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ARTIFICIAL NEURAL NETWORK BASED POWER QUALITY IMPROVEMENT USING SHUNT ACTIVE POWER FILTER

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ABSTRACT: Artificial Intelligence methods are the latest developments in power quality enhancement. Fuzzy logic and neural networks also include Artificial Intelligence. This paper deals with the artificial neural network application to power quality improvement. This paper presents a study designed to enhance Total Harmonic Distortion (THD) caused by improper utilization of electronic control (PE) devices as well as nonlinear loads. Shunt Active Power Filter is also one of controller which is used to suppress source currents harmonic currents and to offset the reactive power as it has ability to minimize the harmonic problems that nonlinear loads cause. The P-Q Instant Reactive Power Theory (IRP) is used for the removal of the harmonic component. In DC-link controller and for current error adjustments Artificial Neural Network (ANN) were employed. The hysteresis current controller scheme can be used to generate trigger pulses and to controlling voltage source inverter swapping. Artificial intelligence gives better results when compared to the conventional methods. Continuous and effective electricity supply is required for the operation of modern and advanced society today. Simulations are performed in MATLAB environments using toolbox power system.

KEYWORDS: Artificial Neural Networks (ANN), Total Harmonic Distortion (THD), Shunt Active Power Filter (SAPF), Power Quality (PQ).

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I. INTRODUCTION

"These days power electronic converters have wide spread application due to the advanced technology. Such power electronic converters have deeply recognized residential and commercial uses Profoundly, but because of power electronic converters we have come across the power quality issue" [1-2]. The truth that the power electronic converters operates as highly non-linear loads tends to cause this problem. Such highly nonlinear loads interrupt the waveform of power supply that passes device axes, resulting of highly harmonic supply currents and thus reduces input power factor. The major causes of nonlinear systems are un regulated bridge rectifiers and phase regulated converters. consequently, Advanced power electronics appliances used mostly in speed-controlled motor drives, thyristors, grinders, un interruptible power supplies (UPSs) and personal desktops are major cause of voltage distortion at point of common coupling (PCC) as well as power flow in transmission lines [3-4]. They result in Total Harmonic Distortion (THD) from voltage supply far higher than the allowable limit set by IEEE 519 standard of 5 percent.

The easier and cheaper technique for eliminating these harmonics currents is the using of passive filters, but they eliminate specific harmonics and require adjusting to reduce others. The issue is related to the characteristics of resonance compensation for the fixed capacitance, inductance and their huge size. Also used were hybrid filters included both passive and active filters, but these are too costly to implement for harmonic discharge [5]. Therefore, Shunt Active Power Filters (SAPF) will built to solve these issues. The Shunt Active Power Filter aim should be delivering current with same magnitude but in reverse direction, which negates the harmonic currents in the network. In general, SAPF provides harmonious mitigation, reactive power compensation and compensation for unbalances, voltage harmonics, current harmonics by improve the power factor. As a harmonic current source, SAPF helps to reduce the harmonic components produced by PE-based non - linear loads.

Recently, due to its accuracy and efficiency, Recent methods like the Artificial Intelligence (AI) are becoming highly widespread. Neurons interconnected show the response depending on the stimulation of the input. The input neurons convert the stimulus to decision as network output. In order to make a decision, data samples are used in an iterative training section, and weights are changed until the expected results are obtained. For efficient service, artificial neural network (ANN) uses algorithms such as recurrent network and Hopfield. ANN adaptability is quicker compared to conventional high-pass filter (HP) control systems and PI controllers. ANN can implement with different approaches based on artificial neural intelligence, where the minimum loss control technique is applied to permanent magnet synchronous motors (PMSM s) which increase motor efficiency and reduce losses. A three-phase SAPF with ANN controller is proposed in this paper, using conventional hysteresis to address the quality of electricity. Using IRP p-q theory, reference signals are calculated. ANN is used to allow the extraction of compensating currents, and its implementation into SAPF's control system makes it stronger and more complex.

II. SAPF PRINCIPLE OF FUNDAMENTAL COMPENSIS

The fundamental principle of compensation for Shunt Active Power Filter that can be seen in Figure 1.

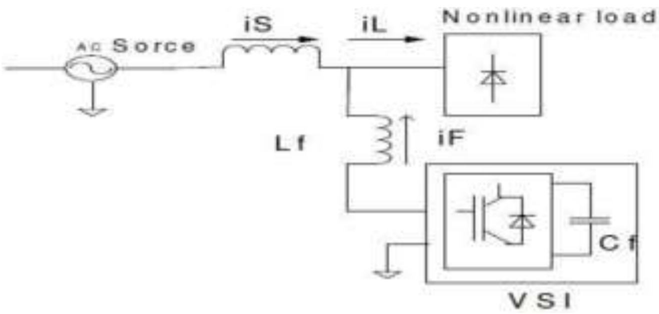


Figure 1: Basic SAPF Principle

Shunt Active Power Filter depending on voltage source inverter is an attractive and efficient way of solve the current emission issues with harmonics and to improve electrical system's power efficiency. The Shunt Active Power Filter by a self-controlled DC bus is directly attached to the distribution systems to minimize harmonic substance, enhance the power factor and keep the network healthy. Figure 1 illustrates the schematic diagram of Nonlinear SAPF Load. The basic concept of SAPF is to inject the harmonic currents produced by a 180degree phase angle load.

For the following reasons Dc link capacitor is being used:

a) To keep a DC voltage at a steady state with a small ripple.
b) To act as an energy-storage function throughout the transient duration to provide real power differential between loads and source.

III.INSTANTANEOUS ACTIVE REACTIVE POWER (PQ) APPROACH

In addition to manage the instantaneous voltages in a three-phase power circuit numerically, this is appropriate to describe such substances with in instantaneous space vectors but rather to optimize the evaluation, The components of the zero-phase series in the three-phase power voltage in this method are better for reducing and recognizing the currents. The basic control algorithm of SAPF was seen in Figure 2.

ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

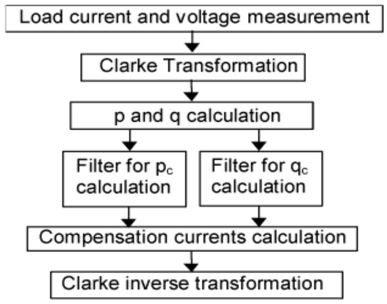


Figure 2: Fundamental Control Algorithm of SAPF based on P-Q Theory

Consider some scheme of A-B-C coordinates where axes A, B and C were also placed along the same plane, and there are $2\pi/3$ rad apart from each other, The A-axis of the instantaneous space vectors, e_A and i_A Their (positive, negative) magnitude and direction change over time. Similarly e_C and i_C are positioned on C-axis e_B and i_B similarly on B-axis. Such space vectors are quickly translated to co-ordinates of α -β as follows:

$$\begin{bmatrix} e_\alpha \\ e_\beta \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} e_A \\ e_B \\ e_C \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{2/3} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_{LA} \\ i_{LB} \\ i_{LC} \end{bmatrix} \quad (2)$$

Both e_α and i_α are both on α -plane, e_β and i_β are both on β - axis and the position of each of their amplitude (negative, positive) varies over time.

A. Instantaneous space variables along α -β coordinates:

On 3-phase circuit, the conventional instantaneous power can be described as:

$$P_L = e_\alpha i_\alpha + e_\beta i_\beta \quad (3)$$

Where p refers to the traditional equations:

$$P_L = e_\alpha i_{LA} + e_b i_{LB} + e_c i_{LC} \quad (4)$$

To measure the active instantaneous power and the reactive power, may assume that instantaneous reactive space vector has been defined.

$$Q_L = -e_\alpha i_\beta + e_\beta i_\alpha \quad (5)$$

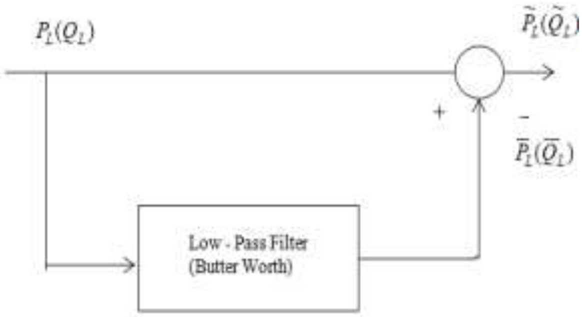


Figure 3: Diagram of Dynamic Computation

As shown in Figure 2 that space vector becomes position of the imaginary axis and right angles to both the real plane on coordinates α -β, to be in line with the law of the right. Considering that e_β is analogous to i_α and e_α is analogous to i_α and also e_α is right angles to i_β and e_β towards i_α traditional instantaneous power, P_L imaginary instantaneous power Q_L .

Let the ac and dc part of P_L have $\tilde{P}_L$ and $\overline{P}_L$. In similar way let $\tilde{Q}_L$ and $\overline{Q}_L$, excude the corresponding relation respectively

$$P_L = \overline{P}_L + \tilde{P}_L \qquad (6)$$
$$Q_L = \overline{Q}_L + \tilde{Q}_L$$

B. Calculating the currents of compensation

The following expression results throughout the circuit measurement P_L and Q_L , circuit measurement of compensation of reference currents.

$$\begin{bmatrix} i^*_{CA} \\ i^*_{CB} \\ i^*_{CC} \end{bmatrix} = \sqrt{2/3}\begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & \sqrt{3}/2 \end{bmatrix}\begin{bmatrix} e_\alpha & e_\beta \\ -e_\beta & e_\alpha \end{bmatrix}^{-1}\begin{bmatrix} P^* + P_{av} \\ Q^* \end{bmatrix} \qquad (7)$$

Where P_{av} is True instant power equal to loss of active filter, P^* and Q^* are determined by

$$P^* = -\tilde{P}_L \quad Q^* = -\tilde{Q}_L \qquad (8)$$

To determine P* values then We want a high pass filtering setup with a low pass butter worth filter but also that system provides a quantities $\tilde{P}_L$ From P_L and $\tilde{Q}_L$ from Q_L Inside the control circuit design considerations of a low pass filter play a significant function because, as shown in experimental results, different Compensation properties are measured in conjunction With cutoff frequency and filter low pass order. All measuring circuits are multipliers, dividers, and op-amps analogues.

IV. HYSTERESIS CURRENT CONTROLLER

The hysteresis band current control scheme shown in Figure 4 has been shown to be more suitable for all appliance in active power filters of current controlled voltage source inverters. The regulation of the hysteresis band current is characterized by unconditional stability, very quick response and good precision [13].

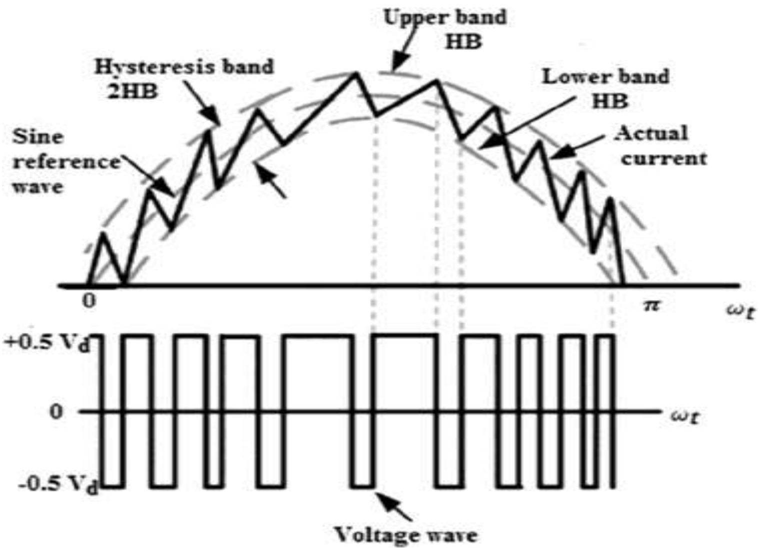


Figure 4: Hysteresis Controller

A. Calculation of the reference signals

Taking into consideration a balanced three-wire system, the p-q IRP method was used for the reference current generation. Currents are determined in IRP p-q theory using the instantaneous time domain factors. Such currents can be further transformed by Clark transformation into three-phase space vectors and two co-ordinates network [10]. We may describe the three-phase quantities for the balanced three-wire network.

B. PWM Signal calculation

The hysteresis band (HB) of the HBCC calculator varies according to Present waveform slope to DC-link voltage (Vdc) And voltage supply (Vs).If the injected current attempts to escape the HB limit, a suitable switch must operate to state ON and OFF, so that the current stays within the HB limit. HBCC thus self-adjusts the HB to fit the designed device. SAPF output is improved by keeping the frequency of the modulation to constant. Control pattern to move the inverter to different check points. The three band phases show the same profile with the variation in phase between them [9].

The corresponding operating switches state the following:

The intial turn is 1 (ON) and the second turn is 0 (OFF)

HB ≥ When (iref−imeas)

The initial turn is 0 (OFF) and second turn is 1 (ON)

HB ≤ When (iref−imeas)

V. PROPORTIONATE INTEGRAL (PI) CONTROLLER

Inner PI Controller management circuit layout shown in Figure.5. The control method composed some kind of limiter, PI controller but also three-phase sinusoidal waveform generator both for development of reference current and switching signal development. By control of DC connection voltage, maximum quantity of reference currents was measured. That real voltage of capacitor in comparison with a given reference value.

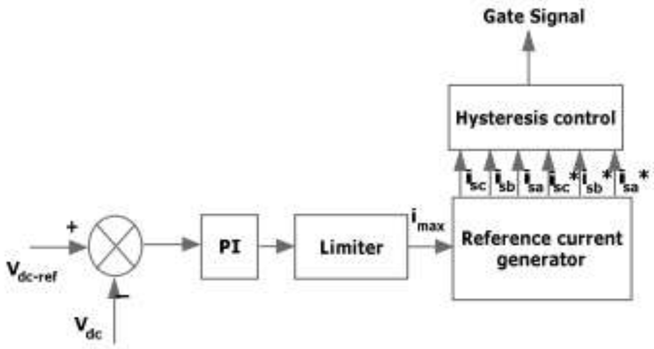
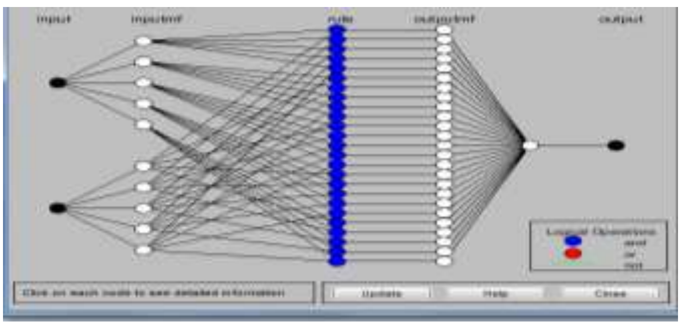


Figure 5: Functional PI Controller

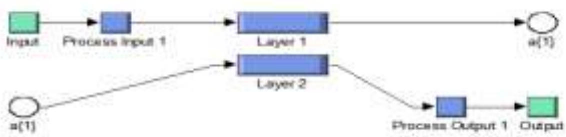
That error value becomes analyzed using such a PI controller that results in the detection of a current reference signal at zero steady loss. That PI controller output signal also known as its source current maximum value ($i_{\max}$), which consists of two layers: (i) The basic real power part of a load current (ii) SAPF reduction element; to maintain a constant mean voltage level for the system. The resulting maximal threshold value ($i_{\max}$) is multiplied by a sinusoidal vectors of the device in step only with corresponding supply voltage which achieve its current relation offsetting. Such predicted reference currents ($i_{SA}^*, i_{SB}^*, i_{SC}^*$) but also actual observed currents (i_{SA}, i_{SB}, i_{SC}) are evaluated by comparing them in hysteresis controller that offers a fault warning modulation method. The whole error signal helps determine a switching action. The supplier / supply current was chosen during the whole entire structure of a control scheme circuit to obey the sinusoidal reference current i_{ABC} within just a fixed hysteretic range. The length of such a hysteresis windows specifies the configuration of source current, the harmonic spectrum and equipment for switching frequency. DC link capacitor voltage is maintained steady and throughout operating period of a converter. Every stage of a converter is inspected in this system Regardless. The lowest switch associated with specific phase is turned further to maximize the current of such a specific section whereas the upper switch of a corresponding converter phase is triggered to decrease the current.

VI. ARTIFICIAL NEURAL NETWORK

Abbreviated as ANN, the Artificial Neuron Network is a programming technique that can easily solve non-linear problems. The algorithm (back propagation) effectively separates its input from each power of relation. Here, the Artificial Neuron Network is the feedforward back-propagation network improving the quality of power. Getting familiar, the network consists of three different levels namely output layers, hidden layers, intermediate layer or input layers. Each one of these layers is made up of interconnected neurons that form a large network of neurons. Depending on the back-propagation algorithm, certain weight values are changed.

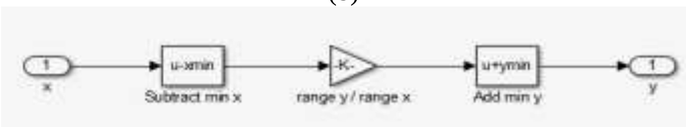


(a)



ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

(b)



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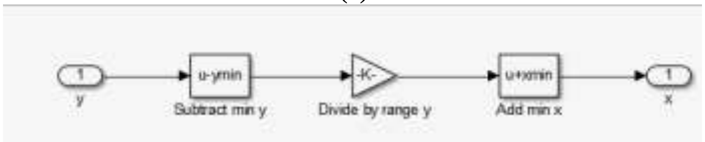

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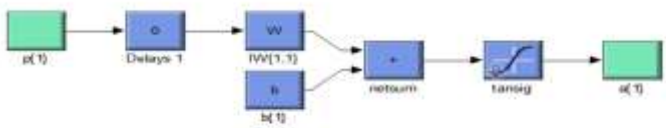

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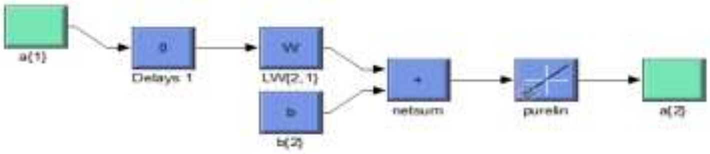

(f)

(g)

(h)

Figure 6: ANN Structure for SAPF (a) Neural Network Model, (b) ANN Fitting Functional Network, (c) ANN Maxima and Minima, (d) ANN Maxima and Minima Reverse, (e) ANN Based layer 1, (f) ANN Based layer 2, (g) ANN Process input 1, (h) ANN Process output 1

The structure of the neural network employed is the following:

Input signal: $x = x_1, x_2, x_3... X_i$.
Output signal: $y = y_1, y_2, y_3… Y_n$.
Neuron weights: W= wi1, wi2, wi3...... win.

ANN are divided into three sections, that is structure, training methods and activation function. Every neuron layer is linked to the other and activated only via activation function [11]. Multilayer perceptron (MLP) is also used for harmonic reduction, and as shown in Figure 4 the model consists of three main inputs. ANN has the benefit of easily calculating the harmonic-equivalent Fourier variables [12]. Transfer functions are logsig for layer 1, and tansig for layer 2 or hidden layer. During the first layer number of hidden neurons is 3, as well as 18 in second layer. The output layer depends on the type of data to be analyzed for optimal / desirable results.

VII. SIMULATION DIAGRAM

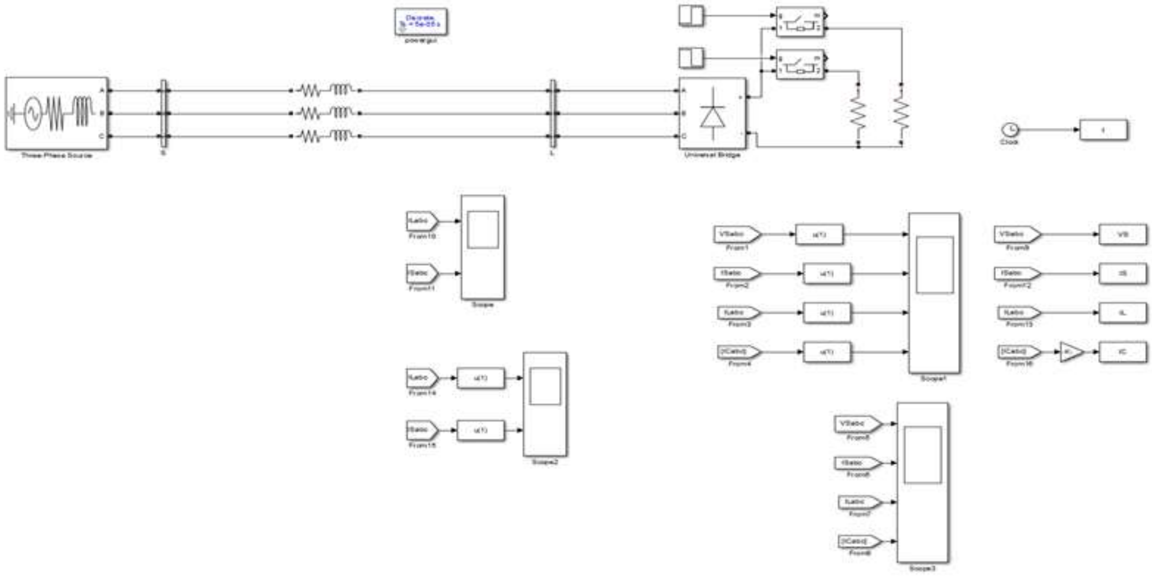

Figure 7: Simulation of System with Non-Linear Load without SAPF

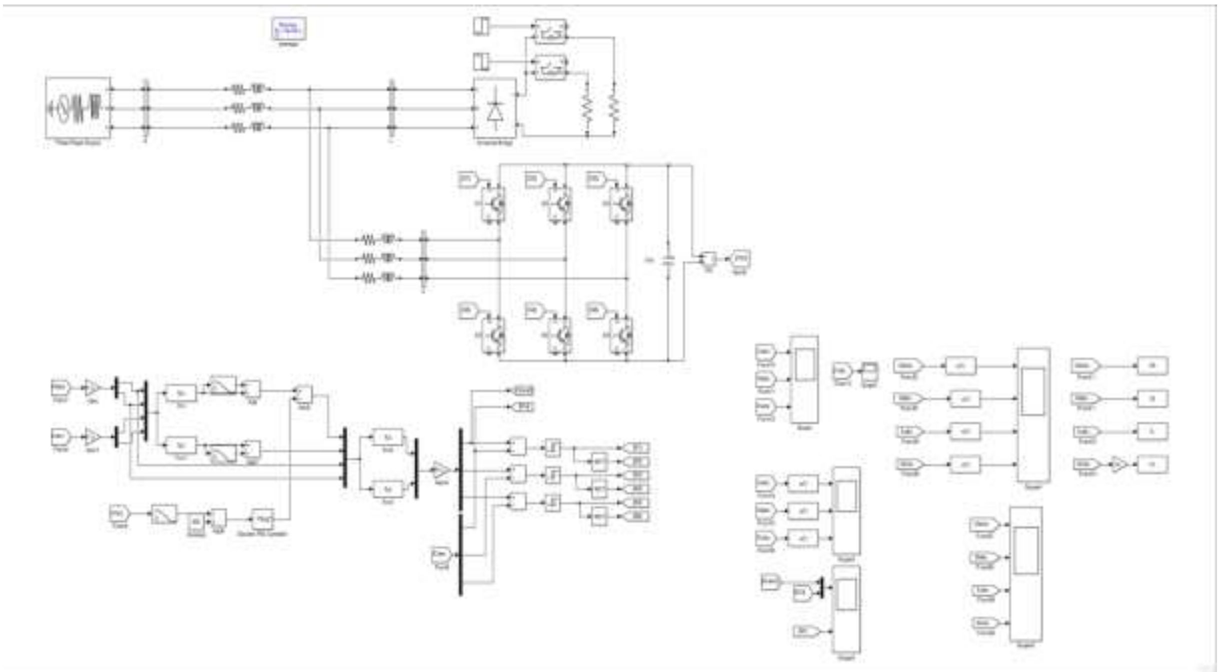

Figure 8: Simulation Diagram of SAPF with PI Controller

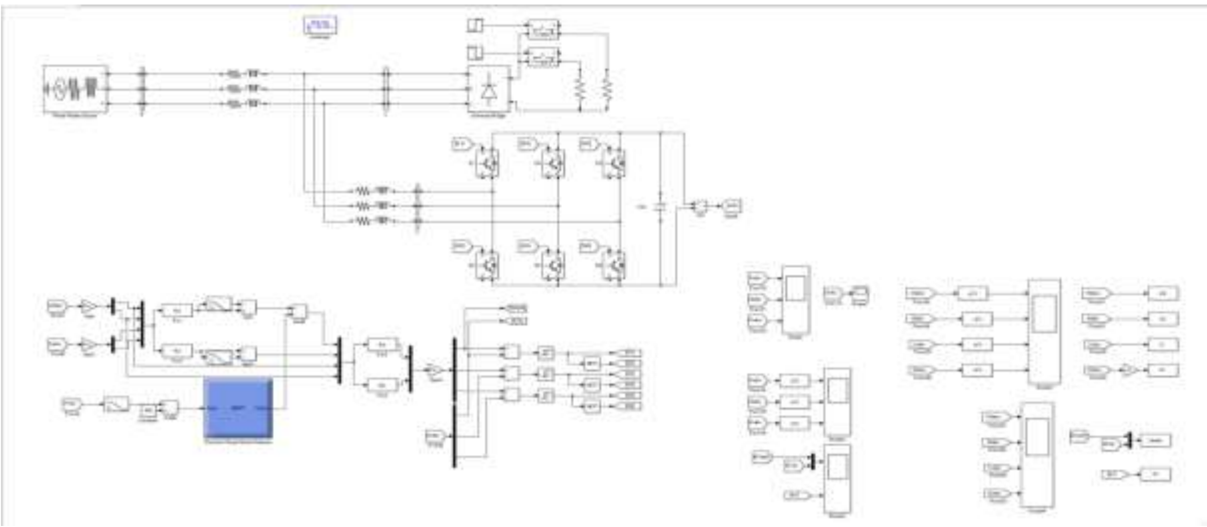

Figure 9: Simulation diagram of SAPF with Artificial Neural Network (ANN)

VIII. RESULTS AND DISCUSSIONS

Table 1: Simulation Parameters

Parameters	Values
Source Voltage (rms)	230V
Frequency	50HZ
Resistance (R)	0.1 ohm
Inductance (L)	1mH
Source Resistance	0.01 Ohm
Source Inductance	1mH
DC Capacitance	1200MF
Intial Load	10 KW
Load increased to	15 KW

The proposed ANN based SAPF is designed but also simulated with MATLAB/ Simulink Tool. Simulation of SAPF is performed with PI Controller and Artificial Neural Networks under dynamic load conditions and the results obtained were compared and checked with IEEE 519 Harmonic standard.

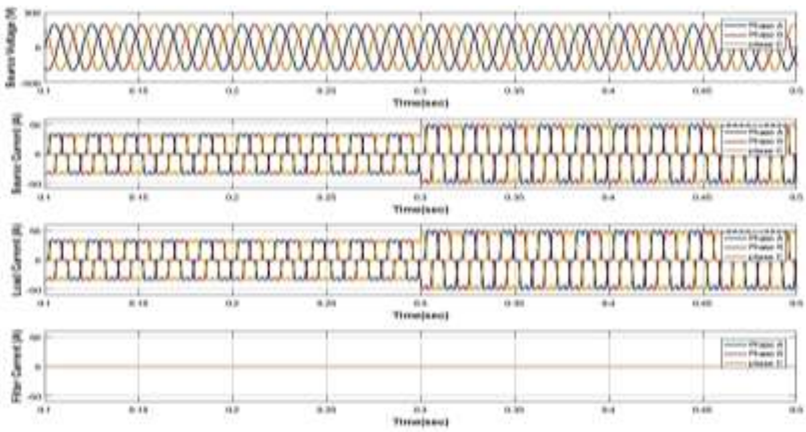

Figure 10: Output waveforms under dynamic load condition without SAPF (a) Source Voltage (b) Source Current (c) Load Current (d) Filter Current

The performance of system without SAPF will be evaluated under dynamic load condition is shown in Figure 10. The Simulation results obtained shows that before load change (up to 0.3 seconds) the current magnitude is less and at the instant of 0.3 seconds a new load of 5 KW is added to the existing load of 10 KW which increases the magnitude of current.

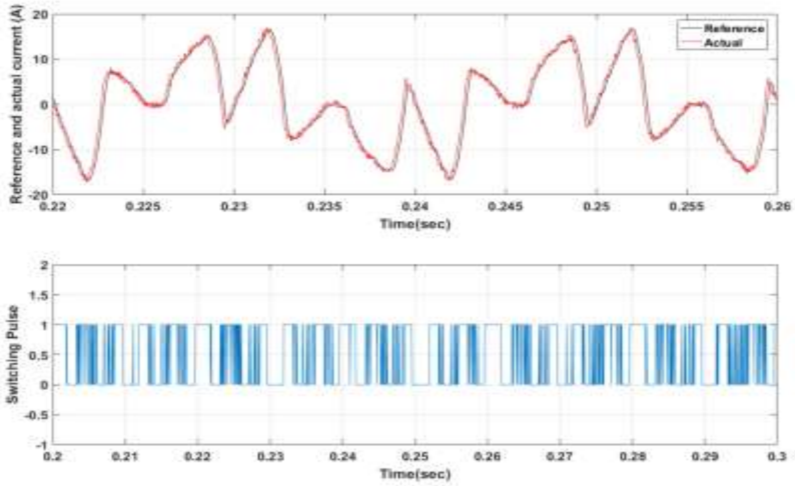

Figure 11: Switching Pulses: (a) Reference and Actual Current (b) Switching Pulses

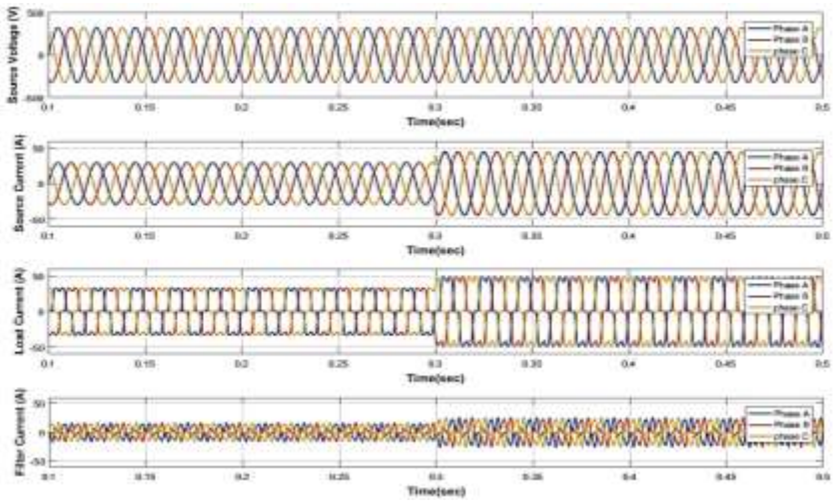

Figure 12: Output Waveforms of SAPF Under Dynamic Load Condition with PI Controller (a) Source Voltage (b) Source Current (c) Load Current (d) Filter Current

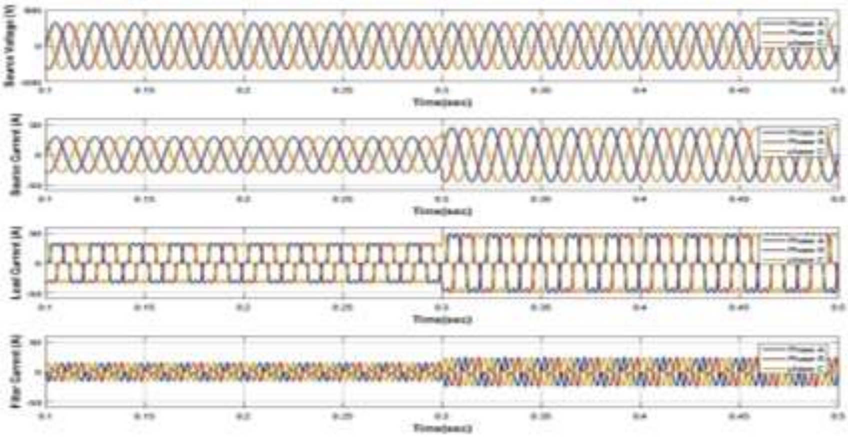

Figure 13: Output Waveforms of SAPF with ANN Control Under Dynamic load Condition (a) Source Voltage (b) Source Current (c) Load Current (d) Filter Current

The performance of system with SAPF will be evaluated under dynamic load condition with PI and ANN is shown in Figure 12 and 13 respectively. The Simulation results obtained shows that before load change (up to 0.3 seconds) the current magnitude is less and at the instant of 0.3 seconds a new load of 5 KW is added to the existing load of 10 KW which increases the magnitude of current. It is observed the SAPF with ANN control responds quickly to the load change and alters the magnitude of filter current at a faster rate.

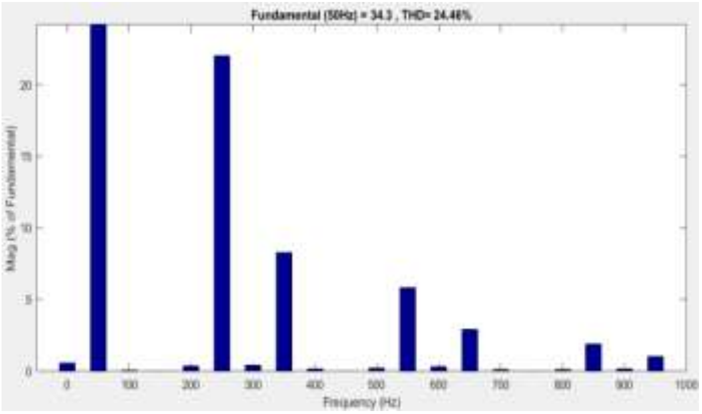

Figure 14: FFT Load Current Analysis without SAPF

The above Figure 14 shows harmonic spectrum evaluation of the load current without SAPF. The % THD is measured as 24.46%.

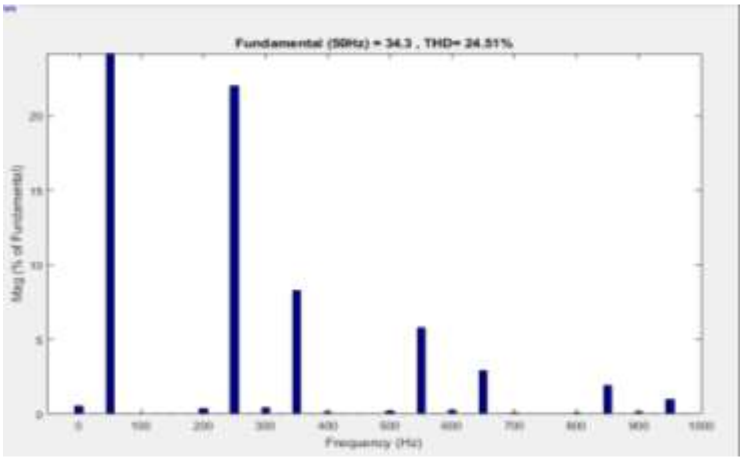

Figure 15: FFT Load Current Analysis with SAPF PI Controller Before Change of Load

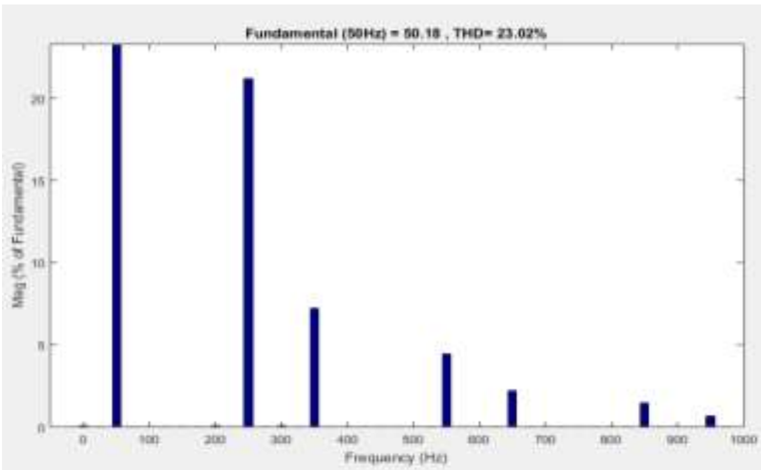

Figure 16: FFT Load current Analysis with SAPF PI Controller after Change of Load

ISSN- 2394-5125 VOL 7, ISSUE 15, 2020

The above Figure 15 and Figure 16 shows harmonic spectrum evaluation of the load current with SAPF PI Controller during dynamic load conditions. The % THD before and after load change is measured as 24.51% and 23.02% respectively.

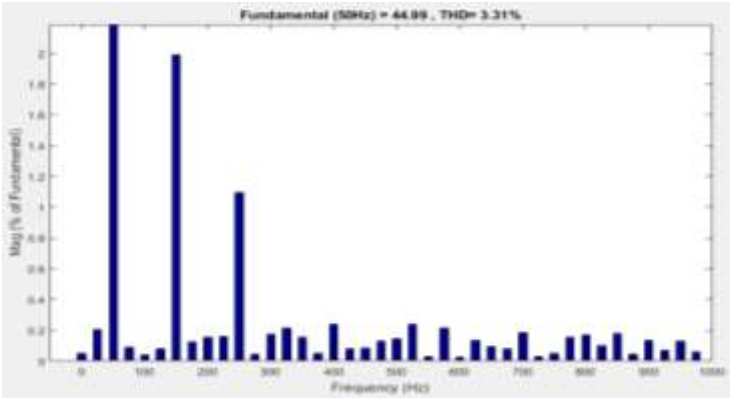

Figure 17: FFT Source Current Analysis with SAPF PI Controller after Change of Load

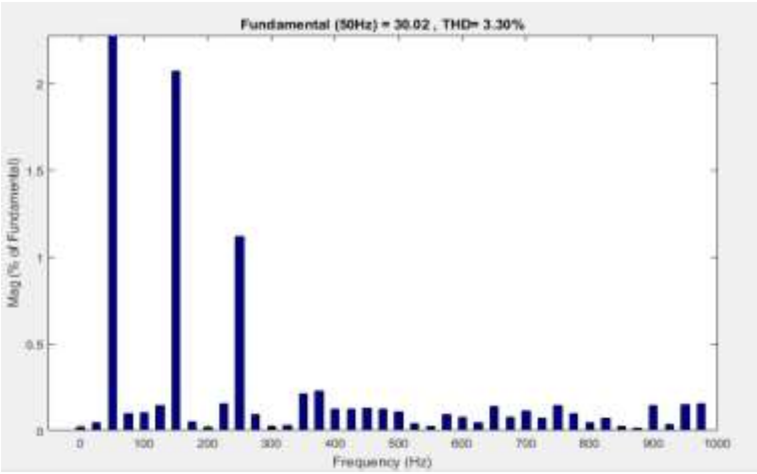

Figure 18: FFT Source Current Analysis with SAPF PI Controller Before Change of Load

The above Figure 17 and Figure 18 shows harmonic spectrum evaluation of the source current with SAPF PI Controller during dynamic load conditions. The % THD before and after load change is measured as 3.31% and 3.30% respectively.

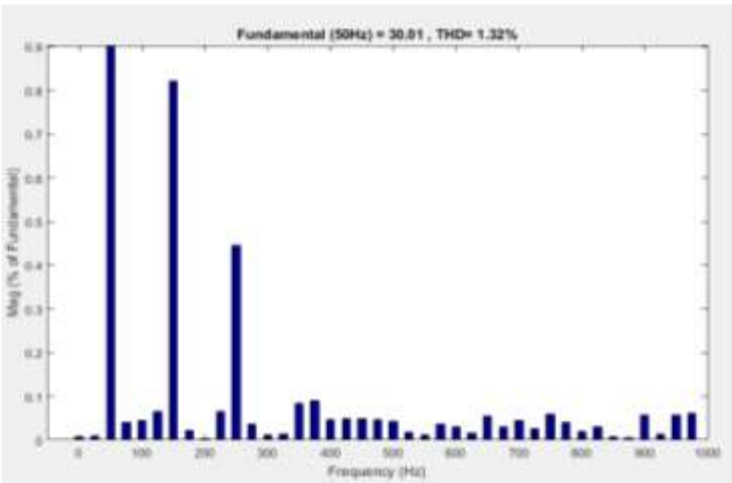

Figure 19: FFT Source Current Analysis with SAPF Artificial Neural network Before Change of Load

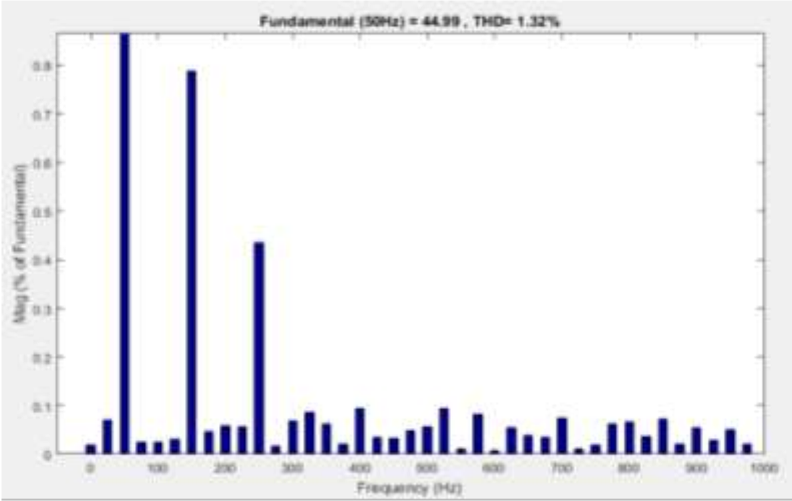

Figure 20: FFT Source Current Analysis with SAPF Artificial Neural Network after Change of Load

The above Figure 19 and Figure 20 shows harmonic spectrum evaluation of the source current with SAPF ANN during dynamic load conditions. The % THD before and after load change is measured as 1.32%.

It is evident from the above results that the Artificial Neural Network get better results when compared to PI controller and Total Harmonic Distortion (THD) level is reduced to 1.32% .

Table 2: Simulation Results

Parameter	Without SAPF	With SAPF			
		Source Current before Load change		Source Current after Load change	
		PI	ANN	PI	ANN
THD (%)	24.46	3.30	1.32	3.31	1.32

IX. CONCLUSION

This paper modifies the SAPF control structure and employs Artificial neural networks. The p-q technique is used to extract reference signals. Artificial neural network the effect is a reducing of THD to sufficient levels. However, the simulation results indicate an outstanding compensation by ANN and are similar to improve harmonic compensation. THD becomes mitigated to that very minimum value, meaning that reactive power but also harmonics produced by a nonlinear load are removed completely.

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