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Power Quality Improvement for Three Phase Four Switch Active Filter

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ABSTRACT

Performance investigation of Active Power Filter for harmonic elimination is an interdisciplinary area of interest for many researchers. This paper presents performance improvement of 3-phase Series Active Power Filter (SeAPF) with Hysteresis Current Control technique for elimination of harmonic in a 3-phase distribution system. The shunt active filter employs a simple method called synchronous detection technique for reference current generation. A proportional-integral (PI) and Fuzzy Logic Controller (FLC) are designed to adjust the parameters of the SePF system. The proposed system has achieved a low Total Harmonic Distortion (THD) which demonstrates the effectiveness of the presented method. This paper presents B4inverter topology which give reduced number of switches and switching losses. The simulation of global system control and power circuits is performed using Matlab/Simulink and Sim P ower System toolbox. The simulation results presented demonstrate improved performance of the SePF system with the proposed fuzzy logic control approach.

Key Words: eries Active Filter, PI, Fuzzy, B4 Inverter Topology.

I. INTRODUCTION

The main objective of the power system is generation of electrical energy to transmit and distribute to the end-user. Many power systems are internally connected into a network. If a fault exists in any one of the network, it should affect the whole power system. Transients, sagging, variations in voltage, harmonics are the some of disturbances affecting power system. The aim of this paper is to reduce the current harmonics. Basically, AC electrical power system mainly uses non-linear loads. For these types of loads, the load current and voltages are non-sinusoidal. So it is necessary to compensate the voltage and current harmonics. Non-linear loads are mainly used in adjustable-speed drives, switch mode power supply (SMPS), and uninterruptable power supply (UPS). These types of loads will cause harmonic voltage drop across the network impedance, resulting in distorted voltage. Harmonics are one of the major concerns in a power system. Harmonics are the non- integer multiples of the fundamental frequency. It is generated in a power system by means of non-linear loads. In order to reduce the harmonic distortion two types of filters can be used. 1) Active filter 2) Passive filter. A passive filter is composed of only passive elements such as inductor, capacitor and resistor. The passive filters are inexpensive.

But they are ineffective due to the inability to adapt to network characteristic variations, which leads the use of active filters. An active filter is implemented when orders of harmonic currents are varying. It uses active components such as MOSFET, IGBT-transistors etc. Its structure may be either of the series or shunt type. Shunt active power filters are widely used for mitigating current harmonics.

Series active filters are widely used for mitigating voltage harmonics. The drawbacks of series active filter are, they have to handle high load currents, which increase their current rating and increasing I_2R losses. It is mainly used at the load because non-linear loads inject current harmonics. It injects equal compensating currents, opposite in phase, to cancel harmonics and/or reactive currents of the non-linear load current at the point connection.More recently, voltage source inverter or current source inverter based active power filter is used. They have many advantages as compared to the previously used methods, which include potential size, weight and cost reduction ,small size and light weight, low power losses, tracking of the power system frequency change, fast dynamic response to load changes and reduction of resonant problems. In addition, APF can provide other conditioning functions such as reactive power control, load balancing and flicker mitigation. Selective harmonic compensation can be used in to reduce the harmonics chosen by the designer. Many types of control schemes and controllers are available. The control algorithms are stationary reference frame theory, indirect current control method, Hysteresis current control, Band-reject filter method, and Synchronous-detection algorithm. Along with these, different soft computing techniques are used such as Artificial Neural Network (ANN), Genetic Algorithm (GA). Here linear current control scheme with PI and fuzzy logic controllers are discussed. This paper presents an alternate and effective method for controlling shunt active power filter. A fuzzy logic control based (FLCB) shunt active filter (SAF) capable of reducing harmonic distortion in power system proposed. The proposed method has advantage that the control block becomes simpler.

The dc link fuzzy control has better dynamic behavior than conventional PI controller. The factors should be analyzed are total harmonic distortion (THD) and power factor(PF) improvement. The shunt active filter control seems to be an attractive solution for harmonic current pollution problem. Here, harmonics reduction in the source current and power factor improvement are considered.

II. SERIES ACTIVE POWER FILTER WITH NON-LINEAR LOAD

Series active filter is used in the load side of the system. Because non-linear loads is to generate harmonics in the current waveform.

A. Basic concept of active power filter

Fig.1shows the configuration of active power filters with non-linear load. The basic operating principle of active power filter is that a non sinusoidal waveform at a bus can be corrected to sinusoidal by injecting current of proper magnitude and waveform.

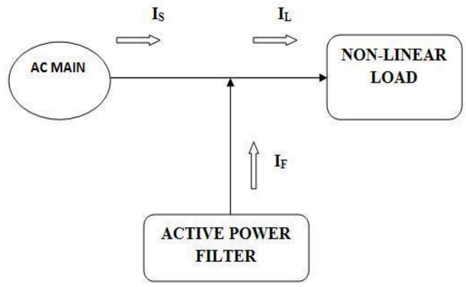

Fig1. Basic concept series active filter.

The basic concept of APF is explained in fig

$$I_L = I_S + I_F \quad (1)$$

The load current having fundamental and harmonic content, and IF is the harmonic compensating current.

$$I_L+I_H=I_S+I_H \quad (2)$$

Filter provide harmonic requirement of the load

$$I_L+I_H=I_S+I_H \quad (3)$$

$$I_L=I_S \quad (4)$$

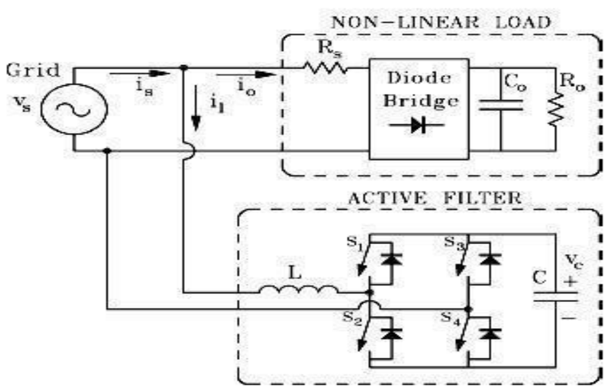

Fig2. Series APF with non-linear load and the full- bridge converter

Thus the supply current represents the fundamental waveform input output harmonics. Fig.2. shows the configuration of active series filter with non-linear load and the full bridge converter. This is almost widely used to eliminate current harmonics, reactive power compensation and balancing the unbalanced currents.

B. Non-linear loads

Non-linear loads are considered as the second category of loads. The application of sinusoidal voltage does not result in a sinusoidal flow applied sinusoidal voltage for non-linear devices. In this system the nonlinear load consists of a diode bridge, a series resistance (Rs), and a Inductive Load.

III. SEAPF WITH PI CONTROLLER

The second proportional integrator (PI) controller used in the outer loop was to enhance the effectiveness of the controller when regulating the dc bus. Thus, a more accurate and faster transient response was achieved without compromising the compensation behavior of the system. According to the theory, the gain G should be kept in a suitable level, preventing the harmonics from flowing into the grid. As previously discussed, for a more precise compensation of current harmonics, the voltage harmonics should also be considered. The compensating voltage for current harmonic compensation is obtained from

$$v_{comp\_i}(t) = \left(-G\hat{i}_S + \hat{v}_L\right) - \left[\left| -Gi_{S1} + v_{L1}\right| \cdot \sin(\omega_S t - \theta)\right].$$

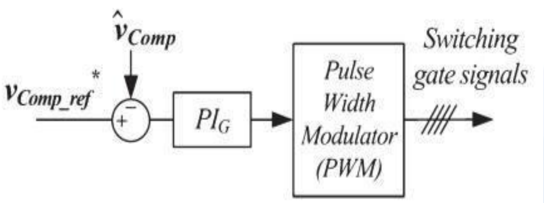

Fig 3. Structure of conventional PI controller.

A low-pass filter is used to attenuate the frequencies higher than the cutoff frequency. It is sometimes called a high-cut filter, or treble cut filter when used in audio applications. A filter with low pass crossover frequency 10Hz is used. Based on the PWM signal the switches will be operated. And the signal is given to the Inverter Bridge. Voltage distortion at the load terminals is notdesired, the voltage sag and swell should also be investigatedin the inner loop. The closed-loop equation allows to indirectly maintain the voltage magnitude at the load side equaltoV*Las a predefined value, within acceptable margins

$$v_{comp\_v} = \hat{v}_L - V^*_L \sin(\omega_S t) \qquad (6)$$

The entire control scheme for the THSeAF presented in Fig.5 was used and implemented in MATLAB/Simulink

For real-time simulations and the calculation of the compensating voltage. The real-time toolbox of dSPACE was used for compilation and execution on the dsp-1103 control board. The source and load voltages, together with the source current, are considered as system input signals. According to Srianthumronget al., an indirect control increases the stability of the system. The source current harmonics are obtained by extracting the fundamental component from the source current.

$$V^* = V_v - V_i + V_{ref} \qquad (7)$$

Where the V_{DC_ref} is the voltage required to maintain the dcbus voltage constant.

$V_{DC\_ref}(t) = V_{O\_DC} \cdot \sin(\omega_S t)$

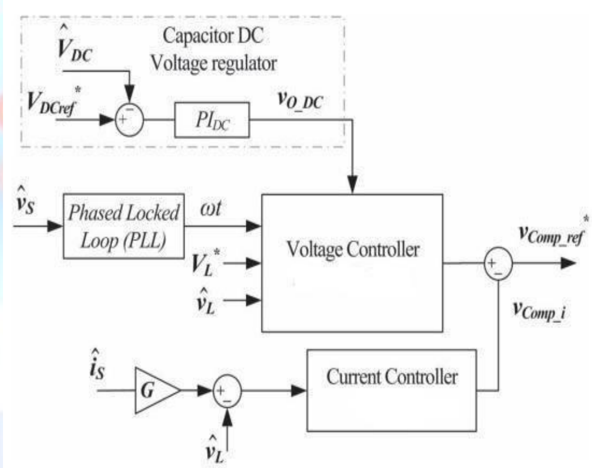

Fig 4. Control system scheme of the active part with PI controller.

IV. PROPOSED CONVERTER

Fig.5 shows the B4 topology having a two leg inverter in which switches (T1–T4) are considered ideal (i.e., no saturation voltage drop and no dead time) for our convenient analysis. Sb and Sc can be used as binary state variables to denote the switching states of leg b (T1,T2) and leg c (T3,T4) respectively. The dc-link is split in to two voltage sources; one load phase is connected to the middle of dc- link. The simultaneous closed states of two switches in each leg are usually avoidable in order to prevent the short circuit of dc-link. Therefore, binaries 1 and 0 will indicate the closed states of upper switch and lower switch respectively. By assuming the three-phase voltages as balanced, the phase- to-neutral voltages VaN ,VbN ,VcN are as follows:

= 1 3 (- -) + 2 3 (2- -)
= 1 3 (2- -) + 2 3 (2- - -1)

VcN = Vdc1 3 (2-Sc-Sb) + Vdc2 3 (2-Sc-Sb-1)

Where Vdc1 and Vdc2 are the upper and lower dc link capacitor voltages respectively,

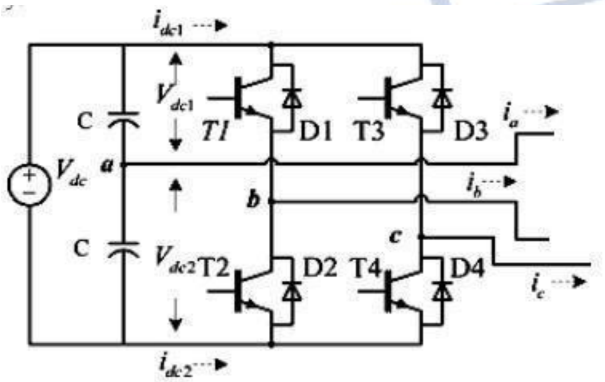

Fig 5. Circuit diagram of B4 inverter.

Table I gives the phase-to- neutral voltages values by considering all the possible combinations of (Sb ,Sc).

States		Switch on		Output Voltage		
S_b	S_c			V_{aN}	V_{bN}	V_{cN}
0	0	T2	T4	$2V_{dc2}/3$	$-V_{dc2}/3$	$-V_{dc2}/3$
0	1	T2	T3	$(V_{dc2}-V_{dc1})/3$	$-(2V_{dc2}+V_{dc1})/3$	$(V_{dc2}+2V_{dc1})/3$
1	0	T1	T4	$(V_{dc2}-V_{dc1})/3$	$(V_{dc2}+2V_{dc1})/3$	$-(2V_{dc2}+V_{dc1})/3$
1	1	T1	T3	$-2V_{dc1}/3$	$V_{dc1}/3$	$V_{dc1}/3$

V. SAPF WITH FUZZY LOGIC CONTROLLER

The Fuzzy Logic tool is a mathematical tool for dealing with uncertainty. It is important to observe that there is an intimate connection between Fuzziness and Complexity.

A. *Fuzzy Logic Controller*

Fuzzy logic controller (FLC) is suitable for systems that are structurally difficult to model due to naturally existing non linear ties and other model complexities. This is because, unlike a conventional controller such as PI controller, rigorous mathematical model is not required to design a good fuzzy controller. The database, consisting of membership functions. Basically membership value should lies between 0 to 1. The operations performed are fuzzification, interference mechanism and defuzzification. The interference mechanism uses a collection of linguistic rules to convert the input conditions into a fuzzified output. Finally defuzzification is used to convert the fuzzy outputs into required crisp signals

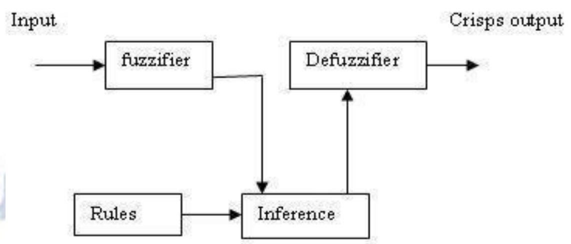

Fig 6. Fuzzy controller block diagram

B. *Fuzzification*

Fuzzification is an important concept in the fuzzy logic theory. Fuzzification is the process where the crisp quantities are converted to fuzzy (crisp to fuzzy).By identifying some of the uncertainties present in the crisp values, we form the fuzzy values. The conversion of fuzzy values is represented by the membership functions

C. *Defuzzification*

Defuzzification means the fuzzy to crisp conversions. The fuzzy results generated cannot be used as such to the applications; hence it is necessary to convert the fuzzy quantities into crisp quantities for further processing.

D. *FLC Design Methodology*

Design of fuzzy logic controller comprises the following steps.

1. Identifying the input signals to FLC.
2. Determining the number of membership function,
3. 3.Decide upon the type of membership function.

E. *Membership function*

The number of membership function determines the quality The number of membership function determines the quality of control which can be achieved using fuzzy logic controller(FLC). As the number of membership function increase, the quality of control improves at the cost of increased computational time and computer memory. Investigations are carried out considering seven membership function for each input and output signal.

Table 2. Fuzzy rule Base

e / de	NL	NM	NS	ZE	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	ZE
NM	NL	NL	NL	NM	NS	ZE	PS
NS	NL	NL	NM	NS	ZE	PS	PM
ZE	NL	NM	NS	ZE	PS	PM	PL
PS	NM	NS	ZE	PS	PM	PL	PL
PM	NS	ZE	PS	PM	PL	PL	PL
PL	NL	NM	NS	ZE	PS	PM	PL

F. Fuzzy control scheme for APF

In the fuzzy logic control algorithm for APF two inputs are required. The inputs are error and chancge in error. The two inputs were related by member functions. Basically forty nine rules are there. Based on the operation it will be used. The membership functions are expressed in negative large (NL), negative middle (NM), negative small(NS), zero(ZE), positive small(PS), positive middle(PM) and positive large(PL). Actual voltage is compared with the reference voltage, based on that error will be produced. It can be compensated by using fuzzy logic controller. Actual current is compared with the reference current, and error is compensated by fuzzy controller. Fuzzy sets support a flexible sense of membership functions.

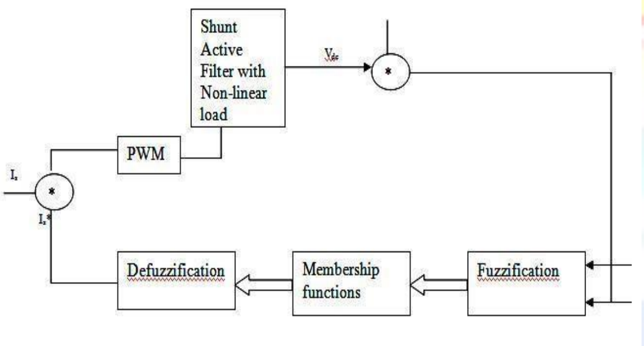

Fig 7. Structure of the fuzzy for APF controller

A triangular membership function has the advantage of simplicity and easy implementation and is adopted in the application. Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The centroid method of defuzzification is generally used, but disadvantage of this method is, it is computationally difficult for complex membership functions. Here bisector method of defuzzification is used. The advantages of bisector method are, it is fast and generally produces good results.

VI. Simulation Results

The proposed transformer less- HSeAF configuration was simulated in MATLAB/Simulink using discrete time steps ofTs= 10 µs.A system with a typical source inductance Ls of 250 µH and a delay of 40 µs is considered stable when the gain **G** is smaller than 10Ω.

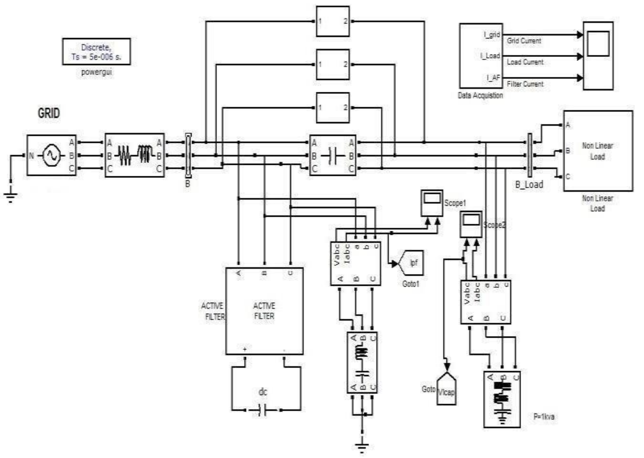

Fig 8. Three phase system with active filter.

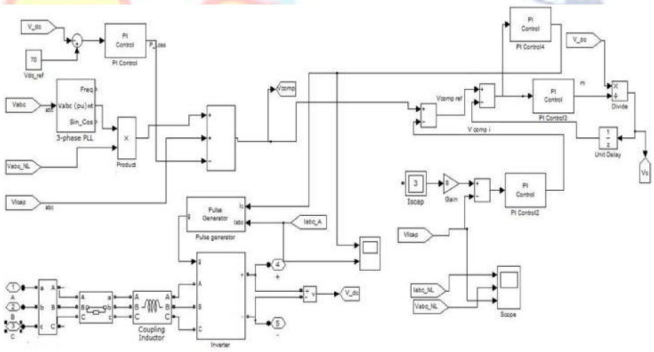

Fig 9. Active filter with pi controller

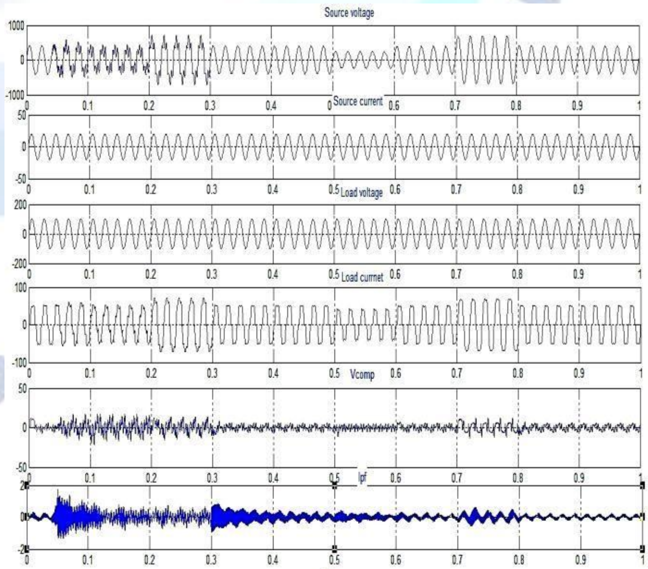

Fig 10. Simulation of the system with PI controller across Phase A (a) Source voltage vS, (b) source current iS, (c) load voltage vL, (d) load current iL, (e) active-filter voltage VComp, and (f) harmonics current of the passive filter iPF.

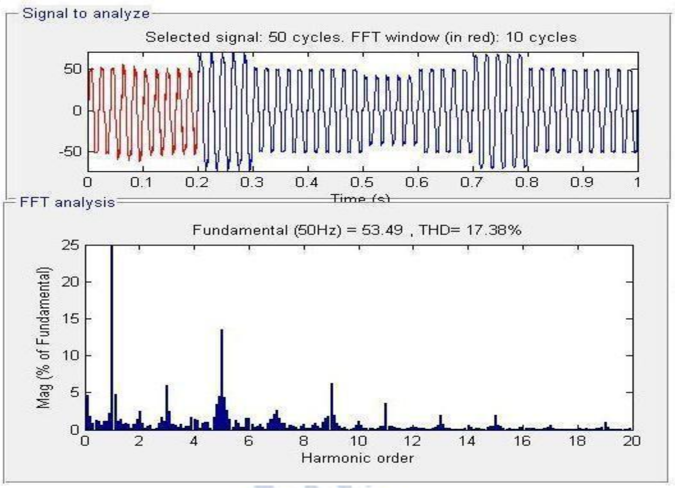

Fig 11. THD of Load Current using PI controller.

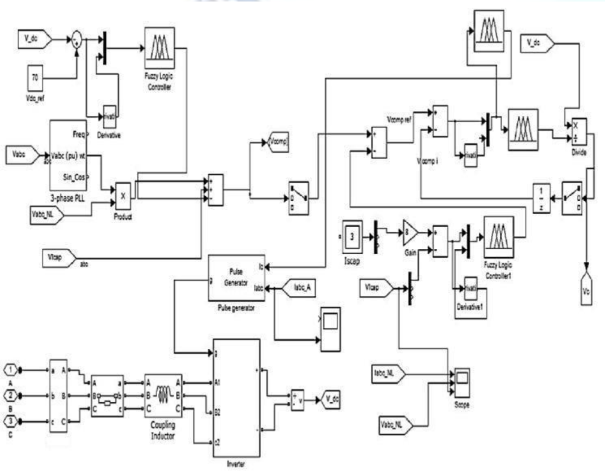

Fig 12. Active filter with Fuzzy controller

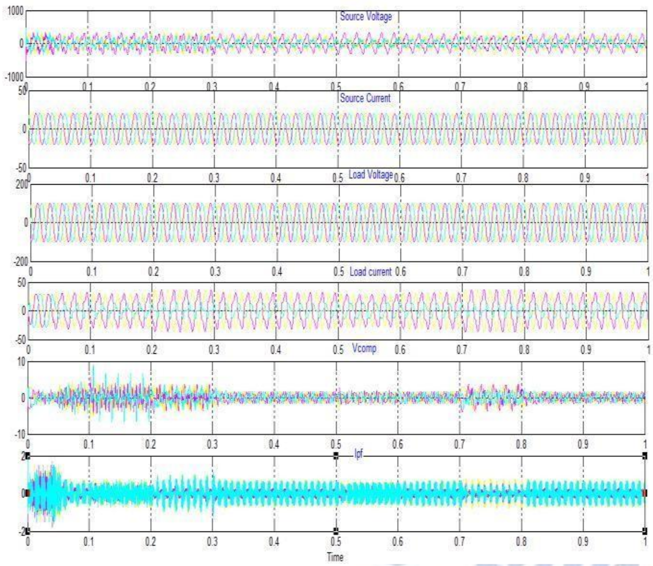

Fig 13. Simulation of the system with fuzzy controller across Three phase (a) Source voltage vS, (b) source current iS, (c) load voltage vL, (d) load current iL, (e) active-filter voltage VComp, and (f) harmonics current of the passive filter iPF.

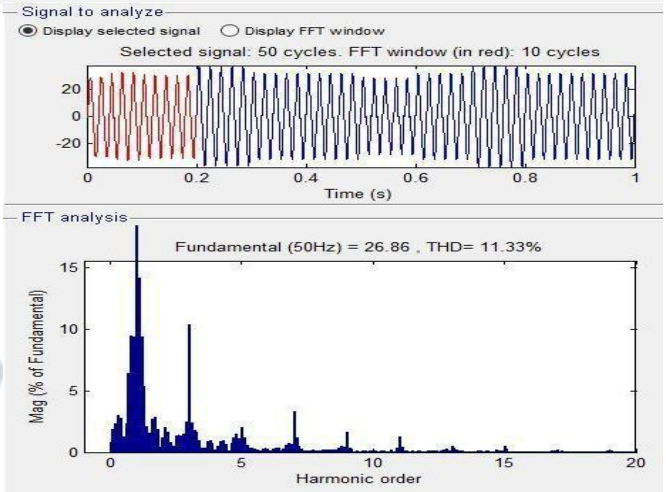

Fig 14. THD of Load Current using Fuzzy controller.

Table 3. THD comparison

Algorithm	Current THD%
PI Controller	17.38%
Fuzzy controller	11.33%

VII. CONCLUSION

The concept of fuzzy controller based series active power filter has been implemented for the improvement of power quality for the system under study. Advantages of the proposed scheme are related to its simplicity, modeling, and implementation. And it has a better dynamic performance. Simulated results have proved the effectiveness of shunt active power filter using proposed fuzzy adaptive controller. Hence it can be seen that total harmonic distortion reduced clearly with the fuzzy controller than the series active power filter with the PI hysteresis current controller. Hence by using fuzzy adaptive controller THD is reduced to 11.33% where as with existing PI current controller THD is 17.38%.

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