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Adaptive Neuro Fuzzy Interface System For Power Quality Improvement Using Shunt Active Power Filter Based on P-Q Theory

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ABSTRACT:

Power Quality is a physical process of electrical supply provided under any operating conditions. Power quality problems arise due to load imbalance, low power factor, degrading the quality of supply. Due to harmonics overheating of neutral conductor, over heating of equipment as a result the equipment failures etc. occur. The harmonic results in the economically impact problems and power quality problem occur on customers and utilities. The current harmonics is the most active power quality problems and usually determined by shunt active power filter. The main objective of this work is to develop ANFIS to analyze and mitigate the current harmonics and to improve the power quality by shunt active power filter under balanced and unbalanced load condition. The main function of the shunt active power filter is to compensate the voltage and current harmonics occurred in load side. When the three-phase voltage source are balanced(ideal) then PI and Fuzzy are meeting to the same compensation features and when the supply voltages are unbalanced (non-ideal), fuzzy logic provides good results but, the shunt active power filter using ANFIS Controller has better and outstanding results as compared to remaining controllers. Thus, the power quality improvement using shunt active power filter using Adaptive Neuro Fuzzy Interface System Controller is proposed. The software used for simulation is simulink/matlab. The simulation results through MATLAB/Simulink are presented and authorized with Adaptive Neuro Fuzzy Interface System. Results shown neuro fuzzy based controller is better than the PI and Fuzzy controllers.

Keywords: PI controller, Hysteresis current controller, PWM controller, Fuzzy logic controller, Shunt Active Filter, Harmonics, ANFI, IEEE-519.

1. Introduction

The large-scale use of non-linear loads such as power electronics devices produce harmonics. The large harmonics and reactive power [1] causes poor power factor and the power converters has added for the impaired in power quality and it has resulted into economic consequences. Thus, it is important to reduce the problem of poor power quality.

In recent years, there has been increase in the significance and concern for the quality of power suppled to factories and commercial applications and residential loads [2]. This is due to increasing day by day usage of harmonics creating non-linear loads such as power electronics device applications. power quality definite as the study of electrical energy and earthing systems so as to maintain the honesty of electrical power supply. IEEE Standards 1159[3] defines the power quality as the idea of electrical energy and grounding sensitive equipment in style that is suitable for the operation.

In majority of the cases power quality refers to the quality of three phase voltage or supply. Because power supply distribution system can control the quality of voltage but not control over the currents draw different loads. Therefore, the poor power quality causes many damages of the system. mainly there should be economical impact on utilities and consumers. The major problem of harmonics can be reduced or mitigated by the use of filters. Therefore, PQ [4] standards are mostly aimed at specifying the requirements on the supply voltage. The ultimate measure is to determine by the performance and productivity of consumer equipment.

The generating voltage at the generating station is mostly sinusoidal. Due to the magnetic field and the winding distribution having non- uniformity in a working AC machine distortions are created, and thus the voltage is not purely sinusoidal. At the point of distortion voltage harmonics occurs. Similarly due to non-linear loads current harmonics are generated. It has to be note down the non-sinusoidal current results in many problems aspects for utility grid power supply such as: low power factor, low energy efficiency, electro-magnetic interference, voltage fluctuation etc.., thus, a perfect compensator is required to eliminate negative sequence harmonics. According to Power Quality standards [3,6] THD value should be less than 5%.

Instantaneous active and reactive power(p-q) theory [4] can be used to calculate the real power and imaginary powers. The DC component is used to regulate the generating the reference pattern of the compensation currents. Generally, the PI controller is used to maintain the magnitude of the DC bus voltage in VSI aspect, to generate reference current patterns.

Recently Fuzzy Logic Controllers are replacing the conventional PI controller [8] due to their advantages. It is simple and accurate, the accurate mathematical modeling is not required in this process, can work with precise inputs, it can handle non-linearities and more robust than conventional PI controller and it is ideal for various applications.

In the proposed work adaptive neuro fuzzy logic controller has been implemented for three-phase shunt active power filter to mitigate the total harmonic distortion.

2. Proposed Active Power Filter

In the proposed work Adaptive Neuro Fuzzy Interface System Controllers are used for supervisory Active Power Filter, to draw/supply the compensating current to the load to mitigate the current harmonics or to completely decline the current harmonics on AC side, to maintain the DC link voltage constant by maintaining the real power flow in the system and reactive power flow to the source, thereby making the source current in phase with source voltage.

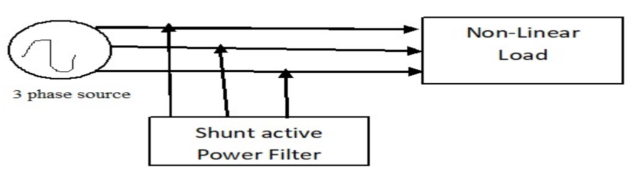


Figure 1Shunt Active Power Filter Principal Compensation

The basic compensation principle of active power filter can be used to compensating the current harmonics of non-linear loads to make reactive power compensation and to balance and imbalance currents [8]. Whenever the load condition changes, the real power in the system i.e., between mains and the loads has changed. Due to this imbalance of the real power in the system the improper functioning of the system happens and thus real power disturbances is cleared by DC link capacitor changes away from the reference voltage. The shunt active power filter sense the load current and inserts a current into the system to compensate current harmonics. The active filter works which can be connected to reduce harmonics by using a set of transistors and capacitors to filter will be used various purpose. The current wave by inserting opposite currents to the undesired harmonic components. Finally, to obtain the optimal performance of the system, the maximum value of the reference source current must be adjusted to proportionally change the real power drawn by source. If the DC capacitor [15] voltage is recovery process by the reference voltage, the real power is supplied by the source is supposed to the equal to the consumption load again. The maximum value of the reference source current can be obtained by regulating the average value of the DC capacitor.

3. DC Link Voltage Regulation

Whenever the load suddenly changes, the active power flowing in the system is disturbed and needs to settle down. The DC Link voltage [4] is used to balance the real power flow in the system, hence the voltage across the DC Link capacitor changes. The main purpose of the active filter is to maintain the DC link voltage and to produce the compensating current to mitigate the current harmonics present in power system network. This paper represents the Adaptive Neuro Fuzzy and Fuzzy controller to control the shunt active power filter. Fuzzy controller is the linear controller, is a non-linear controller [4]. An error signal is then processed through a FLC circuit, which contributes through zero steady state error in tracking the reference current signal. The output of the Fuzzy Logic controller is considered as maximum value of given supply current (I_{max}) So which is considering by two components:(i) fundamental load current and power loss components of active power filter which is keep the average capacitor voltage to constant value (ii) the peak current has obtained, and is multiplied with the different source voltages to obtain the reference compensating currents.

3.1 Instantaneous active and reactive power theory:

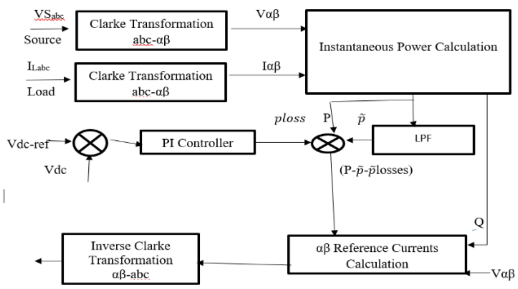
This theory has proposed by Akagi[1], Kanazawa and Nobel in the year 1983-1984. This theory is applied to active power filter control. The calculations are simple, it consists of algebraic equations. It is applied for reference currents calculation and it applies an algebraic transformation known as Clarke's Transformation. In this method load voltage and load currents in a-b-c coordinates are transformed to αβ coordinates the equations are given

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} va \\ v_b \\ v_c \end{bmatrix} ; \begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} ia \\ i_b \\ i_c \end{bmatrix}$$

Where v_a, v_b, v_c refer to the three-phase voltage source at the a-b-c coordinates

i_a, i_b, i_c represents three phase current source at the a-b-c coordinates

v_0, v_α, v_β are the three voltages at the 0-α-β coordinates and i_0,i_α,i_β refer to the three phase currents at 0-α-β coordinates. The system measured in this paper is a three phase three wire system, therefore, the zero-sequence component is inattentive. In the αβ coordinates are the complex sum of the active and reactive power can be represented [1]. Basically, the instantaneous reactive power theory is based on the transformation [2] of the a-b-c stationary reference coordinates to the 0-α-β coordinate called as Clarke transformation. The source voltages and currents are transformed into 0-α-β components.



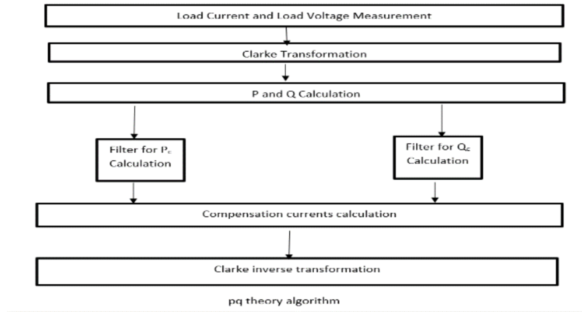


Figure 2block diagram of active and reactive power theory

Figure 3 PQ theory algorithm

With the presence of non-linear load [6], the instantaneous reactive and active power components are decomposed of their AC and DC components, as illustrated as an expression, as shown above figure 2 the DC part of the real power(p) of the instantaneous real power represents the fundamental voltage and current components and corresponds to the power transferred from source to load. The average or DC component of the instantaneous real power, which is only power that should be provided by three phase AC source [4], which is extracted by means of high order low-pass filter regarding to the instantaneous reactive power component(Q). to generate the harmonic reference currents, the AC component of the active and reactive power are essential. To recompose the voltage source inverter switching losses, and to sanctuary the DC link voltage at the essential level, the shunt active power filter consumes a small amount of real power losses from the three phase AC source or an external power supply. Therefore, the AC component of the active power is measured in

Active power $P = \tilde{p} + \tilde{p}$

Reactive power Q=$\tilde{q} + \tilde{q}$

$\tilde{p}$ = instantaneous real power relocated from source to load of mean value.

$\tilde{p}$= instantaneous real power replaced between source and load of alternating value.

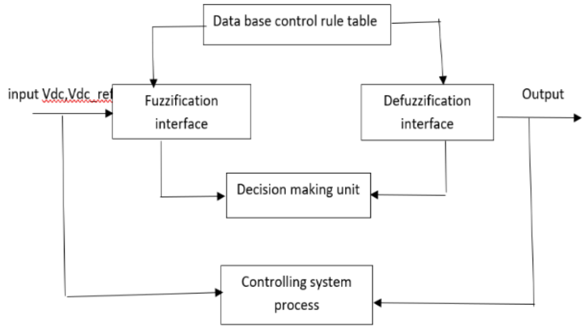
$\tilde{q}$ = the instantaneous imaginary power replaced between source and load of mean value.

$\tilde{q}$ = the instantaneous imaginary power replaced between phase and load of alternating values.

In this representation the fundamental component and harmonic component which are accountable for energy circulation between load phases. In the time domain is presented and the simulation model is built using MATLAB/Simulink.

4. proposed and modeling of fuzzy control scheme

Fuzzy logic control is deduced from fuzzy set theory proposed in 1985, where the transition is between membership and non-membership function. Therefore, limitation of fuzzy sets can be indefinite. Fuzzy logic controllers [20] are an excellent choice when the precise mathematical formula calculations are impossible. The control action can be determined from the evaluation of a set of simple rules. The development of the rules requires thorough conceptual understanding of the process to be controlled, but they don't require any mathematical calculation model of the system. In the control algorithm of a shunt active power filter is closed loop, the DC side capacitor voltage V_{dc} is sensed and compared with chosen reference value Vdc_{ref}.



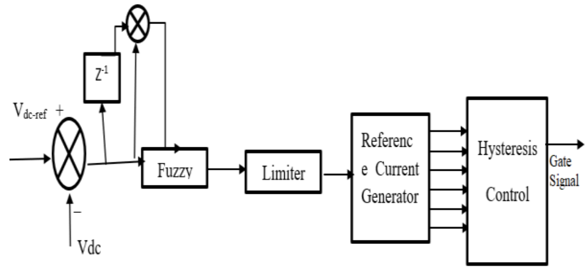


Figure 5 Internal structure of the fuzzy logic controller

Figure 4 Block diagram of Fuzzy Logic Controller

Where changing error signal e(n) = Vdc ref-Vdc is passed through the Butterworth low pass filter with fundamental cut off frequency 30 HZ at nth sampling instants and are used as inputs for the fuzzy processing inputs. After the limit the output of the fuzzy logic controller [6] has considered as the amplitude of the reference currents I_{max}. The I_{max} current takes the care of real power demand of load and power losses in the system. The switching signals for the PWM inverter are determined by comparing the actual source currents (I_{sa}, I_{sb}, I_{sc}) with the reference currents are the conjugate of (I_{sa}, I_{sc}, I_{sc}) using hysteresis current control method. The switching signals are determined, after proper isolation and amplification and are given to switching devices of the [5] PWM converter.

Fig.3 shown the internal architecture of the fuzzy logic controller circuit. The architecture has limiter, fuzzy logic controller, three phase generator for generating reference currents and generation of switching signals. The peak value of the reference currents is calculated regulating the DC link voltage. It is known that the active power of the system changes and that can be compensated by DC link capacitor voltage and it is compared with a reference voltage and a difference signal or error signal is given to the fuzzy logic controller [10]. The error signal is processed through a fuzzy logic controller. The output of the fuzzy logic controller is considered as a peak value of the supply current that will be maximum and using it contributes to zero steady error is tracking by reference current signals. The reference currents are generated through the gating signals. The fuzzy logic controller is categorized as follows: (i) Five fuzzy sets for each input and output. (ii)Fuzzification using continuous creation (iii)Triangular membership functions are simple (iv)Implication using Mamdani's 'min' operative function. The rule evaluator requires control rules based on which decision making is done and they are stored in linguistic rule base table [1].

Neural Network

The general Adaptive Neuro Fuzzy Interface System (ANFIS) [22] control structure contains the same components as the FIS except for the neural network block. The architecture of the network is composed of set of units arranged in five connected network layers, i.e., layer 1 to layer 5. The proposed Adaptive Neuro Fuzzy Interface System controller construction consists of four important blocks that are fuzzification, knowledge base, neural network, Defuzzification. Layer 1 contain the input variables and triangular membership functions. Second layer is membership layer and it inspects for the weights of each membership functions. It receives the input values from the first layer and act as membership functions to represent the fuzzy sets of the respective input variables.[22] Layer 3 is called as rule layer and it receives input from the previous layer. This layer calculating the activation level of each rule and number of layers equals to the number of fuzzy rules. Each node of this layer calculates the weights which will be normalized. Layer 4 is the defuzzification layer delivers the output values resulting from the interpretation of rules. Layer 5 is known as the output layer. Neuro fuzzy is modeled by Takagi–Sugeno (T–S) type systems are considered and it must have the following properties: first or zero order T–S type in the system. It should have a single output attained by using weighted average of defuzzification. All output membership functions has same type or either linear or constant. It will be no rule sharing, i.e., different rules cannot share the same output membership function. The number of output membership functions has equal to number of rules.

Table 1Rule base representation

ΔE / E	NB	N	Z	P	PB
NB	PB	P	Z	Z	N
N	PB	P	Z	Z	N
Z	P	Z	Z	N	N
P	Z	Z	Z	N	NB
PB	Z	Z	Z	N	NB

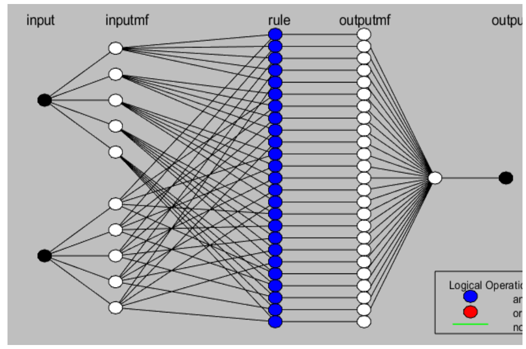


Figure 6 the internal structure of the ANFIS

The ANFIS structure is tuned automatically by least-square estimation and the back propagation algorithm. Because of its flexibility, the ANFIS strategy can be used for a wide range of control applications.

Take example like Rule 1: if (x is 1mf1) and (y is 2mf1) then (f1=p1x+q1y+r1)

Rule2: if (x is 2mf1) and (y is 2mf2) then (f2=p2x+q2y+r2)

as so nearly similar to objective rules. Here, x and y are the inputs and f1 and f2 are outputs parameters determined. during the period of training phase pi, qi and ri are used to designing the parameters.

5.Simulation and Results

The three-phase three-wire system with nonlinear load is equipped with shunt active power filter to mitigate the current harmonics. ANFIS controller is used to control the shunt active filter under balanced and unbalanced source voltage in normal load condition as well as increasing load. The required parameters are taken in Amir [4]

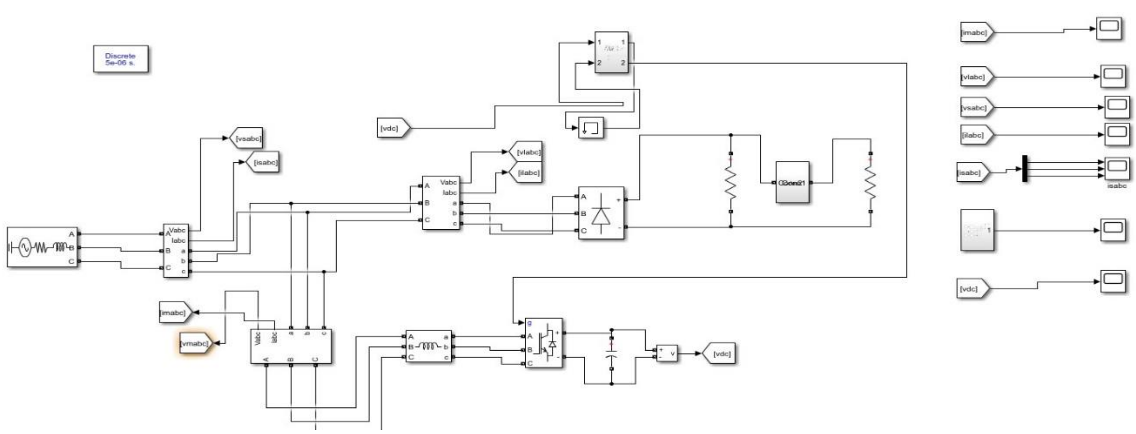


Figure 7 Simulation for shunt active power filter diagram

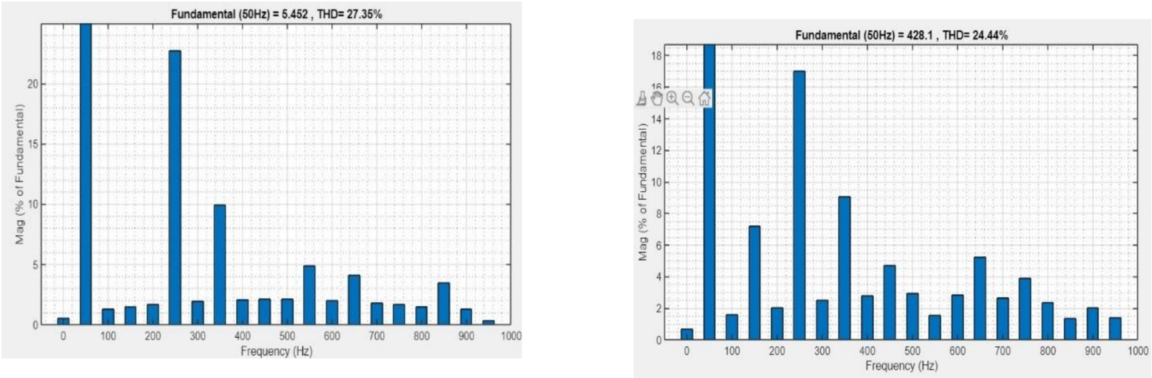


Figure 8 Three phase balanced and un balanced source current without SAPF FFT analysis (ANFIS)

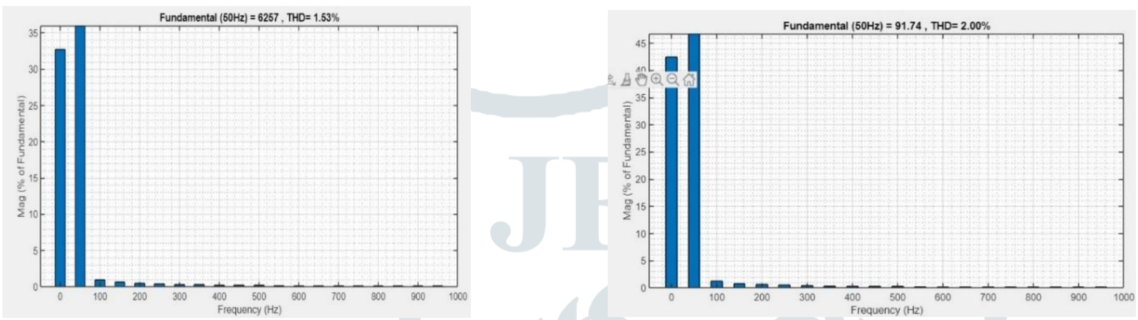


Figure 9 Three phase balanced and un balanced source current with SAPF FFT analysis (ANFIS)

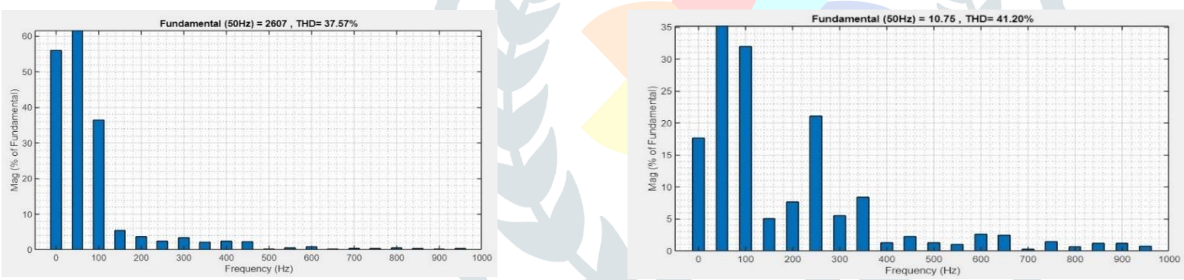


Figure 10 Three phase balanced and un balanced source current without SAPF FFT analysis (fuzzy)

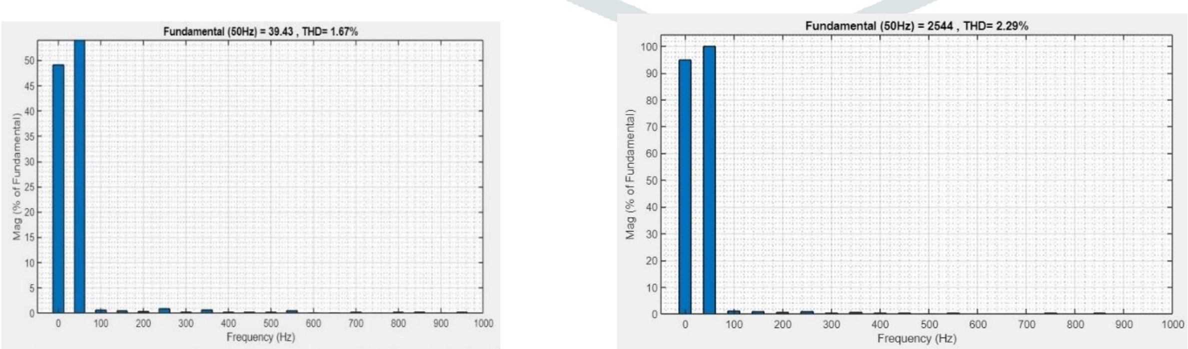


Figure 11 Three phase balanced and un balanced source current with SAPF FFT analysis (fuzzy)

Table 2. Comparison of Fuzzy Logic Controller with ANFIS Controller

s.no	Load Description	% source current	
		fuzzy	Anfis
1	Balanced system non-linear load without SAPF	41.20	27.35
2	Balanced system non-linear load with SAPF	2.29	2.00
3	Unbalanced system non-linear load without SAPF	37.57	24.44
4	Unbalanced system non-linear load with SAPF	1.67	1.53

Conclusion

This paper presents a three-phase shunt active filter using ANFIS controller. It gives the best solution to power quality problems. The low pass filter provides good steady state response and dynamically also. It gives better solution for power factor and current harmonics compensation. The three phase shunt active power filter can compensate load current unbalances to remove the neutral wire current in the supply lines. Some of the advantages of the proposed Adaptive Neuro Fuzzy Interface System are: it is independent of the voltage source distortion and imbalance; quick and fast tracing and accurate while tracing of fundamental component under balanced and unbalanced nonlinear load condition, it has simple architecture and easy for implementation. The proposed SAPF can compensate for balanced and unbalanced nonlinear load currents. SAPF can itself to compensate for variation in nonlinear currents. Simulation results show that systems %THD limit of source current as per the IEEE-519 standard i.e. less than 5%

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