input harmonics. In this paper we have considered model of the 12-pulse rectifier that act as non-linear load. These are commonly found in most of the charging circuits, preliminary supply circuits of various electrical and electronics equipment. Aim of this paper is to reduce the input harmonics effectively from the 12-pulse diode based rectifier. This paper presents a design based on the HAPF (Hybrid Active power filter). We need to reduce the harmonics to minimize THD% to improve power quality. Controller plays an important role in functioning of the system. Conventional static controllers like PI, PID have several limitations for such non-linear rectifier systems. The PI controllers have several limitations since they are non-adaptive and non-robust for such high order non-linear loads. They require very precise design and pre-assumed non-linearity. However, for the dynamic scenario where the disturbance can't be modelled with high precision, they seem to lose their efficiency. In this scenario, fuzzy controllers have advantages. They deal with non-linearity highly effectively. They can be effectively use at the place of for less precise models and unknown disturbances as well. In this paper, we are using the fuzzy logic controller for the design of the Hybrid Active Power Filter for the given system. This fuzzy logic controller is applied to reduce the input current harmonics for the 12-pulse rectifier circuitry. This paper demonstrates that using Hybrid Active Power Filter the input current harmonics as well as load current harmonics has been reduced to a minimal value effectively.

II. HYBRID ACTIVE POWER FILTER

An active filter consists of active components, such as specially controlled inverter, which actively detects the emergence of harmonic current components on an electrical network. Compensated current with a phase difference of 180° then is injected to the network, thus ceasing the harmonics. An active filter is also capable to compensate power factor. A number of harmonic currents can also be compensated using an active filter.

Within a conventional hybrid active filter, the active filter is connected to a shunt passive filter via transformer. This configuration requires a relatively small active filter due to a large voltage drop on fundamental component caused by the capacitor filter. In this paper, a more robust active filter namely hybrid parallel active filter, as shown in Figure 1, is applied to compensate the presence of harmonics. The active filter is connected in parallel to an inductor filter with a transformer, hence reducing load current on the inverter (active filter). This obviously increases the overall performance of the harmonic filter.

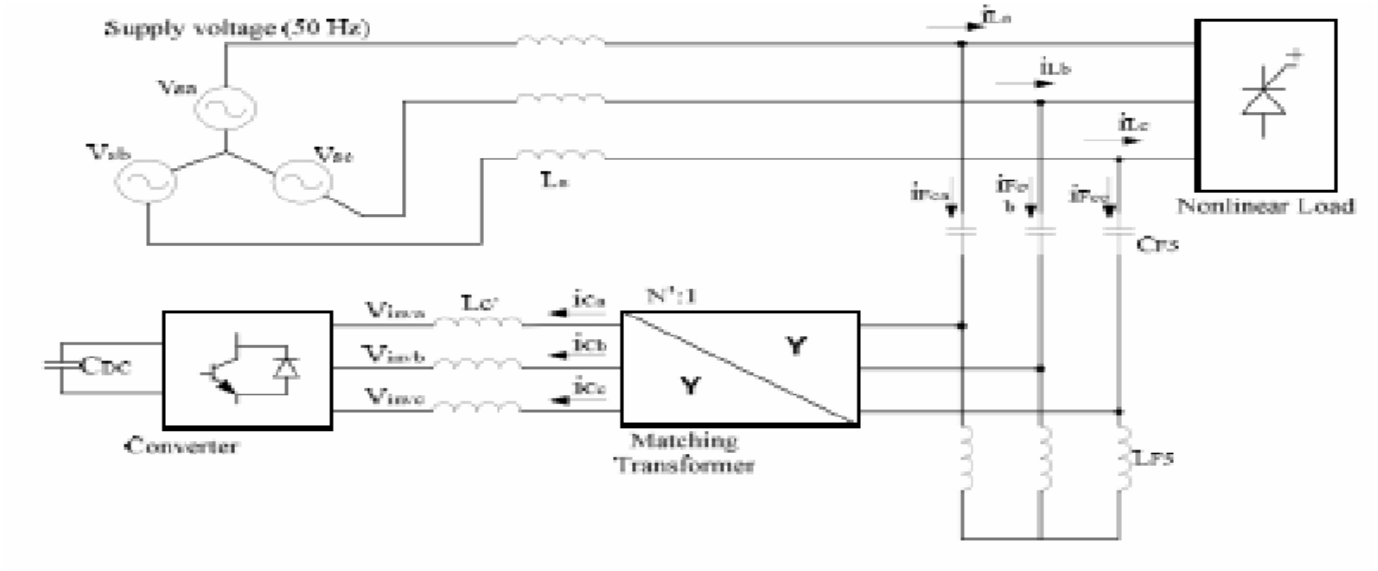

Figure 1: Topology of the hybrid active power filter (HAPF)

Hybrid Filter is a combination of series and shunt filters. Among the various available combinations, active-passive combination is effective as it has the advantages of both active and passive filters. The characteristics of the passive filter is improved, avoiding the problems of series and parallel resonances. The series APF with a shunt connected passive filter is widely used due to the above advantages.

III.FUZZY LOGIC CONTROLLER

A Control System on mathematical system that analyzes analog input values in terms of logical variable that take on continuous value between 0 and 1. In contrast to classical on digital logic, which operates on discrete values of either 1 or 0 (true or false) respectively.

In any fuzzy logic controller, operations are divided into three steps as

A. Fuzzification

B. Fuzzy processing

C. Defuzzification

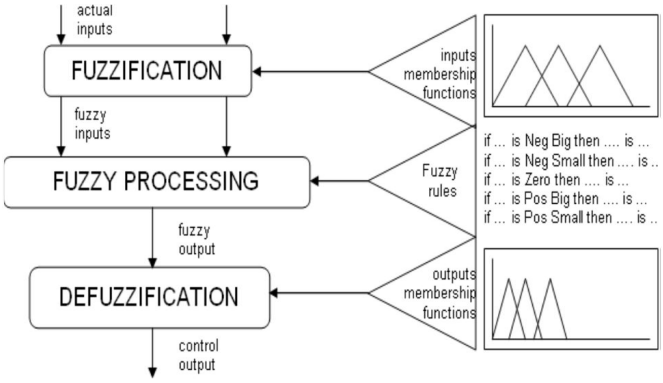

Fig.2 Block diagram of fuzzy logic controller

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Fuzzy control has low requirement for the model accuracy, and can handle nonlinear problem. So it is introduced to 12 pulse rectifier control system.

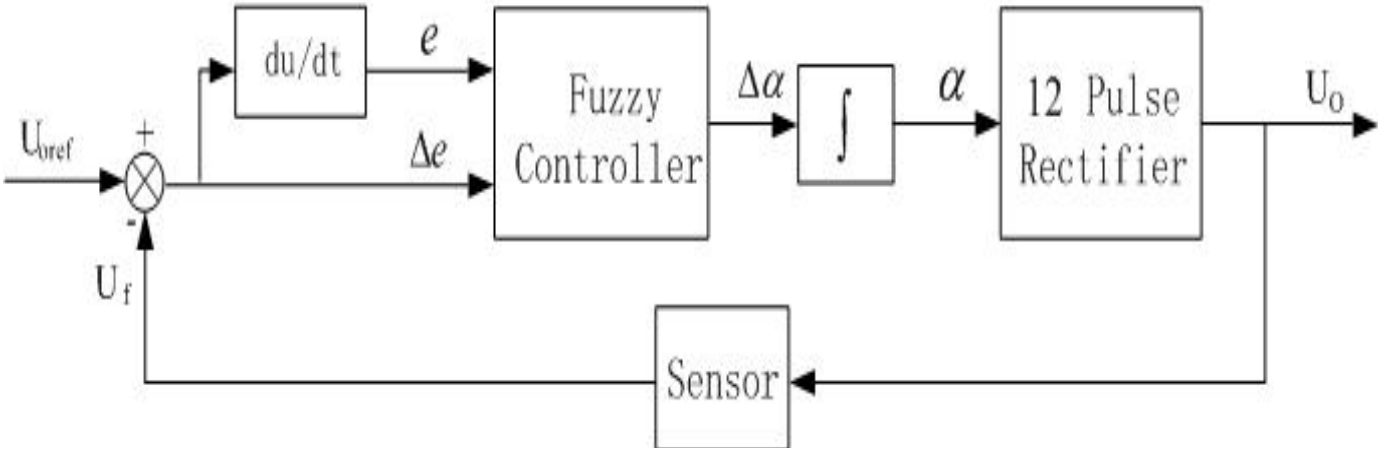

Fig.3 Topology of fuzzy logic controller in HAPF (hybrid Active power filter)

1) *The Input and Output of Controller:* The structure of controller is shown as figure 3. Choose the error between reference and feedback and its time derivative as controller input. The control angle variation is chosen as controller output. There need to be an integral link to calculate actual control angle.
2) *The Fuzzification of Input and Output:* Define the fuzzy set as positive big (PB), positive small (PS), zero (ZE), negative small (NS), negative big (NB) in every input and output respectively**.**

For the error, the 230V error range can be defined as NS and PS according to the system output range to optimize the dynamic performance. The fuzzy set ZE should be as small as possible to improve the system accuracy. For the error time derivative, the fuzzy set should be set according to the dynamic performance requirement. For the control angle variation, the fuzzy set should be set according to the phase transfer range.

D. Simulink Model

The MATLAB/Simulink model has been simulated using simscap power system tool box. Simulink model have three phase voltage balanced supply. In this model HAPF (hybrid active power filter) means connection between active power filter and passive filter is connected with the Transformer.

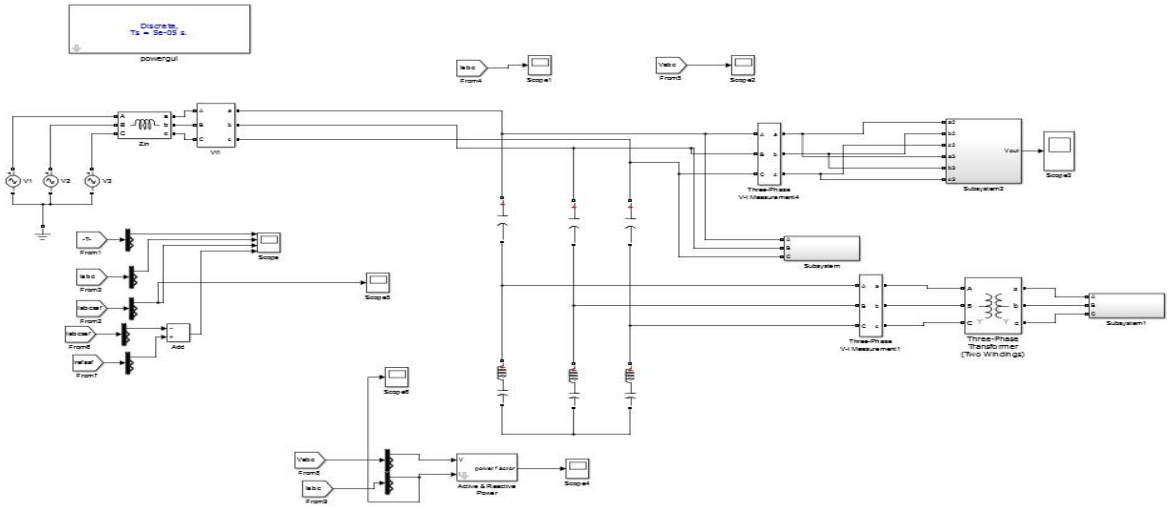

Fig.4 Schematic diagram of HAPF with 12 pulse rectifier circuit load

IV. RESULT AND DISCUSSION

The following table presents the simulation parameter for system. This system consists of sinusoidal three phase voltage supply 230V with practical internal impedance modelled. It also consists of 12 pulse rectifier circuit load which is highly nonlinear in nature. The HAPF (hybrid active power filter) designed for same.

Table1

Supply System	Line voltage (rms value)	230
	Line frequency (Hz)	50
	Source inductance(mH)	1
Active filter	V_{dc}(V)	497.7
	C_{dc}(μF)	60
	L_c(mH)	0.2
Passive filter	C_f(μF)	1.77
	L_f(mH)	49.75
Non linear	R_L(Ω)	250
	L_L(mH)	0.05

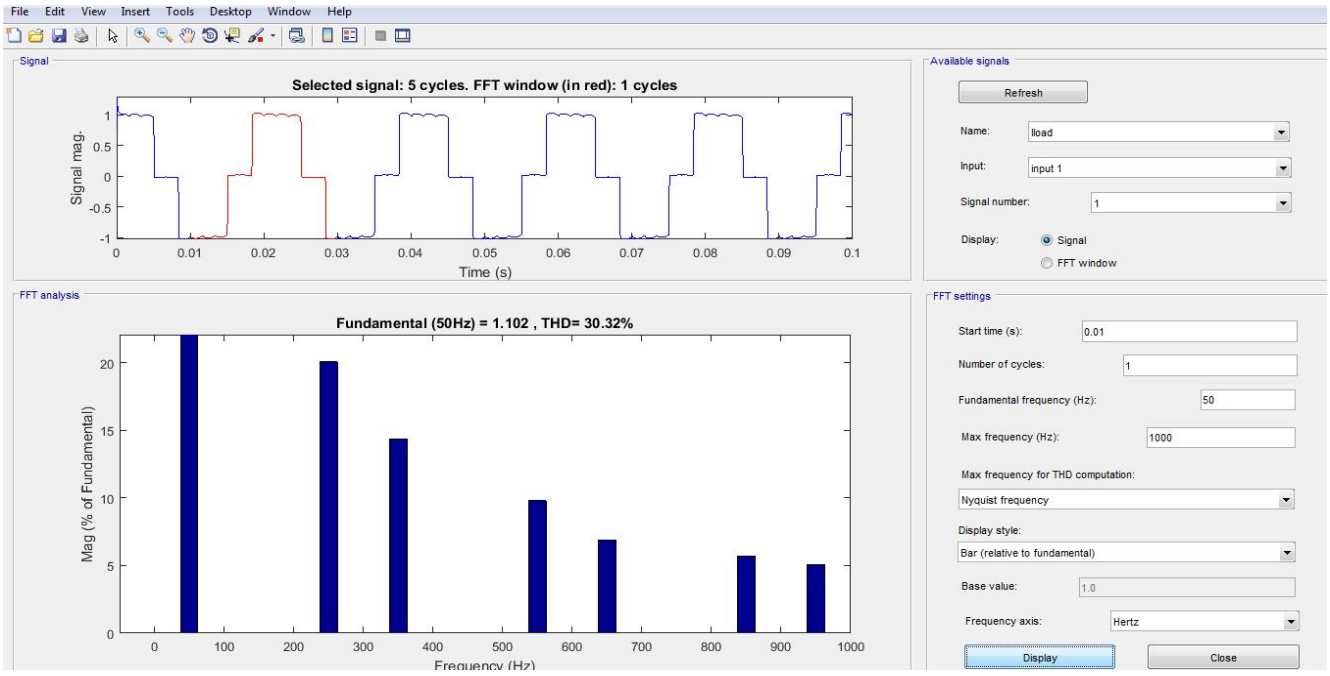

Fig.5 THD analysis of load current with non-linear load without HAPF

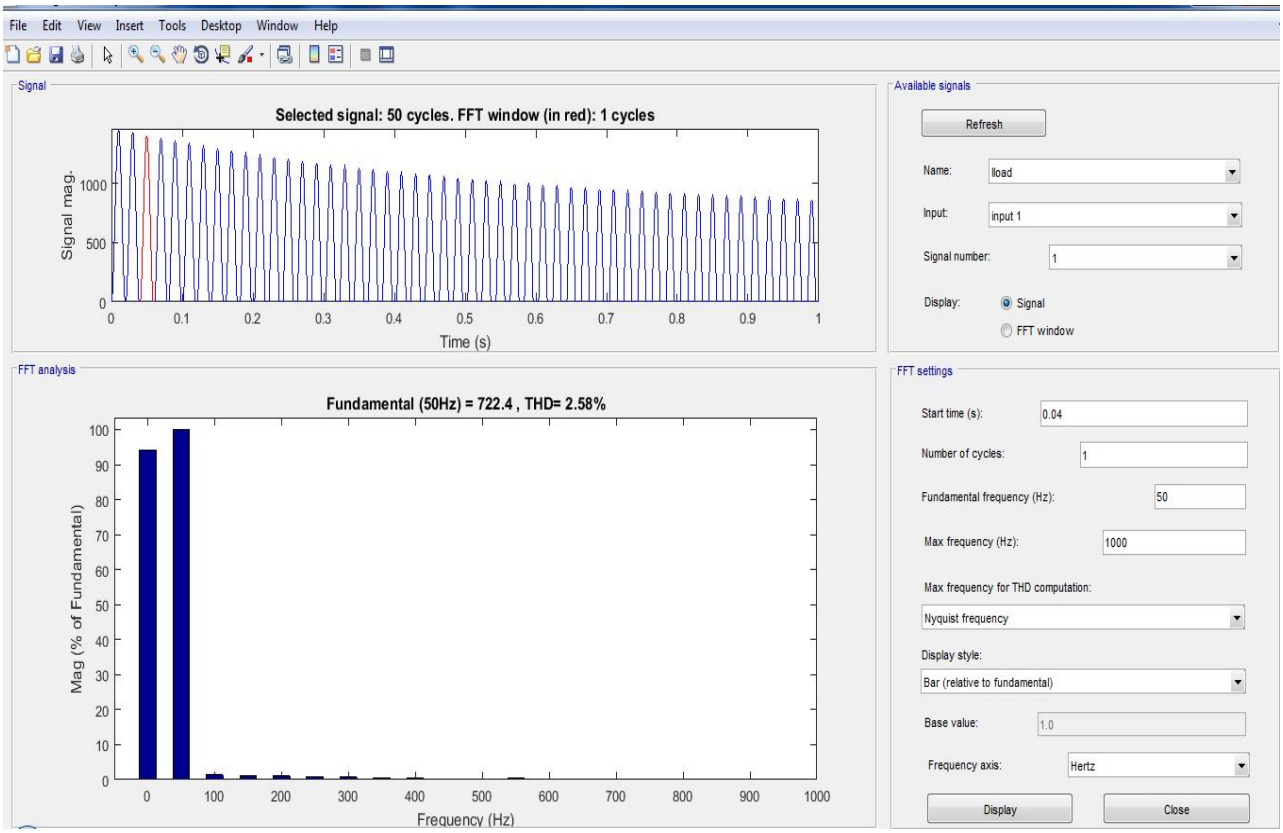

Fig.6 THD analysis of load current with non-linear load with HAPF

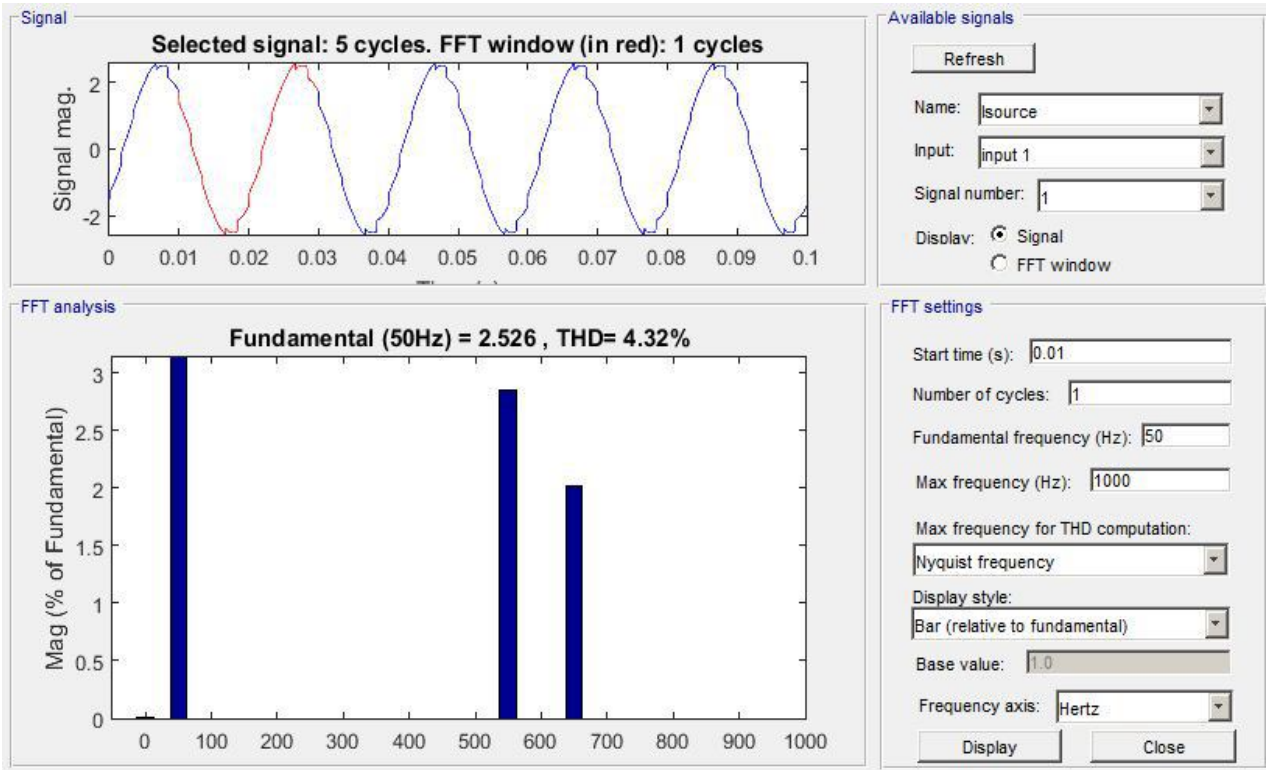

Fig.7 THD analysis of input current waveform without HAPF

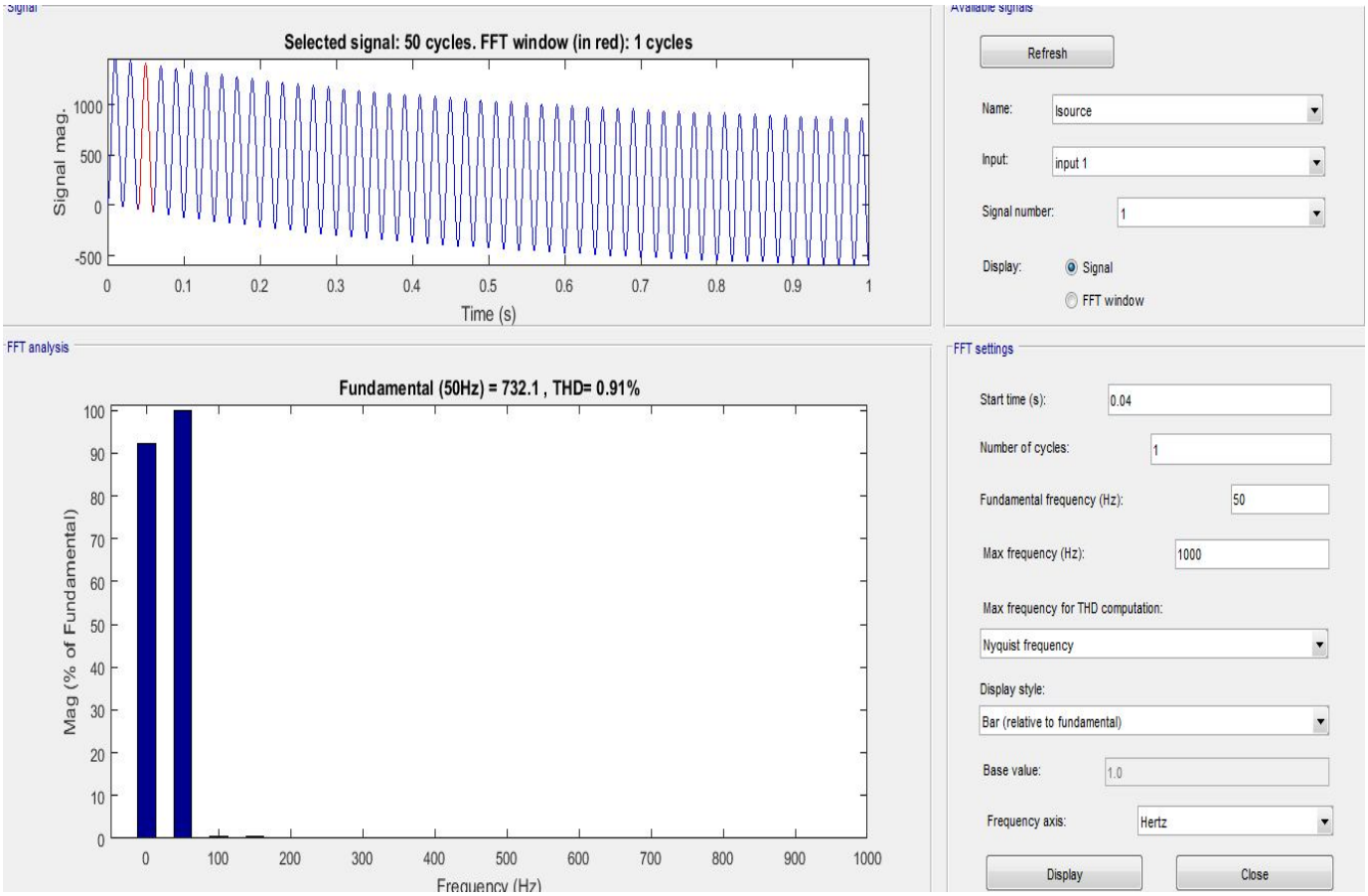

Fig.8 THD analysis of input current waveform with HAPF (Hybrid active power filter)

Table 2

V. CONCLUSION

This paper presents the application of fuzzy logic controller to control the compensating input voltage and current and how effectively Hybrid Active Power Filter reduced THD% to a minimal value. MATLAB/Smulink model has been developed in order to ensure improved THD% for 12- pulse rectifier circuit load, which is highly nonlinear in nature and create harmonics. So we are implementing a HAPF (hybrid active power filter) in this model. This Paper demonstrates that THD% can be reduced to the source as well as to the load to a minimum value by using HAPF with fuzzy logic controller. The results of THD calculation has been presented as obtained by MATLAB/Simulink power GUI analysis (FFT) measurement.

VI. FUTURE SCOPE

This research work can be extended for different load conditions. For future work other efficient controllers can be used such as ANFIS (adaptive neuro fuzzy inference strategy) and BELBIC (brain emotional learning based on intelligent controller). These controllers are computationally efficient, on increasing the dynamic parameters. They provide good stabilization when a sudden fluctuation occurs. This will show the excellent response of the proposed control scheme.

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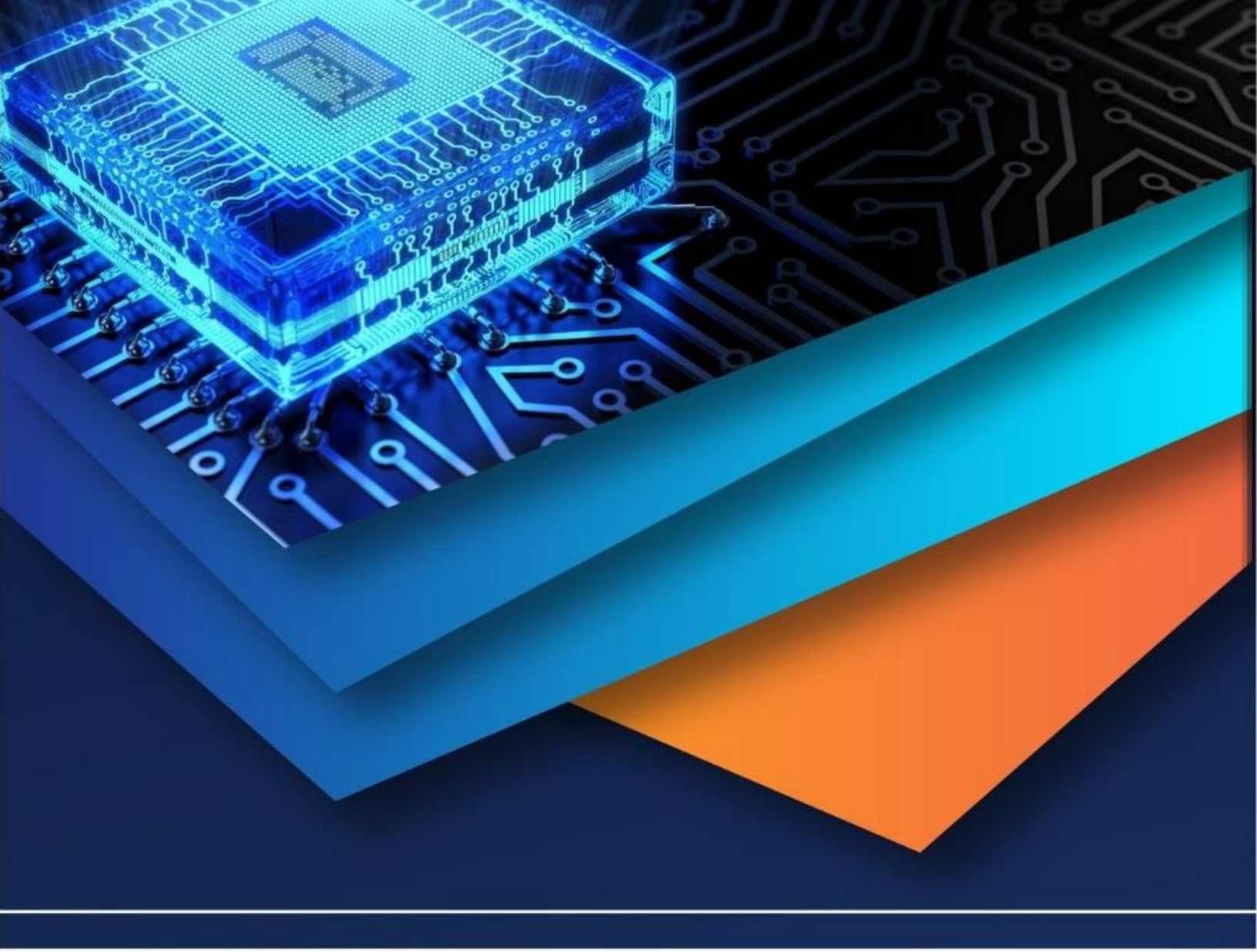

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