Adaptive Method for Power Quality Improvement through Minimization of Harmonics Using Artificial Intelligence

P. Thirumoorthi[1], Raheni T. D.[2]
[1,2] Department of Electrical and Electronics Engineering, Kumaraguru College of Technology, Coimbatore, Tamil Nadu, India

Article Info

Article history:

Received Nov 04, 2016
Revised Jan 10, 2017
Accepted Jan 20, 2017

Keyword:

Artificial intelligence (AI)
Artificial neural network (ANN)
Back propagation algorithm (BP)
Current harmonics
Hysteresis band current controller (HBCC)
Instantaneous power of P-Q theory
Power quality
Shunt active power filter (SAPF)
Total harmonic distortion (THD)

ABSTRACT

Power system harmonics are a menace to electric power system with disastrous consequence. Due to the presence of non linear load, power quality of the system gets affected. To overcome this, shunt active power filter have been used near harmonic producing loads or at the point of common coupling to block current harmonics. The shunt active power filter is designed to minimize harmonics in source current and reactive power in the non linear power supplies which are creating harmonics. In this paper, Instantaneous power of p-q theory is employed to generate the reference currents and PI controller is used to control the dc link voltage. In addition to this, Artificial Intelligence (AI) technique is used to minimize the harmonics produced by nonlinear load. The main objective of this paper is to analyze and compare THD of the source current with PI controller and by artificial neural network based back propagation algorithm. The proposed system is designed with MATLAB/SIMULINK environment.

Corresponding Author:

Raheni T. D.,
Department of Electrical and Electronics Engineering,
Kumaraguru College of Technology,
Chinnavedampatti, Saravanampatty, Coimbatore-641049, Tamil Nadu, India.
Email: raheni92@gmail.com

1. INTRODUCTION

At present day power quality issues plays a vital role. Generally power quality is defined as any deviation of voltage or current waveform from its normal sinusoidal wave shape. Due to the presence of non linear load it draws non sinusoidal current in which it creates distortion in the power system. Non linear load such as controlled and uncontrolled rectifiers, TRIAC based controllers for heating applications, variable speed drives and energy efficient lamps draws current, which consist of high harmonic content [1]. At the same time, when the source is connected to non linear load, load will produces harmonics on load side, due to these harmonics, source will become non linear. At present scenario voltage and current harmonics generated in supply side has become a serious problem in transmission and distribution system. This can be minimized by using filter technique [2]. Various harmonic elimination techniques are proposed. Out of which passive, active and hybrid filters are mainly used to minimize harmonics fed by non linear load. Conventionally passive filters are used for elimination of the harmonics, but by using passive filter it has several drawbacks such as large in size and occurrence of resonance. The above drawbacks can be overcome by shunt active power filter.

The main objective is to reduce the harmonics in power system feeding nonlinear load. In this paper, new control algorithm based on instantaneous power of p-q theory is implemented for three phase SAPF to compensate harmonics and reactive power of a three phase non linear load, uncontrolled bridge rectifier [3]. The shunt type active power filters is connected in parallel for harmonic current compensation. SAPF has the capability to maintain the main current balanced and sinusoidal after compensation regardless of whether the load is non-linear and unbalanced or balanced. The controller is the heart or primary component of the SAPF system. Therefore, it is important to generate reference current in order to compensate the harmonics producing non linear load. The active power filter is made up of Voltage Source Inverter (VSI), Inductive Capacitive element as (LC) filter and a DC link capacitor is used as a supply for three phase inverter [4]-[7]. The corresponding gate pulses are generated by using synchronized six pulse generator. The operation of APF depends on the sequence of pulse generated by the controller. PI controller is used to regulate the DC link voltage. By tuning PI controller, distortions of the source current varies accordingly and need to locate the value to get distortion less current in the supply side. Therefore by tuning the conventional PI controller source current harmonics is minimized as per IEEE standard [8]-[10].

In the proposed system, ANN technique is implemented. While implementing the above process input is taken as the difference of V_{dc} and V_{dc} ref from the PI controller and the target is chosen as compensating current obtained from the IRP theory is given to hysteresis band current controller to generate the pulses and the corresponding pulses is given as input to the voltage source inverter above which filter current is generated. Now the supply current becomes sinusoidal and the THD is minimized which gives better performance when compared to PI controller based IRP theory [11]-[13]. MATLAB/SIMULINK powers system toolbox is used to simulate the proposed system. Out of many techniques neural network is chosen to reduce the harmonic producing loads in supply side. By using neural network the input and target values gets trained for a certain period and produce distortion less current in the supply side when compared to PI controller in it.

2. ACTIVE POWER FILTER FOR HARMONIC CURRENT COMPENSATION

The principle of active power filter is generating compensating current components by detecting the amount of harmonics. The active power filter is a Voltage Source Inverter (VSI) with a DC side capacitor. The APF bridge circuit is connected to the supply line at the point of common coupling (PCC). The shunt active power filter draws or injects a compensating current that is equal and opposite of the harmonic component. Harmonics are cancelled and the resultant source current is sinusoidal. Compensating Principle of SAPF is shown in Figure 1.

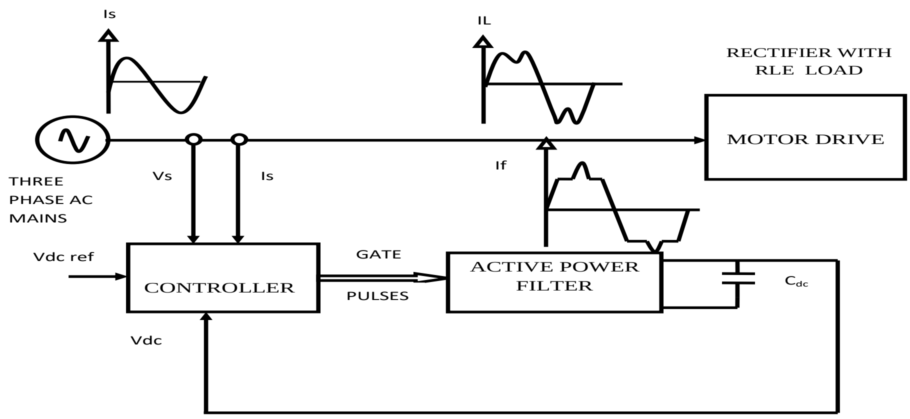

Figure 1. Compensating Principle of shunt active power filter

The three phase supply is connected to the solid state drive through uncontrolled diode bridge rectifier. The voltage and current is measured from three phase VI measurement block which is connected in series to three phase supply. The block diagram of three phase shunt active power filter is shown in Figure 2.

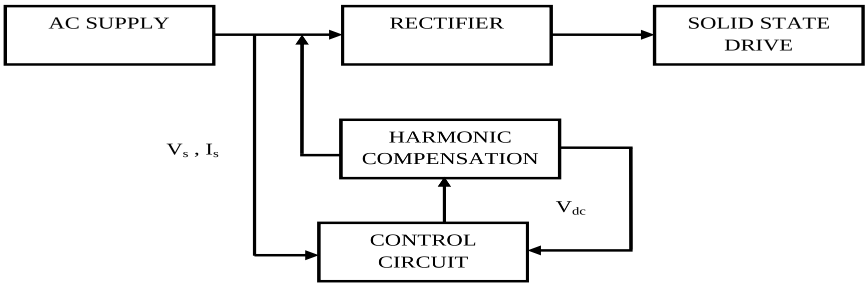

Figure 2. Block diagram of Shunt Active Power Filter

A complete step by step process is explained below. An ac source supply is given to the rectifier which converts ac to dc and it's connected to a solid state drive i.e. an RLE load in it. For the control circuit, input is supply voltage and V_{dc} ref and the output of control circuit is gate pulses. The generated gate pulses are given as input to the harmonic compensator i.e. shunt active filter which is a voltage source inverter and finally compensating filter current is generated which is connected to a point of common coupling. This compensating filter current and load current which are equal in magnitude but opposite in phase get cancel each other and produce distortion less harmonic current which is fed to the supply side.

2.1. Mathematical Modelling Of Sapf

The active power filter is composed of standard three phase PWM based voltage source inverter bridges with a DC bus capacitor to provide an effective current control. A hysteresis based carrier less PWM current is employed to give fast response of the active filter. DC bus capacitor is connected to the input side by replacing the DC voltage source. The modeled system comprises an AC source, non linear load, shunt active power filter and the controller part. The components of the system are analyzed separately and integrated to develop the complete model for the simulation.

In order to obtain the controller for the compensator, a mathematical model is derived. Voltage equation in stationary a-b-c frame is given by

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} Ldi_a \ / \ dt \\ Ldi_b \ / \ dt \\ Ldi_c \ / \ dt \end{bmatrix} + \begin{bmatrix} V_{ia} \\ V_{ib} \\ V_{ic} \end{bmatrix} \tag{1}$$

The above equation is assumed under the power system is balanced, harmonics are absent and R is small. The a-b-c frame equations can be transformed according to $\alpha - \beta$ theory.

$$\begin{bmatrix} Vs_\alpha \\ Vs_\beta \end{bmatrix} = \begin{bmatrix} Ldi_\alpha \ / \ dt \\ Ldi_\beta \ / \ dt \end{bmatrix} + \begin{bmatrix} V_{i\alpha} \\ V_{i\beta} \end{bmatrix} \tag{2}$$

Where V_{ia} , V_{ib} , V_{ic} are generated inverter voltages, i_a , i_b , i_c are inverter currents and V_a ,V_b ,V_c are the phase voltages.

3. DESIGN OF SHUNT ACTIVE POWER FILTER

The shunt active power filter is a well mature technology for the compensation of nonlinear and reactive loads. It consists of three phase ac source, diode bridge rectifier, and the load along with active power filters. Generally non linear load is the sum of source and harmonic currents. Normally, the shunt APF is controlled in such a way that it eliminates the load current harmonics. It is also called shunt conditioners and they are connected in parallel with the AC line and need to be sized only for the harmonic power (harmonic current) drawn by the nonlinear loads. This is the most important configuration and widely used in active filtering applications. SAPF compensate load current harmonics by injecting equal-but opposite harmonic compensating current. The shunt type active power filters need to compensate the harmonic currents. Therefore, it is important to generate the reference compensating current. The proper operation of the controller results in the generation of gate signals for three phase inverter which in turn is responsible for generating compensating current. Designing of filter is given below:

$f = \frac{1}{2\Pi\sqrt{LC}}$
Rated frequency = 50Hz
Assuming capacitor, C = 100μF
By substituting the above values we get,
L = 0.1017H and C=100e-6F

Thus the passive filter is designed for fundamental frequency of 50Hz. Classical approaches includes synchronous reference frame theory and P-Q theory based technique. In this paper P-Q theory is used for generating filter current. A typical active filter includes a power electronic converter with either a capacitor or inductor acting as an energy storage element and a controller for determining the desired reference signal and generating the converter gating pulse patterns. The ideal active filter would cause the rectifier load to appear as a restive load at all times to the ac system. System configuration of SAPF is described below in Figure 3 and their corresponding parameters are mentioned in Table 1.

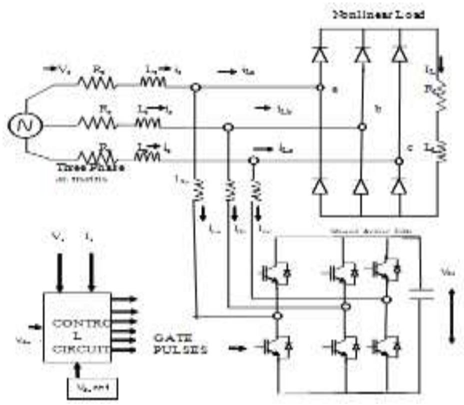

Figure 3. System Configuration of Shunt Active Power Filter

Table 1. Parameters of Shunt Active Power Filter

Parameter	Values
Supply Voltage	440V
Mains	Three phase
Frequency	50Hz
R_L	250Ω
I_L	1mH
E_b	1v
C_{dc}	3500μF
V_{dc}	620V
Proportional gain	0.5
Integral gain	1.0
Passive filter(LC)	0.1017H,100e-6F

The DC side capacitor of the APF is the significant element in filtering the harmonics. Charging and discharging of the DC capacitor provides the compensating current. The DC capacitor voltage control is maintained by a PI regulator and the current reference obtained in the proposed control method is added to reactive current component. Generally reference current component is compared with actual load harmonic current. The compensating reference current is obtained by comparing the actual filter current and the reference current. Then the three phase compensating current is given to synchronized six pulse generator to generate the pulses which are given as input to the active power filter.

4. CONTROL SCHEME FOR SHUNT ACTIVE POWER FILTER

4.1. Instantaneous Power of P-Q Theory Algorithm

The following steps explain about the instantaneous power on P-Q theory by using Clarke and Inverse Clarke transformation to generate reference current and the corresponding reference current is given to pulse generator to generate the pulses. The output of gate pulses is given as input to the shunt active power filter, so that above generated filter current is equal in magnitude but opposite in phase get cancel each other and produce distortion less current in source side. The P-Q algorithm clearly explains about reference current generation which is implemented by using Clarke's and Inverse Clarke's transformation**.**

Step 1 : Start the process by initializing source current and source voltage.
Step 2 : Transforms source voltage and current from three phase (a-b-c) coordinate to two phase (α-β) coordinate by Clarke transformation
Step 3 : Then calculation for p and q is done by the following equation

$p = v_\alpha i_\alpha + v_\beta i_\beta$
$q = v_\beta i_\alpha - v_\alpha i_\beta$

Where p- instantaneous real power
q- instantaneous imaginary power

Step 4 : Compensating current calculation is expressed as IC_1 and IC_2.

Step 5 : Compensating current in terms of abc phases are calculated by taking inverse clarke transform of alpha beta compensation current then the above equation can be written as
IC_a . IC_b. IC_c = I_{cal} (IC_1 , IC_2)

Step 6 : Then the corresponding compensating current is given as input to the synchronized six pulse generator to generate gate pulses and the corresponding gate pulses is given as input to the shunt active filter and the filter currents are generated which are equal in magnitude but opposite in phase get cancel each other and produce harmonic less current in supply side.

4.1.1. Modelling of Instantaneous Power of P-Q Theory

The proposed system deals with P-Q theory. The theory crystal clearly explains about the three phase voltages in the a-b-c coordinates to the α-β coordinates, followed by the calculation of the P-Q theory power components. For calculating P-Q theory, generally there are two transformations applicable. First method is based on Clarke transformation and the second method is on Park transformation. In this paper Clarke transformation is implemented. This transformation explains about three phase quantities that are translated from the three-phase reference frame to the two-axis orthogonal stationary reference frame and from a two–axis orthogonal stationary reference frame to a three-phase stationary reference frame is done by using Inverse Clarke transformation.

4.1.2. Calculation for Compensating Current

The process for the calculation of the compensating current is explained. IC_a , IC_b , IC_c determines the compensating current in the a-b-c coordinates and I_α and I_β shows the compensating current in αβ coordinates. It explains the above transformation occurs from three phase frame to two axis orthogonal stationary frames. The transformation matrix associated is as follows:

$$\begin{bmatrix} i_\alpha \\ i_\beta \\ i_o \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/\sqrt{2} & 1/\sqrt{2} & 1/\sqrt{2} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

This is similar to voltage equations. Therefore the values obtained from the matrix form are converted to equation form. I_a, I_b , I_c are three phase quantities and I_α and I_β are two phase stationary orthogonal reference frame (i1= I_a i2= I_b , i3= I_c).

$$I_\alpha = \frac{2}{3} I_a - \frac{1}{3} (I_b + I_c) \qquad (1)$$

$$I_\beta = \frac{1}{\sqrt{3}} (I_b + I_c) \qquad (2)$$

We know that, $I_a + I_b + I_c = 0$, therefore $I_c = -(I_a + I_b)$ by substituting I_c values in equation 1 & 2 we get $I_\alpha = I_a$ and $I_\beta = \frac{1}{\sqrt{3}} (I_a+2I_b)$.The above equation is similar to voltage.
In αβ axis
Voltage vector, $e = v_\alpha + jv_\beta$
Current Vector, $i = i_\alpha + j\, i_\beta$

$$\begin{aligned} S = e^*I &= (v_\alpha + jv_\beta)^*(i_\alpha + j\, i_\beta) \\ &= (v_\alpha i_\alpha + v_\beta i_\beta) + j\,(v_\beta i_\alpha - v_\alpha i_\beta) \\ &= p + jq \end{aligned}$$

So therefore p and q can be calculated by the following expression as,

$$p = v_\alpha i_\alpha + v_\beta i_\beta \qquad (3)$$

$$q = v_\beta i_\alpha - v_\alpha i_\beta \qquad (4)$$

From this p and q, alpha beta current is calculated.

4.1.3. Alpha Beta Current Calculation

Oscillating component of active power, reactive power, V_α and V_β are used to find harmonic currents in alpha – beta co-ordinates.

$$IC_1=(-1/((V_1^2+V_2^2))*((P_{osc}*V_1) + (q*V_2)) \quad (5)$$

$$IC_2=(-1/((V_1^2+V_2^2))*((P_{osc}*V_2) - (q*V_1)) \quad (6)$$

4.1.4. Compensating Current Calculation

Compensating current in terms of abc phases are calculated by taking inverse Clarke transform of alpha-beta compensation currents then the above equations can be written as

$$IC_a\ ,\ IC_b\ ,\ IC_c\ = \text{Ical}\ (IC_1\ ,\ IC_2)$$

$$IC_a = \sqrt{\frac{2}{3}} * IC_1 \quad (7)$$

$$IC_b = \sqrt{\frac{2}{3}} *((-0.5*IC_1) + (\sqrt{\frac{3}{2}} *IC_2) \quad (8)$$

$$IC_c = \sqrt{\frac{2}{3}} *((-0.5*IC_1) - (\sqrt{\frac{3}{2}} *IC_2) \quad (9)$$

From this equations compensating current are generated. By this process the compensating current is injected back into power line at PCC and thus suppressing the current harmonics present in the line. PI controller is used to remove steady state error. If V_{dc} is lesser then it would create a positive P_{loss} signal and if V_{dc} is greater than V_{ref} it would create negative P_{loss} signal.

4.2. Artificial Intellegence (AI) Technique

Artificial Neural Networks (ANN) is generally presented as a system of interconnected “neurons” which exchange messages between each other. The connections have numeric weights that can be tuned based on experience, making neural nets adaptive to inputs and capable of learning. ANN is one of the branches of AI technique. This technique provides an alternative approach for power system application. The network consists of a set of input neurons, output neurons and two hidden layer and it finally flows out of the network through the output layer. The network has a simple interpretation as a form of input-output model, with network weights as a parameter. Multi layer NN architecture is shown in Figure 4.

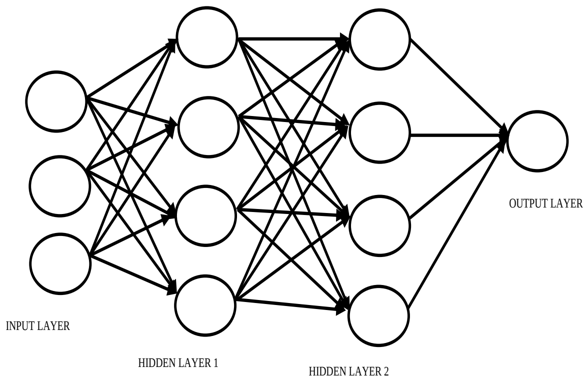

Figure 4. Multi Layer Neural Network Architecture

The training cycle has two distinct paths, the first one is forward propagation (it passes the set of inputs through the neural network structure to its output) and the second one is the error back-propagation (it passes the output error to the input in order to estimate the individual contribution of each weight in the network to the final output error).The weights are then modified to minimize the output error. To train the neural network current controller, Quasi-Newton Levenberg - Marquardt training algorithm is used, it is efficient, easy to implement and is not time consuming [14]-[18]. By training the network it has one input layer, two hidden layer and it comprises of 20 neurons and one output layer. Input layer is given as tan-sigmoid function as activation function and the output layer is being given the Pos-Linear activation function. The neural network is created with the set number of neurons in the each layer using the BP algorithm. At each training session, 323 iterations are done and the error occurrence in it.

4.2.1. Algorithm for the Control of SAPF

Neural Network for shunt active power filter consists of input layer, hidden layer and output layer. In order to improve the performance and obtain better results in the harmonic elimination of neutral current, the neural network based controller is implemented. The training of the network layer gives the required mitigation of harmonics. For obtaining the required harmonics reduction, back propagated neural network is used. These networks are purely based on supervisory training. The input of ANN controller is the difference between V_{dc} and V_{dc} (ref). Procedure for algorithm is given below:

Step 1 : Start the process and arrange a set of input and output vectors as a column in matrix. Then configure the NN Fitting tool and click next to proceed.
Step 2 : Read the input and target options in the select data window then need to load the data from MATLAB workspace.
Step 3 : Select the corresponding input and output data's. The input file is chosen from the PI controller i.e. the difference between V_{dc} and V_{dc} ref and the output is taken as compensating current generated by IRP theory.
Step 4 : Then select the training algorithm and train the network.
Step 5 : If data satisfies with the network, generation of simulink diagram is created or else repeat from step 2 to step 4.
Step 6 : End the process

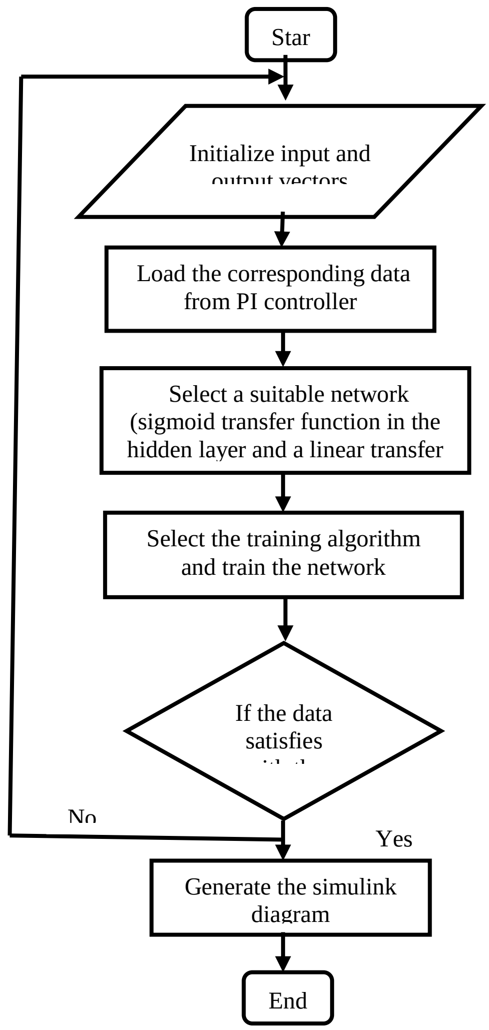

Figure 5. Flowchart for control of SAPF

5. RESULTS AND DISCUSSIONS

In order to encapsulate the performance of proposed SAPF, rectifier with RLE load is considered as a non linear load. The SAPF is constructed and simulated in MATLAB environment. The model is implemented with RLE load, and it is observed that without addition of filter the distortion in supply side is not minimized up to IEEE standard due to the presence of non linearity. The block diagram of conventional diode bridge APF for an input of 440V is shown in Figure 6, 7 and 8.

Figure 6. Block diagram – nonlinear load without filter

The model is implemented with PI controller based on IRP theory and it is observed that, minimization of low-order harmonics from a given voltage/current waveform is achieved by IRP based PI controller. In the IRP technique compensating current is generated by using transformation theory based on Clarke and Inverse Clarke transformation. Here, the lower order harmonics is reduced (THD). This method is simple and easy implementation for reducing the THD. The generated compensating current is given to pulse generator to generate pulses which is given as input to inverter gate pulse and the corresponding filter current is obtained. The filter current is equal in magnitude but opposite in phase get cancel each other and produce distortion less harmonic current in supply side.

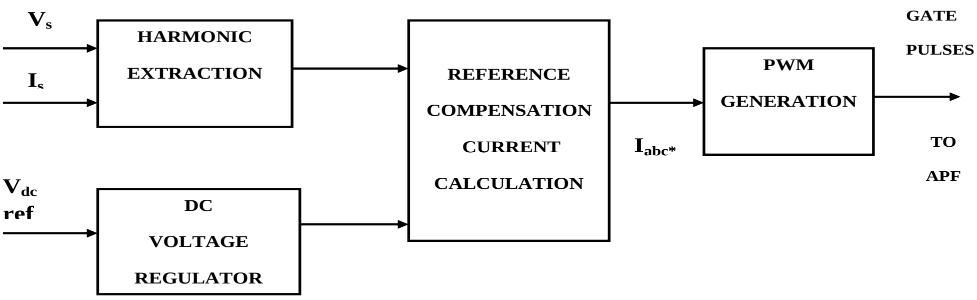

Figure 7. Block diagram of shunt active power filter based on PI controller

By using ANN method the values from PI controller is extracted and given as input to the neural network and the corresponding compensating current from IRP method is taken as target to neural network output. The simulation results are discussed for IRP theory and for ANN technique with constant DC sources. The model is implemented with ANN controller based on back propagation algorithm in which neurons get trained and it is observed that, source side harmonic current is minimized as per IEEE standard which gives better performance when compared to PI controller.

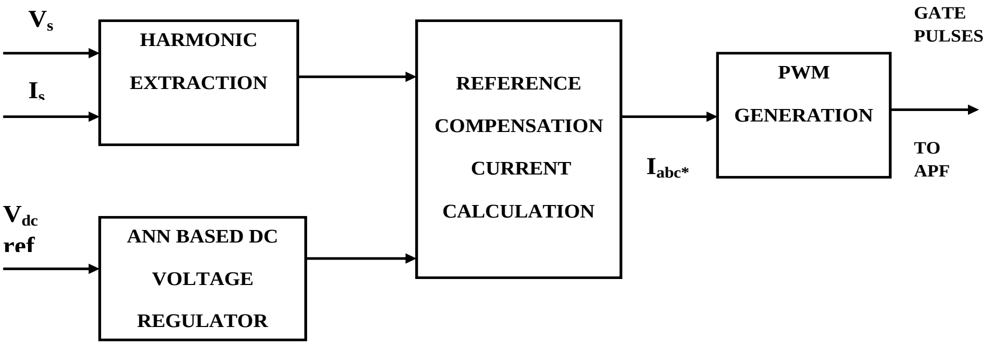

Figure 8. Block diagram of shunt active power filter based on ANN controller

5.1. Extraction of Negative Sequence Currents

In order to extract negative sequence currents, a three layer feed forward back propagation algorithm is used and is shown in Figure 9 and 10 and the required inputs and outputs are generated in MATLAB. By taking around 323 samples in a cycle and arranging them in a vector of rows, output arranged in a required vector size depends on the number of inputs. The input and output vector size should have same number of columns. The number of data requires depends upon network architecture. Once the network is trained the architecture is converted into simulink block via generating simulink diagram in the toolbox.

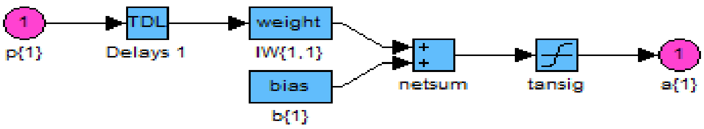

Figure 9. Simulink model of input layer

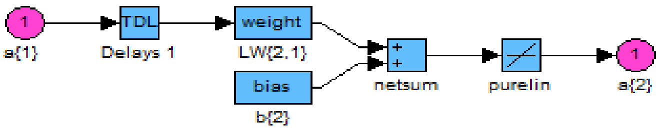

Figure 10. Simulink model of output layer

5.2. Simulation Output Without Filter

5.2.1. Source Voltage Profile

The system parameters are three phase ac mains, input voltage =440V, non linear load of R=250Ω, L=1mH, E=1V. It is observed from the results, that the above mentioned values chosen give the improved voltage of 600V when compared to other values. The output of source voltage THD results in 2.78 %.

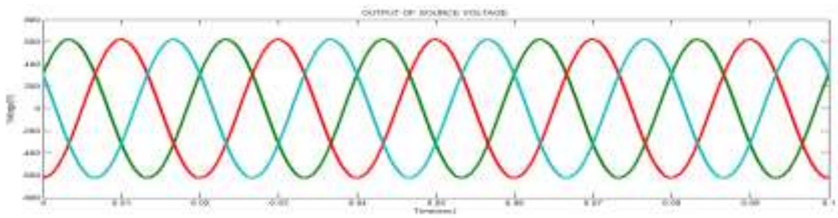

Figure 11. Result of source voltage without filter

5.2.2. Source Current Profile

The system parameters are three phase ac mains, input voltage =440V, non linear load of R=250Ω, L=1mH, E=1V. It is observed from the results, that the above mentioned values chosen give the improved current with the amplitude of 0.8A when compared to other values. The output of source current THD results in 11.60 %.

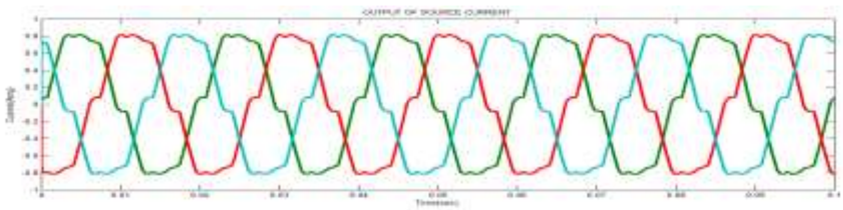

Figure 12. Result of source current without filter

5.3. FFT Analysis of Source Current

In the simulation result it is observed that load current drawn by diode rectifier is non sinusoidal due to the presence of harmonics.

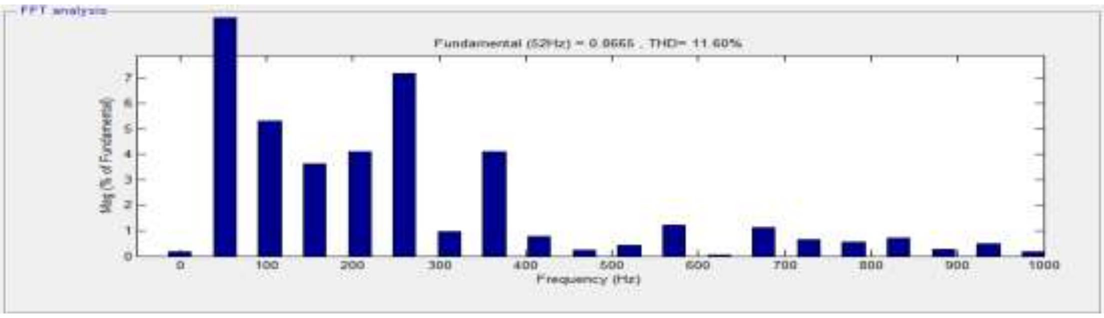

Figure 13. FFT analysis of source current without filter

5.4. Based on PI Controller With SAPF

5.4.1. Source Voltage Profile

The system parameters are three phase ac mains, input voltage =440V, non linear load of R=250Ω, L=1mH, E=1V. It is observed from the results, that the above mentioned values chosen give the improved voltage with the amplitude of 600V when compared to other values. The output of source voltage THD results in 0.12%.

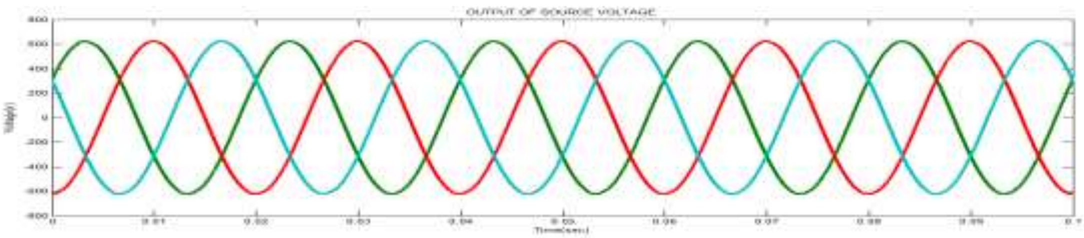

Figure 14. Result of source voltage with PI controller

5.4.2. Source Current Profile

The system parameters are three phase ac mains, input voltage =440V, non linear load of R=250Ω, L=1mH, E=1V. It is observed from the results, that the above mentioned values chosen give the improved current with the amplitude of 0.8A when compared to other values. The output of source current THD results in 2.74%.

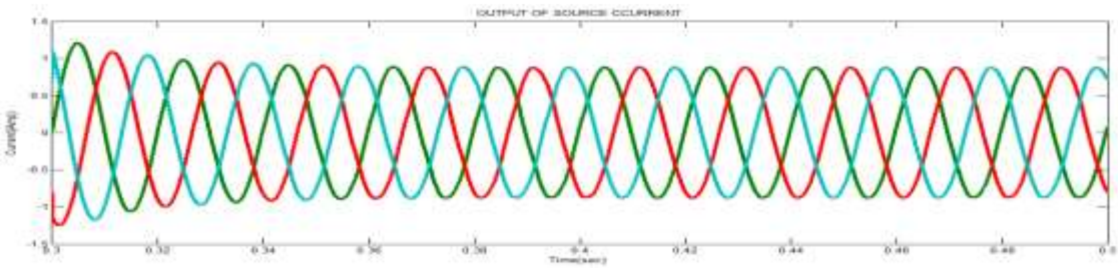

Figure 15. Result of source current with PI controller

5.5. FFT Analysis of Source Current-PI Controller

In the simulation result, the active filter is supplying the compensation current which is equal to the harmonic current. Now the shape of the supply current is sinusoidal. Thus the active power filter connected across the supply minimizes the distortion in the supply current waveform.

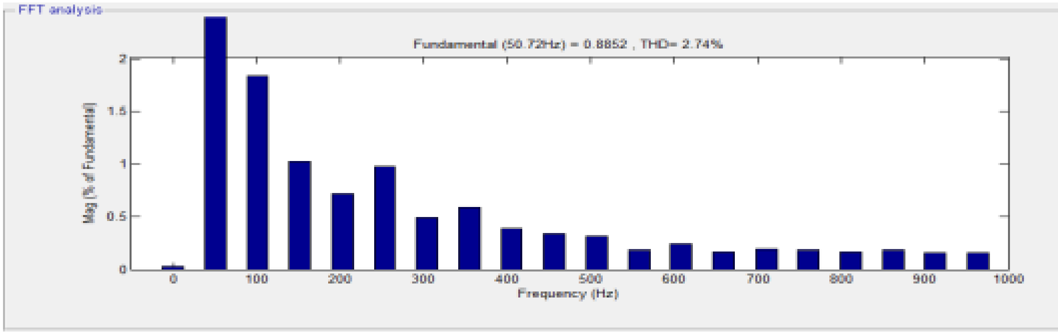

Figure 16. FFT analysis of source current with PI controller

5.6. Based on Neural Network Controller With SAPF

5.6.1. Source Voltage Profile

The system parameters are three phase ac mains, input voltage =440V, non linear load of R=250Ω, L=1mH, E=1V. It is observed from the results, that the above mentioned values chosen give the improved voltage of 600V when compared to other values. The output of source voltage THD results in 0.02%.

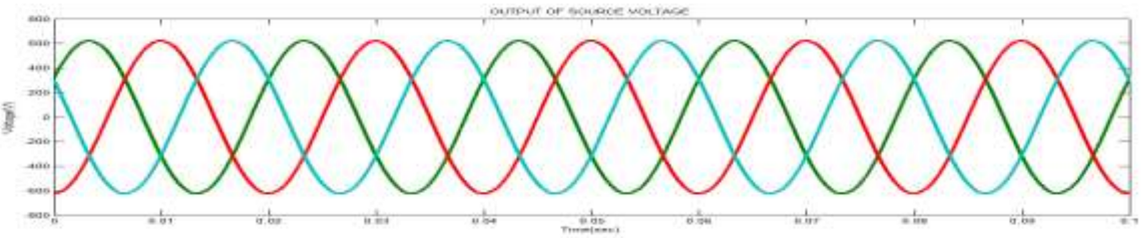

Figure 17. Result of source voltage with ANN controller

5.6.2. Source Current Profile

The system parameters are three phase ac mains, input voltage =440V, non linear load of R=250Ω, L=1mH, E=1V. It is observed from the results, that the above mentioned values chosen give the improved current with the amplitude of 0.8A when compared to other values. The output of source current THD results in 0.98 %.

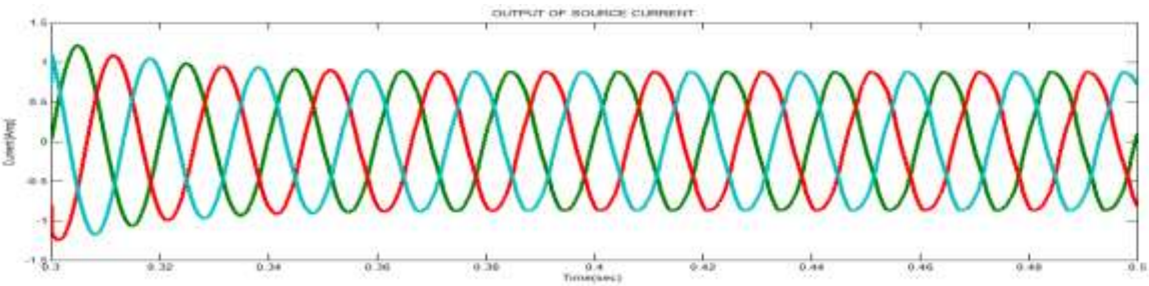

Figure 18. Result of source current with ANN controller

5.7. FFT Analysis of Source Current –ANN Controller

From the simulation results it is viewed that the load current drawn by the diode bridge rectifier results in distortion and harmonics. Then the filter add the compensating current (I_c). Now the supply current becomes sinusoidal and in phase with the supply voltage (V_s). Finally DC capacitor voltage is maintained around the reference value.

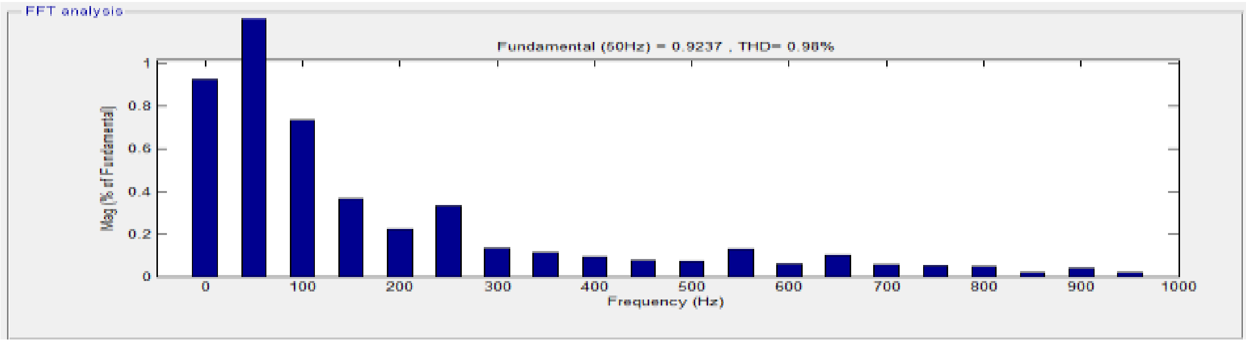

Figure 19. FFT analysis result of source current with ANN controller

Table 2 shows the comparison of our proposed approach with some power quality based shunt active power filter detection works. In comparison with some of the prior work, our approach has achieved better performance when using PI controller and Artificial Neural Network based Shunt Active Power Filter.

Table 2. Comparison Table

S .No	Author Name	Technique Employed	Performance of Source Current THD (%)
1	Quoc-Nam Trinh et al	Conventional Proportional-Integral (PI) and Vector PI (VPI) controllers	12.70%,1.72%
2	T. Mahalekshmi	PI controller using the stationary-frame generalized integrators	4.85%,1.96%
3	D. L. Popa et al	Statics Excitation System for Shunt Active Power Filter using Fast Fourier Transform	1.37%
4	G. Sathish Goud et al	Shunt Active Power Filter based PI Controller , ANN Controller	2.92%, 1.77%
5	Mr. CH. VNV HariKrishna et al	(i)Adaptive and predictive ANN based controller for a SAPF (ii)Adaptive and predictive ANN based controller for a type HAPF	(i) 2.25 (ii) 1.49
6	Proposed Method	Shunt Active Power Filter based PI Controller, ANN Controller	2.74%, 0.98%

6. CONCLUSIONS

In this paper, detailed analysis of Shunt Active Power Filter for various operating condition has been analyzed. The operation of shunt active filter using conventional PI Controller and Artificial Intelligence Technique based Neural Network under non-linear load conditions has been implemented. From the analysis it is observed that the voltage and current harmonics is being mitigates by shunt active power filter strategy using PI and Back Propagation Algorithm. The improvement of harmonic currents in supply side and the reactive power consumption by the non-linear load has been achieved by the proposed shunt active power filter strategy. The better computation efficiency of the proposed artificial intelligence approach shows that it can be applied to a wide range of power quality problems. These test results bring out the benefit of Artificial Neural Network based Back propagation Algorithm for current controller of shunt active power filter for power quality enhancement. Therefore it is accomplished that, the proposed control strategy shows the simplicity and effectiveness of the designed SAPF in the combination of both conventional PI and Intelligent controller technique that has been projected in this paper to improve the dynamic performance of the system.

REFERENCES

[1] D. Rivas, *et al.*, "Improving passive filter compensation performance with active techniques," *IEEE Trans .Ind.Electron*., vol/issue: 50(1), pp. 161–170, 2003.
[2] S. Jain, *et al.*, "Design simulation and experimental investigations on a shunt active power filter for harmonics and reactive power compensation," *Electrical Power Components and Systems*, vol/issue: 32(7), pp. 671–692, 2003.

[3] L. H. Tey and Y. C. Chu, "Improvement of power quality using adaptive shunt active filter," *IEEE Transactions on Power Delivery*, vol. 20, 2005.

[4] H. Akagi, *et al.*, "Instantaneous power theory and applications to power conditioning," *Wiley IEEE Press*, 2007.

[5] M. I. M. Montero, *et al.*, "Comparison of control strategies for shunt active power filters in three-phase four-wire systems," *IEEE Trans. Power Electron*., vol/issue: 22(1), pp. 229–236, 2007.

[6] K. K. Shyu, *et al.*, "Model reference adaptive control design for a shunt active-power-filter system," *IEEE Trans. Ind.Electron.*, vol/issue: 55(1), pp. 97–106, 2008.

[7] M. Singh and V. Tiwari, *"Modelling analysis and solution of Power Quality Problems,"* Eighth International Conferences on Environment and Electrical Engineering, 10-13 May, 2009.

[8] E. H. Watanabe, *et al.*, "Instantaneous p-q Power Theory for Compensating Non sinusoidal Systems," *International School on Non sinusoidal Currents and Compensation Lago*, Poland, 2010.

[9] T. Mahalekshmi, "Current Harmonic Compensation and Power Factor Improvement by Hybrid Shunt Active Power Filter," *International Journal of Computer Applications*, vol/issue: 4(3), 2010.

[10] Z. Chao, *et al.*, "Shunt Active Power Filter System Design for Inter-harmonic," *International Journal of Power Electronics and Drives Systems (IJPEDS),* vol/issue: 3(4), 2013.

[11] D. I. Popa and P. M. Nicolae, *"Analysis and Simulation of Line Notching Attenuation for a Static Excitation System in a Power System,"* 4-th International Youth Conference on Energy IYCE, Hungary, 2013.

[12] S. Gautam, *et al*., "Evaluation of Fundamental d-q Synchronous Reference Frame Harmonic Detection Method for Single Phase Shunt Active Power Filter," *International Journal of Power Electronics and Drives Systems (IJPEDS),* vol/issue: 4(1), 2014.

[13] S. Rahmani, *et al*., "A combination of shunt hybrid power filter and thyristor-controlled reactor for power quality," *IEEE Trans. Ind. Electron.*, vol/issue: 61(5), pp. 2152–2164, 2014.

[14] D. Suresh and S. P. Singh, *"Performance investigation of the shunt active power filter using neural network*," IEEE students conference, 2014.

[15] S. Jarupula, *et al.,* "Power Quality Improvement in Distribution System using ANN Based Shunt Active Power Filter," *International Journal of Power Electronics and Drives Systems (IJPEDS),* vol/issue: 5(4), 2015.

[16] G. S. Goud and A. L. Joshi, "Artificial Neural Network Controlled Shunt Active Power Filter For Power Quality Improvement," *International Research Journal of Engineering and Technology,* vol/issue: 2(4), 2015.

[17] C. H. V. N. V. H. Krishna, *et al*., "Power Quality Improvement with Shunt Hybrid Active Power Filter Using ANN-Based Predictive and Adaptive Controllers," *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET),* vol/issue: 4(9), 2015.

[18] K. K. Pedapenki, *et al*., *"Comparison of PI and neural network based controllers for shunt active power filter*," International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT), Kumaracoil, pp. 214-218, 2015.