COMPARATIVE ANALYSIS OF FILTERS TO MITIGATE HARMONICS FOR POWER QUALITY ENHANCEMENT

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Abstract— Due to the advancement in power electronic equipments and increase in the usage of non-linear loads in power distribution system, the undesirable harmonics are introduced that degrade the quality of power. Presence of harmonics are always detrimental to power system that results in irreversible failure of electrical components, sometimes apart from frequently known heating issues in it. There are several approaches that can be considered to compensate for harmonics in power system with varying degree of effectiveness and approaches. The objective of this paper is to use passive filter and Fuzzy logic controller based shunt active filter for harmonic mitigation and study their performance. The performance of proposed filters is evaluated through computer simulation using Matlab R2010b/Simulink platform. Evaluating the simulation results, the Fuzzy logic controller based shunt active power filter is more effective in reducing total harmonic distortion and improving the power factor of the source signal when compared to passive filter.

Index Terms— Fuzzy Logic Controller, Passive Filter, Power Factor, Power Quality, Shunt Active Filter, Total Harmonic Distortion.

I. INTRODUCTION

In recent decades, the quality of electrical power is degrading mainly due to harmonics. Particularly, current harmonics produced by nonlinear loads have become serious problems in deteriorating the quality of power in power transmission and distribution systems [1-3]. The increase in use of non-linear loads like computers, TV set, Battery charger, etc are growing in a rapid rate both in industry and domestic application. Power electronics based equipment connected to the grid causes non-sinusoidal current due to its non linear characteristics .These current causes voltage distortion and increase the overall reactive power needed by the load. Sensitive loads require pure sinusoidal supply voltages for their prompt operation. Therefore, it is necessary to improve the quality of power by some sort of compensations. To meet these requirements, conventionally passive L-C filters [4] and active power filters are used to improve power factor of the ac loads. Among the various topologies of active filters, Shunt Active Power Filter (SAPF) has proved to be the best choice to eliminate harmonic currents and to compensate reactive power for non-linear load [5]-[8]. In the present investigation, Fuzzy logic controller beads SAPF is developed and its performance is compared with conventional passive filter.

The functioning of SAPF is to sense the load currents and extracts the harmonic component of the load current to produce the compensation current and regulate the DC link voltage. After compensation, voltage at load terminal and source current will be sinusoidal and power factor will be unity. The SAPF needs to be controlled to obtain the best performance for reducing current harmonics. Various control schemes have been introduced to control SAPF [9]-[10]. The effectiveness of SAPF is known by design of power inverter, dc bus voltage control and use of current controller types. The method used to generate reference current is multiplication with sine function. Here, SAPF uses 6 IGBT devices to build the Voltage Source Inverter (VSI) for injecting the compensation current to the system at Point of Common Coupling (PCC). Indirect Current controller technique is adopted in the present study. Nowadays, the soft intelligent technique of Fuzzy Logic Controller(FLC) plays a vital role because of increasing the efficiency, stability, accuracy, robustness, and tracking ability of the systems of each component have been introduced[11]-[12]. Therefore, in the proposed work, performance of FLC based SAPF to mitigate current harmonics is analysed and compared with passive filter. Total Harmonic Distortion (THD) and power factor values are taken along with a various current and voltage signals for both filters and the results are compared. From the results, it is proved that the Fuzzy logic controlled SAPF is more effective and superior for power quality enhancement when compared to passive filter.

II. ACTIVE FILTER WITH NON LINEAR LOAD

A Shunt Active Power Filter is a voltage source inverter which is placed between three phase source and non linear load in such a way to absorb all the disturbances produced by the load. The single line diagram of active filter is shown in Fig. 1.

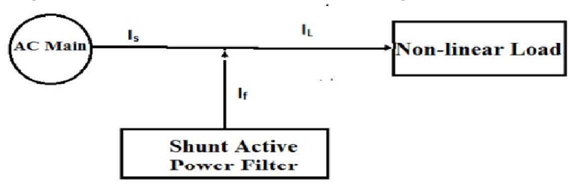


Figure 1. Single Line Diagram of Shunt Active Filter

If the active filter provides the total reactive and harmonic power, then is (t) will be in phase with the utility voltage and purely sinusoidal. At this time, the active filter must provide the following compensating current.

$$I_f(t) = I_L(t) - I_s(t)$$

So, it is necessary to compute the fundamental component of the load current which will be determined using peak value of the reference current. This peak value is multiplied by unit vectors in phase with source voltages to give the corresponding reference source currents.

III. SHUNT ACTIVE POWER FILTER BASED ON FLC CONTROL TECHNIQUE

The schematic diagram SAPF using fuzzy logic controller is shown in Fig.2

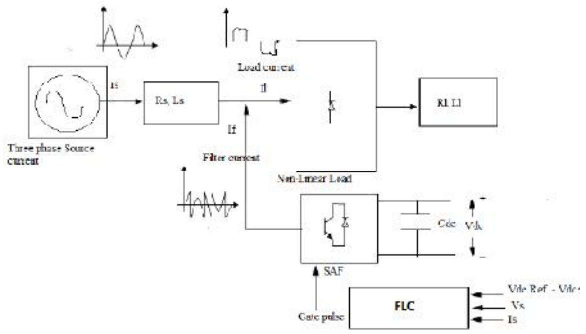


Figure 2: Shunt Active Power Filter using FLC

In this method SAPF is implemented with current controlled PWM rectifier. The current controlled rectifier maintains source current sinusoidal not detecting both load and filter current. The peak value of reference currents is estimated regulating the DC link voltage. 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 ($V_{dc}(k)$) is now compared with a reference voltage ($V_{dc\text{-}ref}$). The difference (or) error signal i.e., (e(k)= $V_{dc\text{-}ref}$ -V_{dc}(k)) and its derivative, ce(k)= e(k)-e(k-1) are the two inputs to FLC. The error signal is then processed through FLC. The output of FLC is the peak value of reference source current (I_{max}) and then gate pulses are generated to turn on the active filter. The fuzzy logic controller is characterized as follows:

- Nine fuzzy sets for each input and output.
- The input variable is a numeric variable converted to fuzzified variable is fuzzification.. The nine fuzzy levels or sets are chosen as: NVB (negative very big), NB (negative big), NM (negative medium), NS (negative small), ZE (zero), PS (positive small), PM (positive medium), and PB (positive big), and PVB (positive very big). Fuzzification using continuous universe of discource.
- Triangular membership functions for simplicity
- Implication using Mamdani's 'min' operator.
- Defuzzification using the 'centroid' method.

Fig. 3 shows the internal structure of the control circuit of FLC. The input- output relations forming the set of rules of triangular membership function based on knowledge of input data base is properly chosen for good decision making. To improve the system performance the formulation of rule set plays an important role in fuzzy system design and it is shown in Table 1. 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 [13]-[15]. Fig.4 shows the membership functions for the input and output variables of FLC.

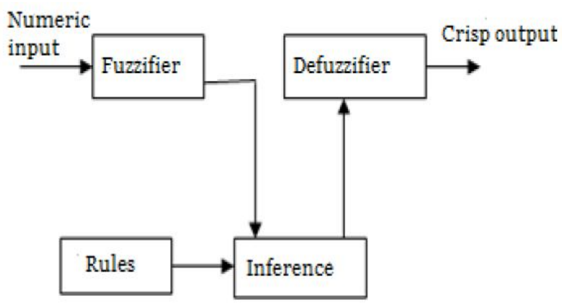
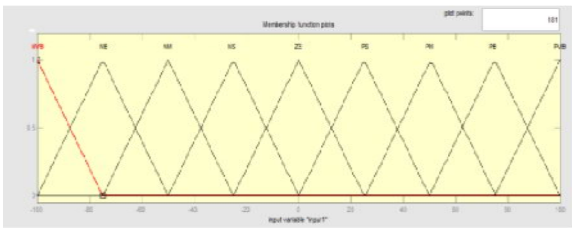
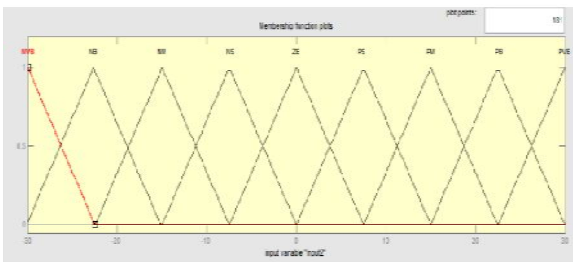


Figure 3. Internal structure of control circuit of FLC

Table 1: Fuzzy Rule

ce(k) \ e(k)	NVB	NB	NM	NS	ZE	PS	PM	PB	PVB
NVB	NVB	NVB	NVB	NVB	NVB	NB	NM	NS	ZE
NB	NVB	NVB	NVB	NVB	NB	NM	NS	ZE	PS
NM	NVB	NVB	NVB	NB	NM	NS	ZE	PS	PM
NS	NVB	NVB	NB	NM	NS	ZE	PS	PM	PB
ZE	NVB	NB	NM	NS	ZE	PS	PM	PB	PVB
PS	NB	NM	NS	ZE	PS	PM	PB	PVB	PVB
PM	NM	NS	ZE	PS	PM	PB	PVB	PVB	PVB
PB	NS	ZE	PS	PM	PB	PVB	PVB	PVB	PVB
PVB	ZE	PS	PM	PB	PVB	PVB	PVB	PVB	PVB





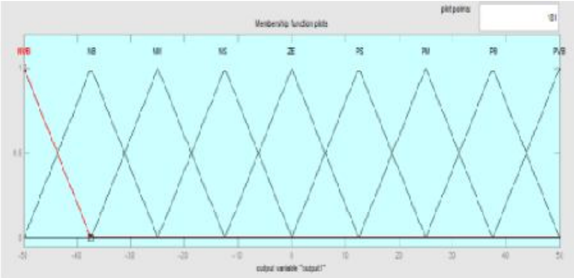


Figure 4. Membership functions for the input and output variables

IV. SIMULATION MODEL

The Fuzzy Logic based SAPF is modeled and simulated in MatlabR2010b/ Simulink. The simulink model without filter and with FLC based SAPF are shown respectively in Fig. 5 and Fig.6. The three phase diode rectifier is considered as non-linear load.

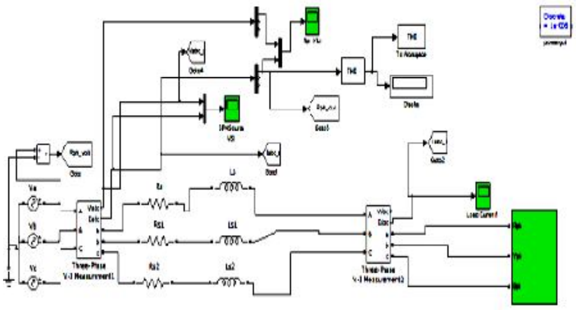


Figure 5. Simulink model without filter

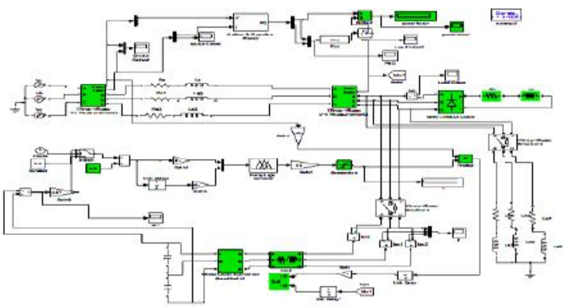


Figure 6. Simulink model with Fuzzy logic controlled SAPF

The system parameters are shown in Table 2.

Table 2: System Parameters

Source voltage	120 V
Source resistance	0.1 Ω
Source inductance	2 mH
DC link capacitor	4400 μF
Reference Voltage	310 V
Load resistance	15 Ω
Load inductance	40 mH
Passive element Inductance	13.5 mH
Passive element Capacitance	30 μF
FIS type for FLC	Mamdani
Membership function for FLC	9X9 Triangular
Implication for FLC	Min
De-fuzification	Centroid

V. RESULT AND DISCUSSION

A. Without Filter

Fig.7(i) shows simultaneously three phase simulated waveform of the source current and voltage before compensation. The three phase load current having fundamental and harmonics is presented in Fig.7(ii) From Fig.7(iii), the values of Total Harmonic Distortion (THD) without filter was estimated. It is proved that before the application of filter, the source current is highly distorted and rich in harmonics with THD 14.77% and power factor is 0. 9557.

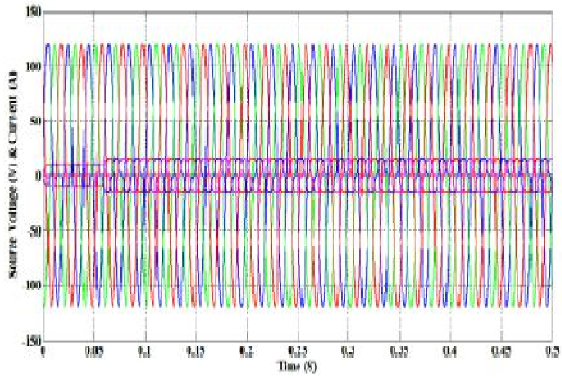


Figure 7(i).Three phase source voltage and current

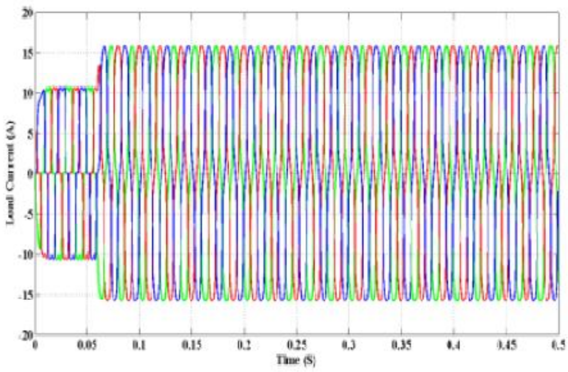


Figure 7(ii).Three phase load current

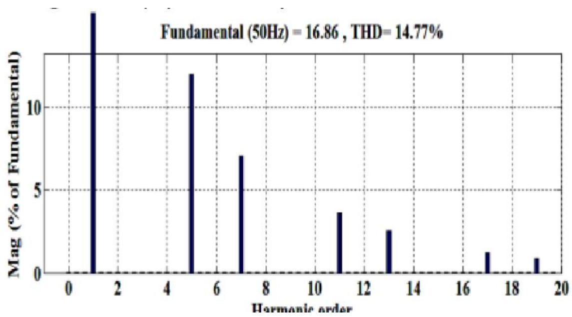


Figure 7(iii). FFT analysis

Figure 7 (i)-(iii). Simulation Result without Filter

B. With Passive filter

The simulation waveforms of three phase source voltage and current and load current are shown in Fig.8(i) and Fig.8(ii) respectively. It is noted from the harmonic spectrum (Fig.8(iii)) that the THD value of source current is considerably reduced to 7.62% but, it is above the limit specified by IEEE standard 519-1992. The power factor has improved to 0.9761

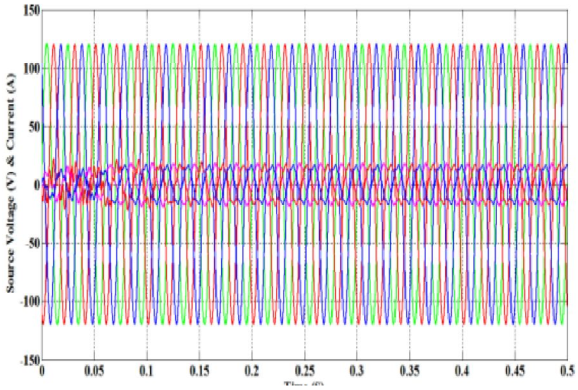


Figure 8(i).Three phase source voltage and current

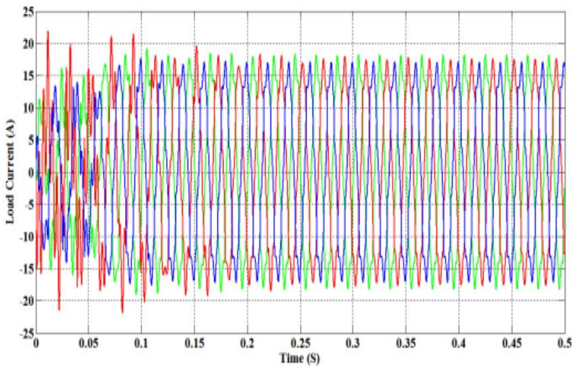


Figure 8(ii).Three phase load current

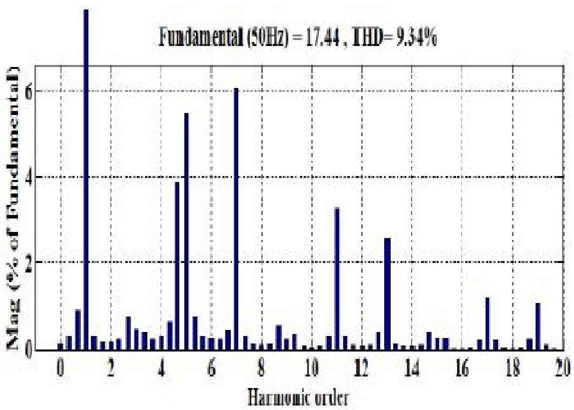


Figure 8(iii). FFT analysis

Figure 8 (i)-(iii). Simulation Result with Passive Filter

C. With FLC based Shunt Active Filter

The waveform of three phase source voltage and current is shown in Fig.9(i). The three phase load current with the content of fundamental and harmonics is presented in Fig.9(ii). The applied compensation current of equal in magnitude and opposite in direction of load current is presented in Fig.9(iii). The DC link voltage is shown in Fig. 9(iv). From Fig. 9(v), it can be noticed that the THD of source current is reduced to 1.30% which is less than previously discussed passive filter and also meet the IEEE standard 519-1992 specification. Also, the FLC based SAPF approached the power factor to unity.

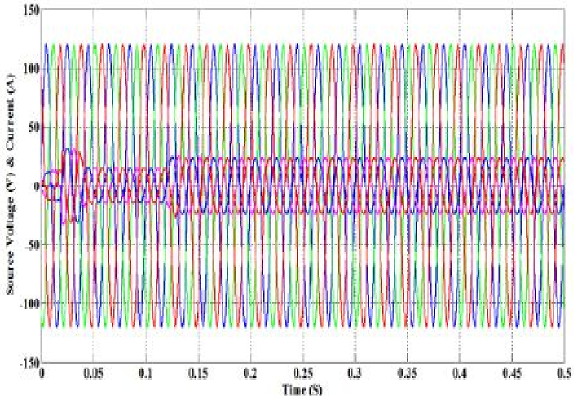


Figure 9(i). Three phase source voltage & source current with FLC

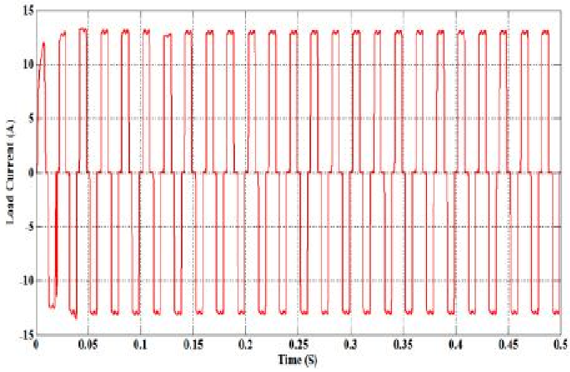


Figure 9(ii). Load current (phase a) with FLC

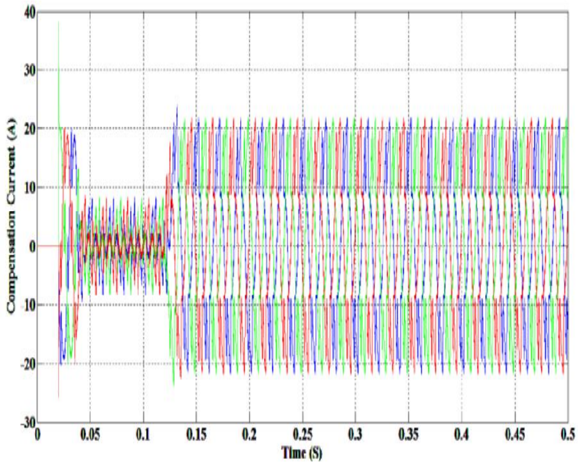


Figure 9(iii). Compensation current with FLC

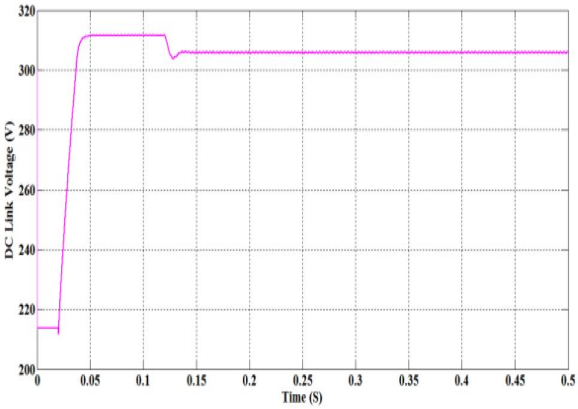


Figure 9(iv). DC link voltage with FLC

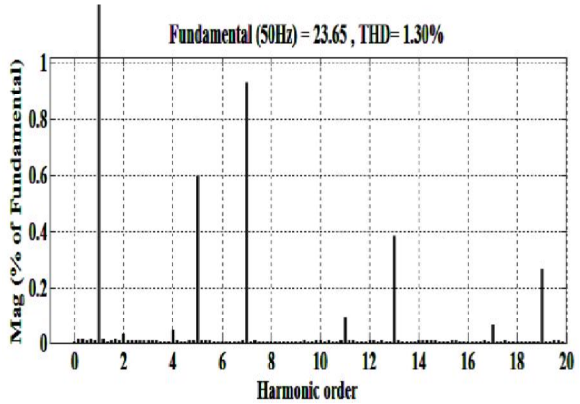


Figure 9(v). FFT analysis with FLC

Figure 9 (i)-(v). Simulation Result with FLC based SAPF

Total Harmonic Distortion and Power Factor with and without filter are shown in Table 3.

Table 3: Performance Comparison table with and without filters for Total Harmonic Distortion and Power Factor

Parameter	Without Filter	With Passive Filter	With Shunt Active Filter
THD	14.77	7.62	1.30
Power Factor	0.9557	0.9761	1

Figure 10 & Figure 11 shows the graphical representation for harmonic suppression and power factor improvement respectively.

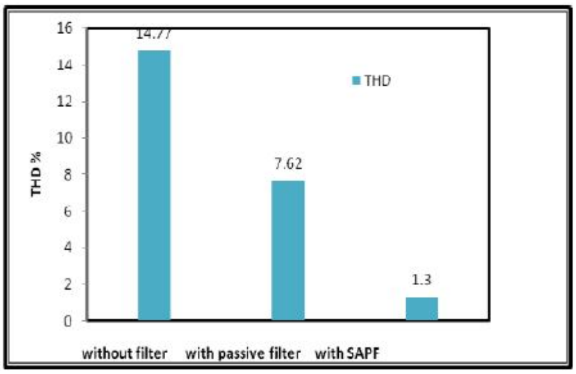


Figure 10 . Graphical Representation of THD

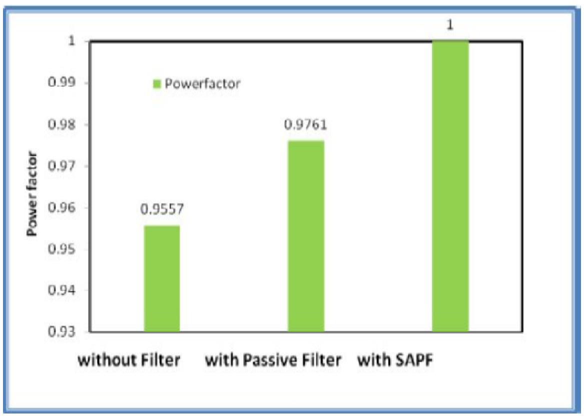


Figure 11 . Graphical Representation of Power factor

CONCLUSION

In this work, passive and FLC based SAPF model was developed for harmonic mitigation. From the simulation result, it is clearly understood that by using passive filter the THD dropped to 7.62 % from 14.77 % which is above the restriction imposed by IEEE Standard519-1992. In the case of fuzzy logic based shunt active power filter, the THD is 1.30% which is well below the limit imposed by above IEEE Standard. Also, the power factor is improved from 0.9557 to 0.9761 in the case of passive filter and to unity in the case of FLC based SAPF. Thus, it is clearly concluded that Fuzzy logic controller based Shunt Active Power filter provides an effective solution for harmonic mitigation when compared to passive filter. In future, this work will be extended to examine the present simulation results by developing a prototype model.

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