PI, FUZZY and ANFIS Control of 3-Phase Shunt Active Power Filter

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***Abstract*—this paper describes control of 3-phase shunt active filter by using PI, fuzzy and ANFIS controls to improve the power quality and reactive power compensation and harmonic current compensation due to nonlinear loads. The controller is capable of controlling the DC capacitor voltage capable of reference source current. Hysteresis control is used to control the current in PWM inverter. The simulation results reveals that comparative study of all this results shows the advantage and disadvantages of 3 control strategies.**

Keyword- power quality, current harmonics, Fuzzy Logic controller (FLC), Adaptive nuero-fuzzy inference systems (ANFIS*)*

I. INTRODUCTION

Now a days we are using many non linear loads such as drives fans and many other power electronic equipments. Because of non linear nature of the loads input source current will be non sinusoidal. So if other load connected to the same source will be damaged need to eliminate the source current harmonics need to eliminate. Passive filters are used to compensate the harmonics but the problem with resonance and weight and fixed compensation. So Active power filters (APF) is alternate solution to eliminate the harmonics which is more effective than other methods. Conventional control is required mathematical analysis of the system so soft computing is alternate solution to control the active power filters means how the biological systems solves the problems. The authors in this paper therefore have developed fuzzy and ANFIS controlling the shunt active power filters.comparitive merits and demerits with conventional PI controller have discussed.

II. BASIC COMPENSATION

In Fig1 shows Shunt active power filter [1] to [3] is a Power electronic converter which is having the capacitor on the DC side by controlling DC capacitor voltage pulses [4] are generated to operate the Shunt active power filter

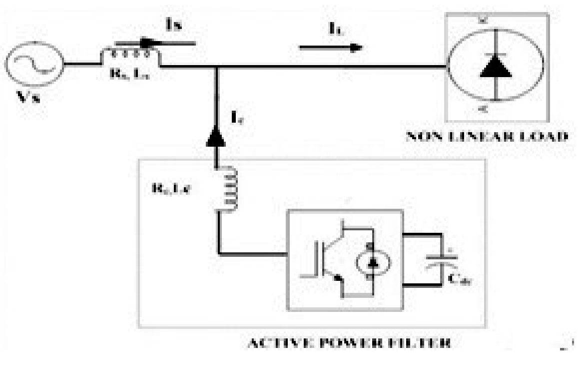


Fig1: Shunt active power filter

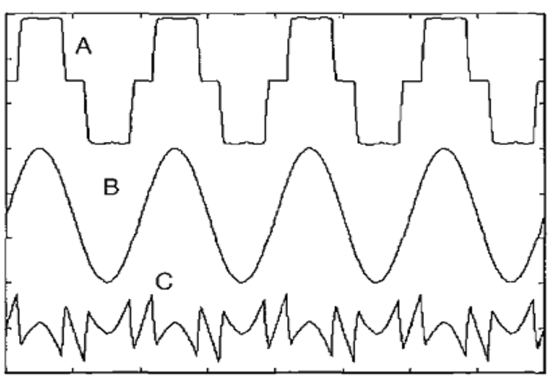


Fig2: Load current(A),line current(B) desired filter current(C)

In Fig2 it is clearly shows that I_L is not Sinusoidal so line current is not a sinusoidal by injecting the compensation current line current By generating the current which is equal in magnitude to the harmonics in source current which is 180^0 degrees is cancels the harmonics present in source current[5]. So the Source current will be sinusoidal without affecting the magnitude of load current. The switching frequency of bridge determines the frequency range of harmonics currents that are generated by the active power filter. The aim is now to control the switching so that voltage source lines, nonlinear load, and APF work together. So need design an algorithm which is best suited to compensate the harmonics and reactive power compensation

III. ROLE OF DC CAPACITOR

The DC capacitor has two main purposes. It will maintain the voltage constant with small ripples in the steady state. In transient state it will supply the real power difference between load and source. The difference between load sources.

If the load change there is a change in the real power difference between source and load. This real power is compensated by the capacitor changes the voltage from the reference voltage. The amount of real power charges/or discharges the capacitor.

Peak value of the reference source current is proportional change in the capacitor voltage. If the capacitor voltage is recovered and reached to the reference value then the real power supplied by the source is equal to the value of the load consumed. By this way controlling the value of reference source current will generate.

IV STUDY OF UNCOMPENSATED SYSTEM

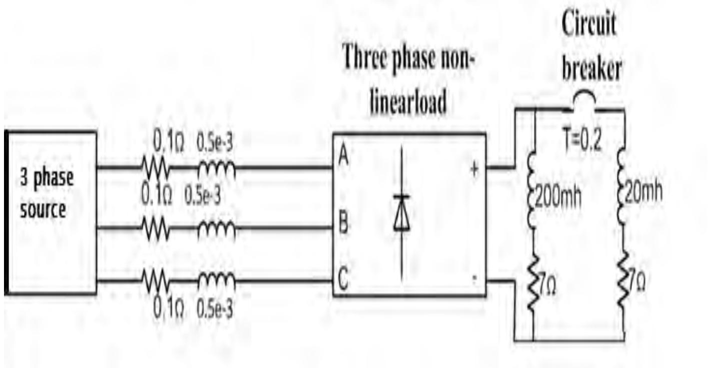


Fig3: uncompensated system

Fig3 clearly shows that 3-phase voltage source connected to non-linear load and having impedance load and after 0.2s extra amount of load is connected to load side so extra amount of current will be drawn from source.

A. Simulations and study of waveforms

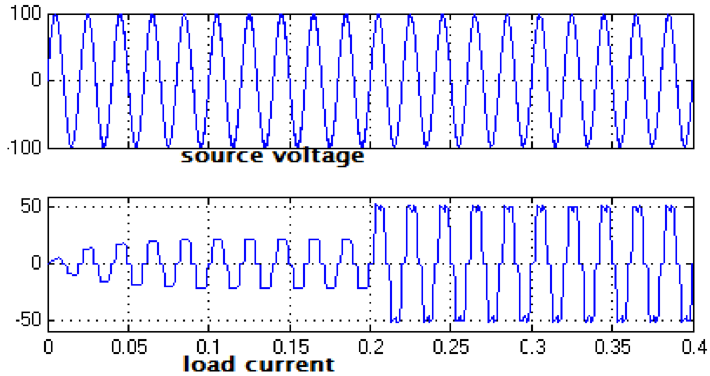


Fig4 source voltage and load current

For better understanding per phase voltage are shown remaining will be 120^0phase displacement source voltage and load current respectively

After 0.2s circuit breaker will on because of the extra resistive load magnitude of current only will increase because we use only the resistor as shown in the fig3

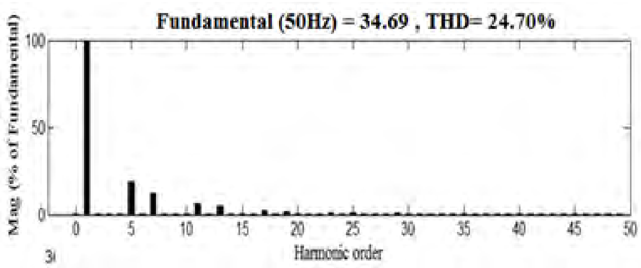


Fig5: THD analysis of the source current

In fig5 clearly shows that the harmonic analysis of input current.THD value of the source current is 24.79% because the present of the harmonic currents. And the fundamental value of the current is 34.69 A.

V.CONTROL METHODS

A. Conventional PI Controller

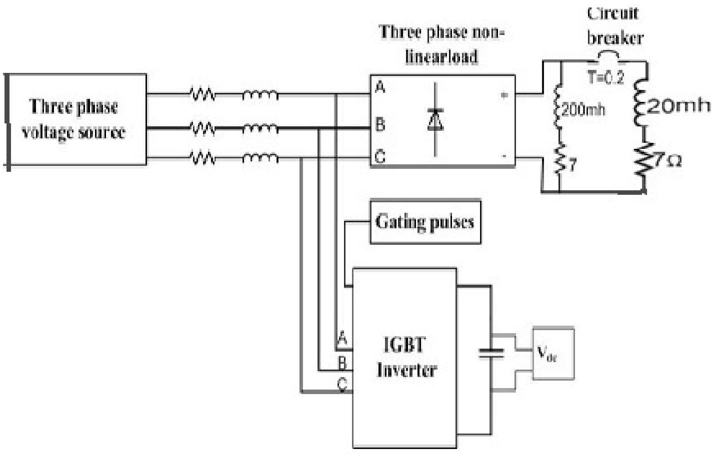


Fig6: Block diagram Shunt active power filter

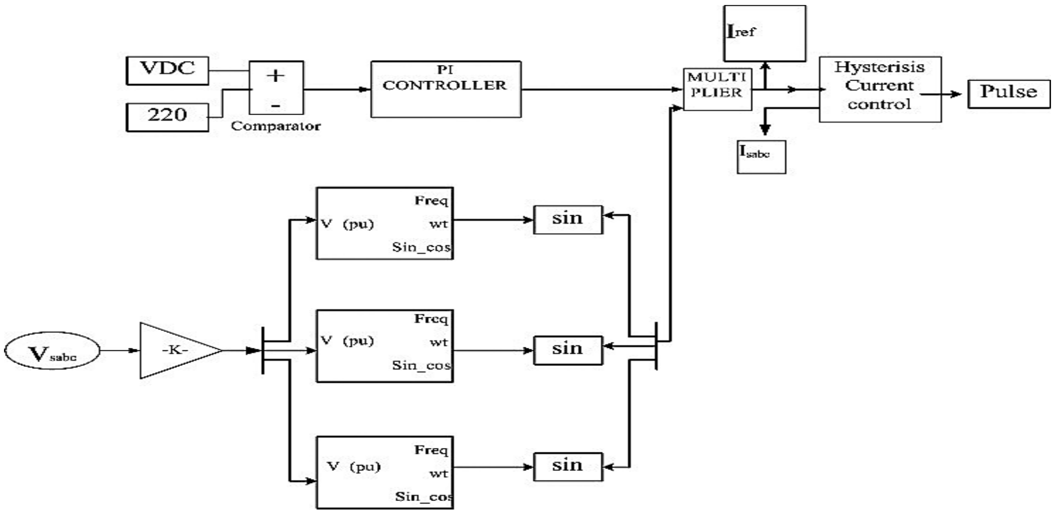


Fig7: Control scheme for PI controller

In fig6 shows that IGBT Inverter is connected in parallel to the load. Capacitor voltage is compared with the reference voltage [6] and the error signal is given to the PI controller and its output is the maximum value of the magnitude of the reference source current and the phase information is obtained from voltage source by generating the unit magnitude it is multiplied with the magnitude it will be the reference current is compared with source current. By comparing with the source current by using hysteresis then the pulses are generated will operate the IGBT INVERTER [11].

*Simulations and study of waveforms***:**

$V_{s(p-p)}$rms=120v,R_s=0.1Ω,L_s=0.5e^{-3}mH, R_L=7Ω,L=200mH,R_{ex}=7Ω,Lex=20mh f=50HZ,C=2100µF

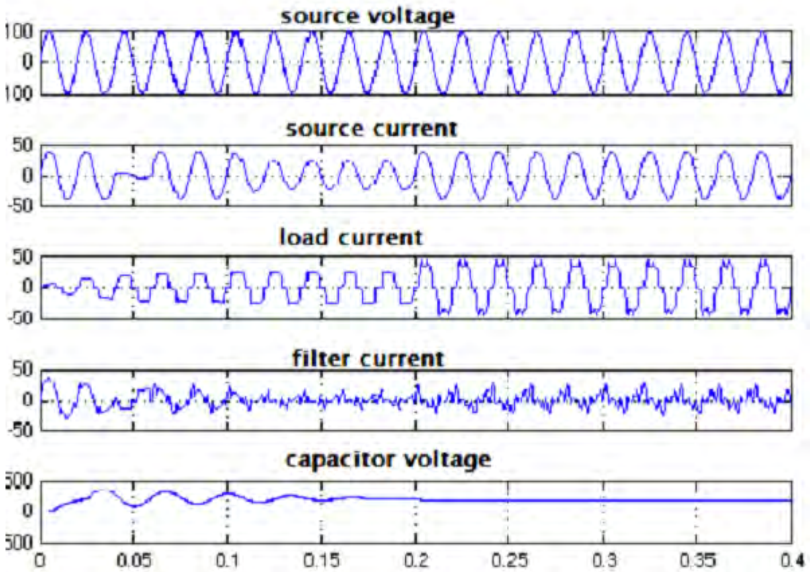


Fig8: simulation results with PI controller

In fig8 is shown that harmonics of the source current eliminated by injecting the capacitor current By maintaining the capacitor voltage near to constant. Capacitor voltage takes 2 to 3 cycles to reach the steady state.mathamatical model required to design PI controller.

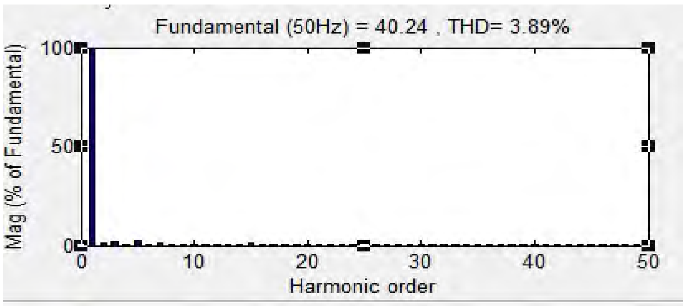


Fig9: THD analysis of input source current with PI controller

Fig9 shows the THD analysis of the input source current the input fundamental component of input source current was improved from 23.77A to 40.24A and the harmonics are eliminated shown by THD decreases from 24.70% to 3.89%.

B. FUZZY Logic Controller

Fuzzy logic controller is a multilevel logic scheme in which each variable have associated membership function [7]. It has 3 main components.1.degree of membership function along vertical axis(Y).2.associated variables along horizontal axes(X).3.set of membership functions represents vertical axes values to horizontal axes[10].

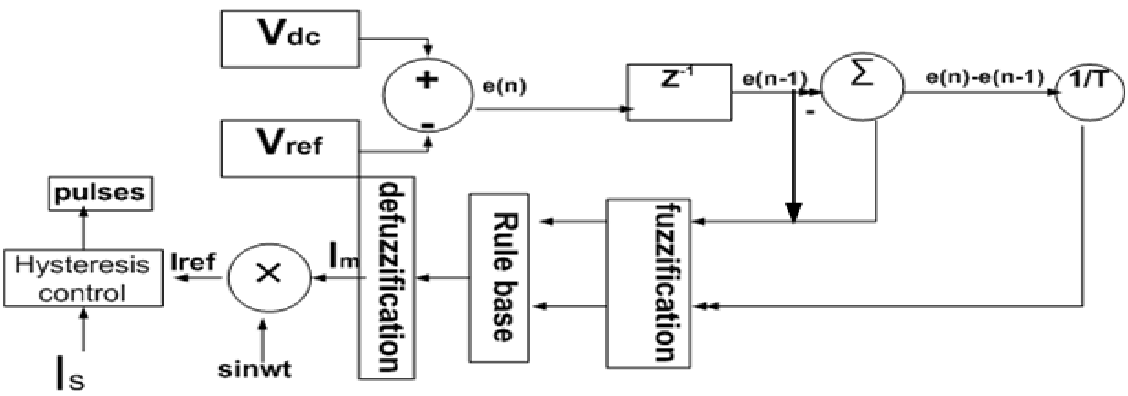


Fig10: control scheme for fuzzy logic

Capacitor voltage is compared with the reference voltage and the voltage error e(n) and the integration of the error i.e. change in error e(n-1) are the input to the fuzzy logic tools there 3 main blocks.[8],[9].

(i).fuzzification

It is used to fuzzification of the crisp variables to linguistic variables. Assign the values to the membership function each represents the degree of to corresponding values on the Y axis. There are many types of membership functions are available. By comparing best one we are using that is triangular membership function. Mandeni type function is used. Range of error is (-90,90), and the change of error is (-50,50), output change of reference current is (-90,90) is assigned to each membership function.

negative very big(NVB),negative big(NB),negative medium(NM),negative small(NS),zero(ZE),positive very big(PVB),positive big(PB),positive medium(PM),Positive small (PS).

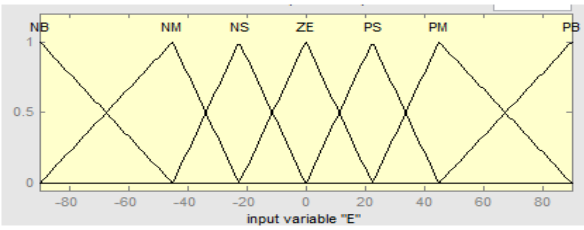


Fig11: error voltage

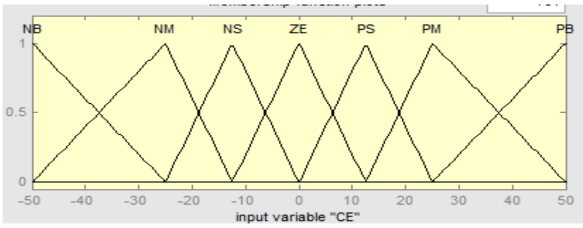


Fig12: change in error voltage

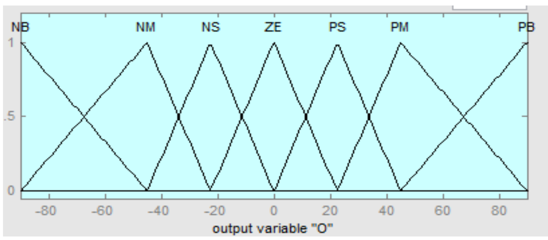


Fig13: reference current output

ii) Rule base:

Based on the rules table error and change error output reference current will be generated

E / CE	NB	NM	NS	ZE	PS	PM	PB
NB	NVB	NVB	NVB	NB	NM	NS	ZE
NM	NVB	NVB	NB	NM	NS	ZE	PS
NS	NVB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PVB
PM	NS	ZE	PS	PM	PB	PVB	PVB
PB	ZE	PS	PM	PB	PVB	PVB	PVB

Table1: rules table

1.if E&CE are zero maintain the present controller setting o/p=zero

2. If E is not zero but approaching maintain the present controller setting

3. **E** is growing change of controller setting depends on **E and CE** magnitude and sign force the controller change of output controller **zero.**

iii) Defuzzification:

Conversion of linguistic variables to crisp variables is known as defuzzification.lot of methods is available for this conversion we are using centre of area method (COA) is used.

The output of the fuzzy controller is the peak value of the reference current and it multiplied with sin function which is phase information obtained from PLL as shown in fig7. Reference current compared with source current in hysteresis generate pulses.

Simulation results:

$V_{s(p-p)}$rms=120v,R_s=0.1Ω,L_s=0.5e^{-3}mH,R_L=7Ω L=200mH,R_{ex}=5Ω,f=50HZ,C=2100µF,L_{ext}=20mH

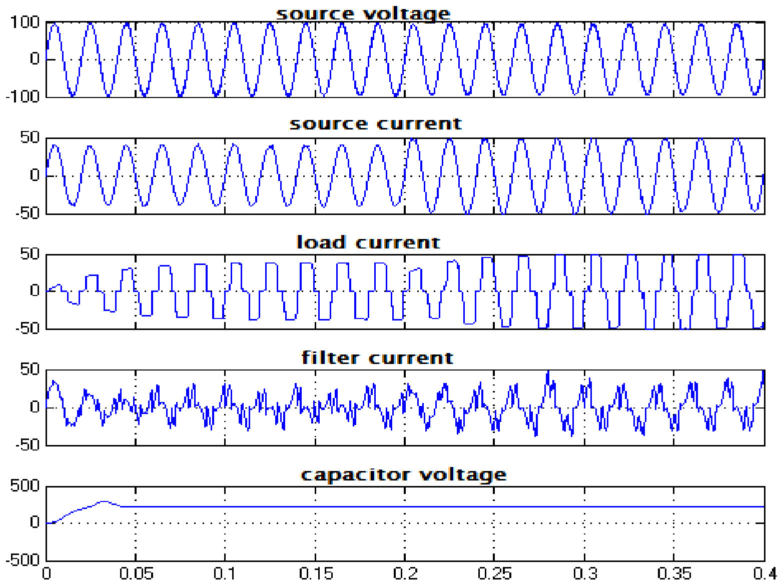


Fig14: output waveforms for fuzzy controller

By using the fuzzy controller there is no need to study the mathematical analysis of the system simply from expert's knowledge. And the transient. Response also improved it clearly shown by the capacitor voltage takes only 1 cycle to reach study state value.

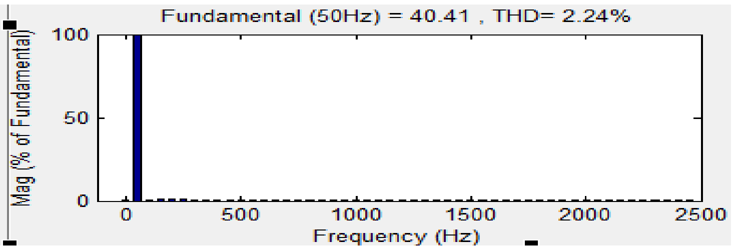


Fig15: THD analysis of source current with fuzzy controller.

In fig 15 shows the THD analysis of source current and it shows that source current fundamental is slightly improved from 40.24A to 40.41A from PI controller to fuzzy controller. And THD value also reduced from 3.89%to 2.24% because the capacitor voltage reaches to the study state value so early.

B.ANFIS Controller

Adaptive fuzzy neuro inference system (anfis) is a hybrid approach to deal the linguistic variables and numerical variables [9].fig16 show general diagram of anfis controller. In fuzzy we are choosing the linguistic variables by system behaviour in ANN is used to tune the membership function.sugeno type function is used to design anfis because its output is always constant or linear [7]. The output of each rule z_i is firing strength of the W_i of the each rule. And Rule aforementioned here is firing strength is given by

$$W_i\text{=AND } [F_1(x), F2(x)]$$

Where F (.) is the inputs of the 1 and 2.final output is the weighted average of all the outputs computed.

(i)ANFIS control for APF

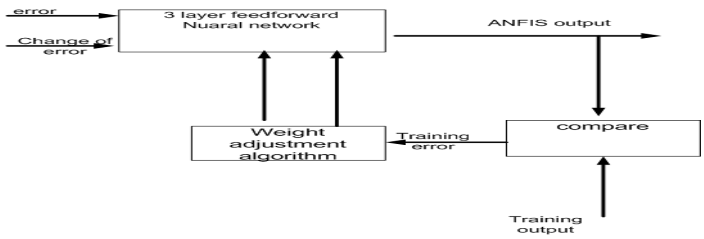


Fig16: ANFIS control for APF

Neural networks are used to customise the membership function .first network is used to fuzzyfies the crisp data and the second network is used implement the rules and third network is used to defuzzyfies the crisp data. The inputs to the input is error and change of error and output is maximum value of the reference current to trigger the APF.output is generated based the trained input data as shown in the fig16.anumber of iterations was performed to train the input data.trainging error is compared with the output data and ANFIS control data. Training error is required checking process in order to prevent the over fitting data. The following steps are required to design the ANFIS controller by the fallowing steps is listed below.

Step1.an error containing the range of values (-90.90),and the change of error values (-50,50) and step size will be 0.5(mamdani type and 49 rules triangular membership function) as the trained data

Step2.an error containing the range of values (-90,90), and the change of error values (-50,50), with a step size of 1(mamdani type and 49 rules triangular membership function as checking data

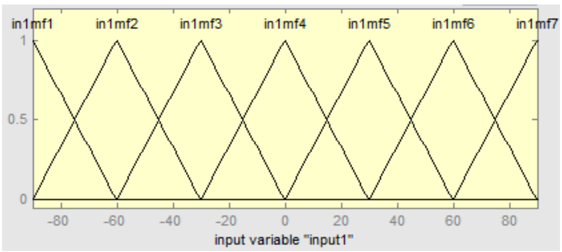


Fig17: error in voltage

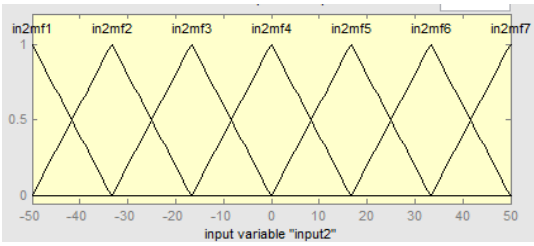


Fig18: change in error

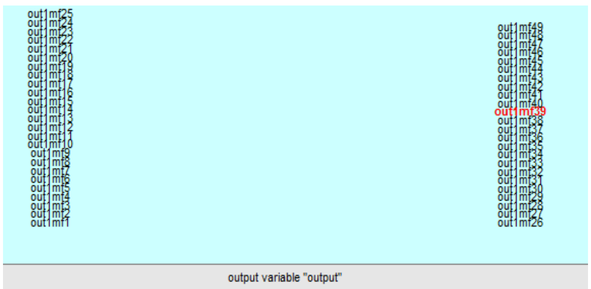
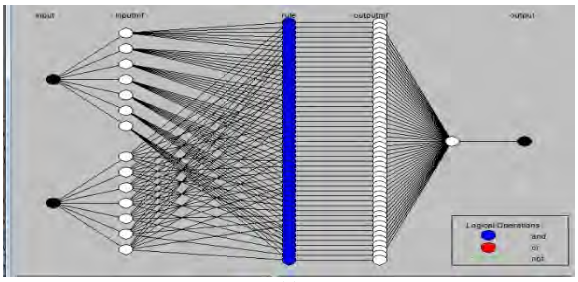
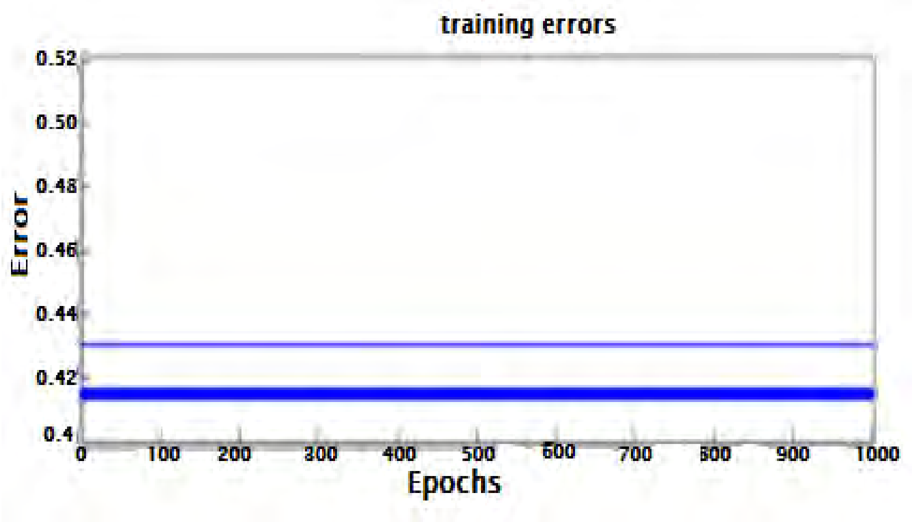


Fig19: reference current I_m

Hybrid method is used to generate the FIS with a training error is zero.1000 epochs are used to and the training error and with 49 rules are shown in the form of neural as shown in the fig20 (a).and the training error 0.41 and checking error is 0.43 as shown in fig20 (b) with out increase iteration shows over fitting is eliminated



(a)



(b)

Fig20:a.trained model (b).error VS epochs

Simulation results:

$V_{s(p-p)}rms=120v, R_s=0.1\Omega, L_s=0.5e^{-3}mH, R_L=7\Omega$ $L=200mH, R_{ex}=5\Omega, f=50HZ, C=2100\mu F, L_{ext}=20mH$

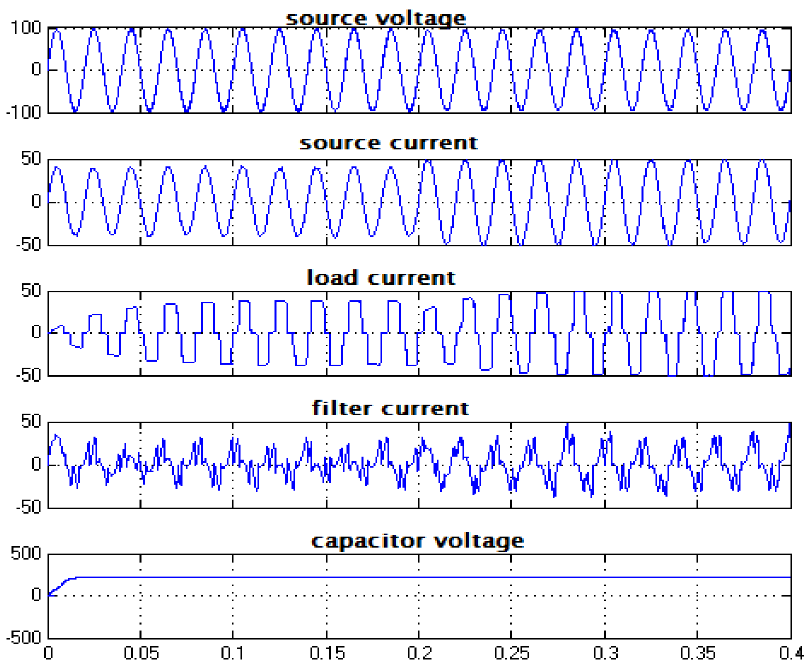


Fig21: simulation results of APF with ANFIS

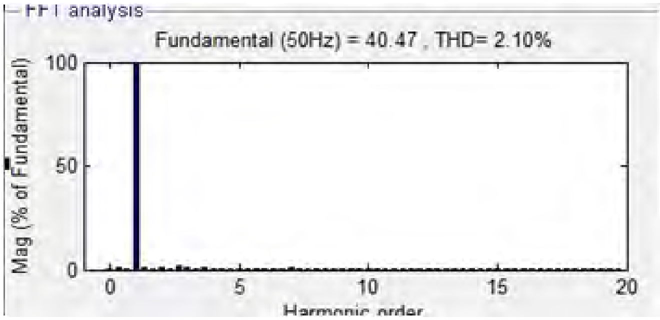


Fig22: THD analysis of source current with ANFIS controller

Fig22 shows the THD analysis of source current with anfis controller. Current slightly improved from the fuzzy logic logic controller that is from 40.41A to 40.47A.and the THD value reduced to 2.10% because exact tuning of membership function.

VI.COMPARISON

	PI CONTROLLER	**FUZZY CONTROLLER**	**ANFIS CONTROLLER**
(THD %)	3.89%	2.24%	2.10%
Control	Simple control	Robust control	Robust control
Error range	economical for a set of designed PI parameters	Compensates large errors	Compensates large errors
tuning	Manual tuning of PI parameters	Auto-tuning	Auto-tuning
membership functions	-------	Manually	automatically by ANN.

Table2: comparison of controller

VII.CONCLUSION

The overall aim of this project is to consider methods of achieving better utilization and control of active power filters. Alternative schemes based on soft computing techniques have been proposed to eliminate the harmonics and to compensate reactive current. Nonmodel-based controllers designed around fuzzy logic and neural network are applied to control the switching of the active power filter. The results show better response under varying load and supply conditions.

The choice of the fuzzy controller's membership function (MF) is very important to derive optimum performance and The Neural network is used to derive the fuzzy MFs and their partitioning.

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