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COMPARISON OF ANN CONTROL AND SINUSOIDAL CURRENT CONTROL TECHNIQUE APPLIED IN ACTIVE FILTER FOR HARMONIC REDUCTION

*Niyaz hasan Kazmi[1], *Anurag Tripathi[2]

[1]Research Scholar Sai Nath University, Ranchi, Jharkhand , India, [2] Department of Electrical Engineering Institute of Engineering & Technology, Lucknow, Uttar Pradesh, India

***Address for correspondence:**
Niyaz Hasan Kazmi, Research Scholar Sai Nath University, Ranchi, Jharkhand,India, Email ID: niyazkazmi@gmail.com; Dr .Anurag Tripathi, Associate Professor, Department of Electrical Engineering, Institute of Engineering & Technology, Lucknow, India, Email ID: anurag.tripathi@ietlucknow.ac.in

ABSTRACT

This paper studies the effect of Sinusoidal current control strategy on the performance of a shunt active power filter. Sinusoidal current control (SCC) Strategy has been employed here for the analysis and simulation point of view of the APF and its comparison has been done to the Artificial Neural Network (ANN) control optimized Active power filter. In this paper, a comprehensive analysis and comparison of the APF's performance have been carried out between these two techniques. The two parameters THD and compensation time have provided a quantitative and qualitative basis for the comparison of performances when applied APF to the System.

***Keywords**: Active power filter; Total harmonic distortion, ANN*

1. INTRODUCTION

Unfortunately the power electronic loads have an inherently nonlinear nature, and they therefore draw a distorted current from the mains supply. That is they draw non-sinusoidal current, which is not in proportion to the sinusoidal voltage. As a result, the utility supplying these loads has to provide large reactive volt-amperes. Also the harmonics generated by the load pollutes it. As nonlinear loads, these solid-state converters draw harmonic and reactive power component of current from ac mains. The injected harmonics, reactive power burden, unbalance and excessive neutral current cause low system efficiency and poor power factor. They also cause disturbance to other consumers and interference in nearby communication networks, excessive heating in transmission and distribution equipment, errors in metering and malfuctioning of utility relays. The inflictable tariffs levied by utilities against excessive vars and the threat of stricter harmonics standards have led to extensive surveys to quantify the problems associated with electric power networks having nonlinear loads. i.e. the load compensation techniques for power quality improvement.

Conventionally, the passive L-C filters were used to reduce harmonics that are tuned to the frequency of the harmonic to be reduced and capacitors were employed to improve the power factor of the ac loads. Some of the advantages of VAR compensation or power improvement and harmonic filtering are:

- Minimum power loss.
- Better utilization of generation, transmission distribution and substation capacity.
- Minimum voltage-drop and improved voltage regulation.
- No interference with communication lines.
- Better quality of electric energy at the user's end.
- Large life span of the equipment.

This paper has been designed in following way. Section 1 gives the problem statement, section 2 presents the details about active power filter. Section 3 discusses about the control techniques. Section 4 shows the loads used and the results after the compensation. Section 5 concludes the paper.

2. ACTIVE POWER FILTER

Ideally, active filters will provide an injected current that will completely compensate for the non-sinusoidal requirements of the load. In practice this seems unlikely and a more reasonable requirement is to reduce harmonics distortion to a minimum acceptable level for a given condition.

Active power filters (Figure 1) may be used, which compensate for current unbalances high and low order harmonics sub-harmonics and reactive power resulting in sinusoidal in phase and symmetric line currents.

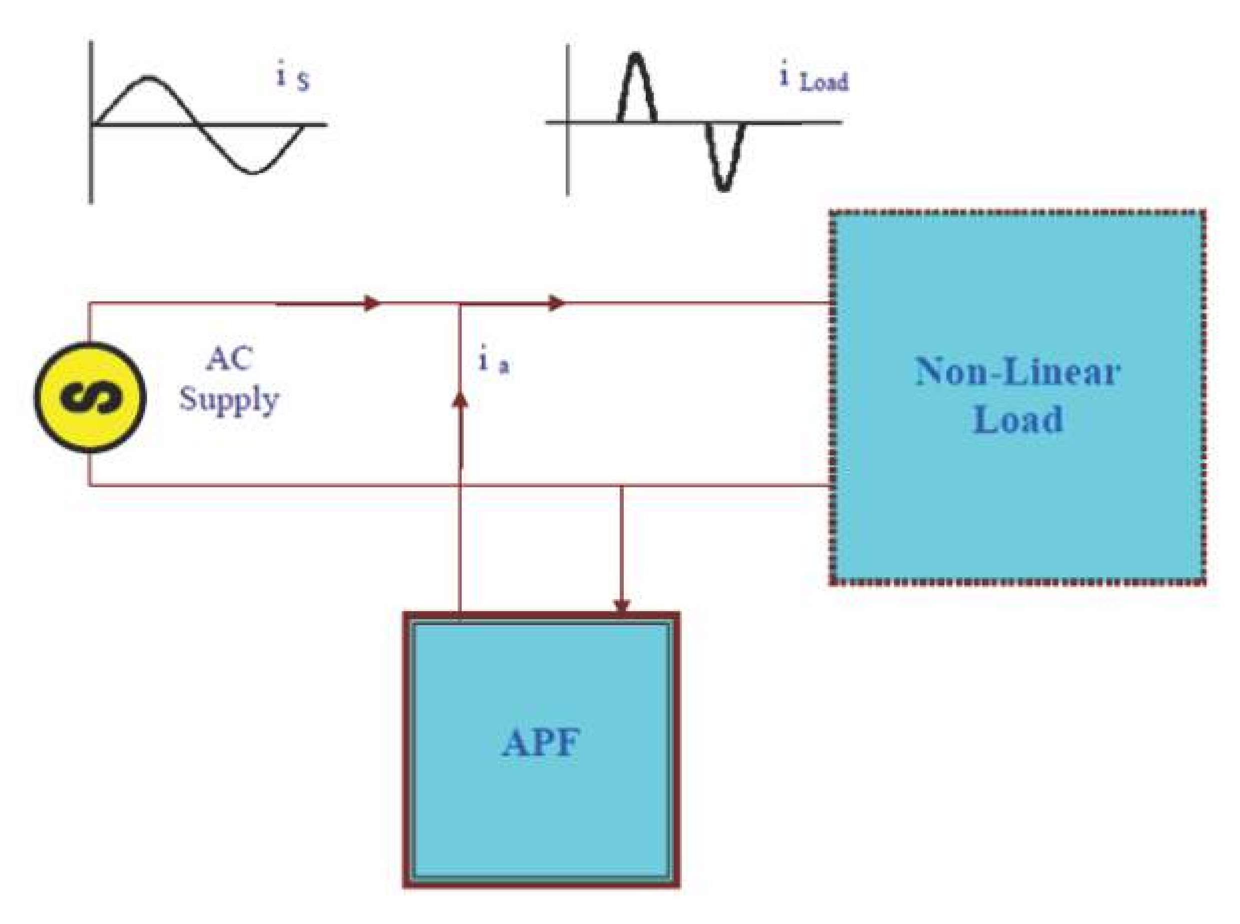

FIGURE 1 ACTIVE POWER FILTER CONCEPT

3. CONTROL TECHNIQUES

In this paper sinusoidal current control(SCC) technique has been used as a basic control technique. ANN has been used to optimize the SCC.

3.1 Sinusoidal Current Control Strategy:

With some modification in constant instantaneous power control strategy, the new strategy can be used under unbalanced conditions too. The new strategy has been named as Sinusoidal current control strategy.

Fig. 2 shows the control diagram of shunt active filter using sinusoidal current control strategy which is modified version of constant instantaneous power control strategy and able to compensate load currents under unbalanced conditions too. The modification includes a positive sequence detector which replaced the 800 Hz cutoff frequency low-pass filters and correctly finds the phase angle and frequency of the fundamental positive sequence voltage component and thus shunt active power filter compensates the reactive power of the load.

While designing this detector, utmost care should be taken so that shunt active filter produces ac currents orthogonal to the voltage component, otherwise it will produce active power. i,i , p' and q' are obtained after the calculation from --0 transformation block and send to the - voltage reference block, which calculates v, and v.. Finally, --0 inverse transformation block calculates the V'_a, V'_b, and V'_c In place of the filtered voltages used previously, V'a, V'b, and V'c are considered as input to the main control circuit.

Now fundamental negative sequence power, harmonic power, and the fundamental reactive power, are also included in the compensating powers. It should be noted that the controller for supply systems can be treated as a simplification, just considering $v_0 = i_0 = p_0 = 0$ and the elimination of signal .

The sinusoidal current control strategy makes the active filer to compensate the current of a nonlinear load to guarantee balanced, sinusoidal current drawn from the network, even under an unbalanced and/or distorted system voltage. We know that neutral current is a big problem for aircraft system and this strategy compensates also the neural current of the load.

Fig. 3 shows the complete control block diagram of the shunt active filter that realizes the sinusoidal current control strategy for aircraft systems. One simplification was done in the positive-sequence detector shown in Fig. 4, and included as part of the controller of the aircraft shunt active filter.

At this point, it is important to remark that the voltage regulator of Fig. 2 that generates the signal p_{loss} has received an additional ask besides those listed in the last sections to correct errors in power compensation. This occurs because the feed forward control circuit is now unable to supervise the zero-sequence power. Since the active filer compensates the whole neural current of the load in the presence of zero-sequence voltages, the shunt active filter eventually supplies. $\Delta \bar{p}$ is replaced simply by $\overline{p_{loss}}$. Therefore, if the active filer supplies $\overline{p_0}$ to the load, this causes dc voltage variations, which are sensed by the PI controller of the dc voltage regulator. Hence, an additional amount of average real power, numerically equal $\overline{p_0}$ is automatically added to the signal plot that is mainly used o provide energy to cover for losses in the power circuit of the shunt active filter. Actually, the constant instantaneous power controller presented would behave in the same manner if $\Delta \bar{p}$ is replaced only by $\overline{p_{loss}}$.

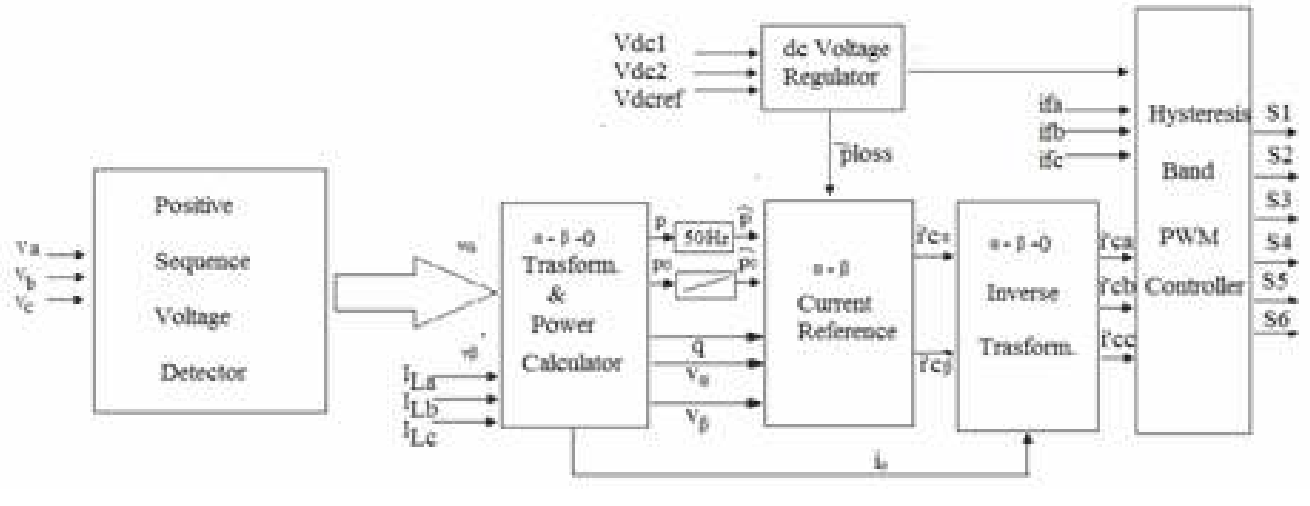

Fig. 2 Control Diagram of the Shunt Active Filter Controller using Sinusoidal Current Control Strategy

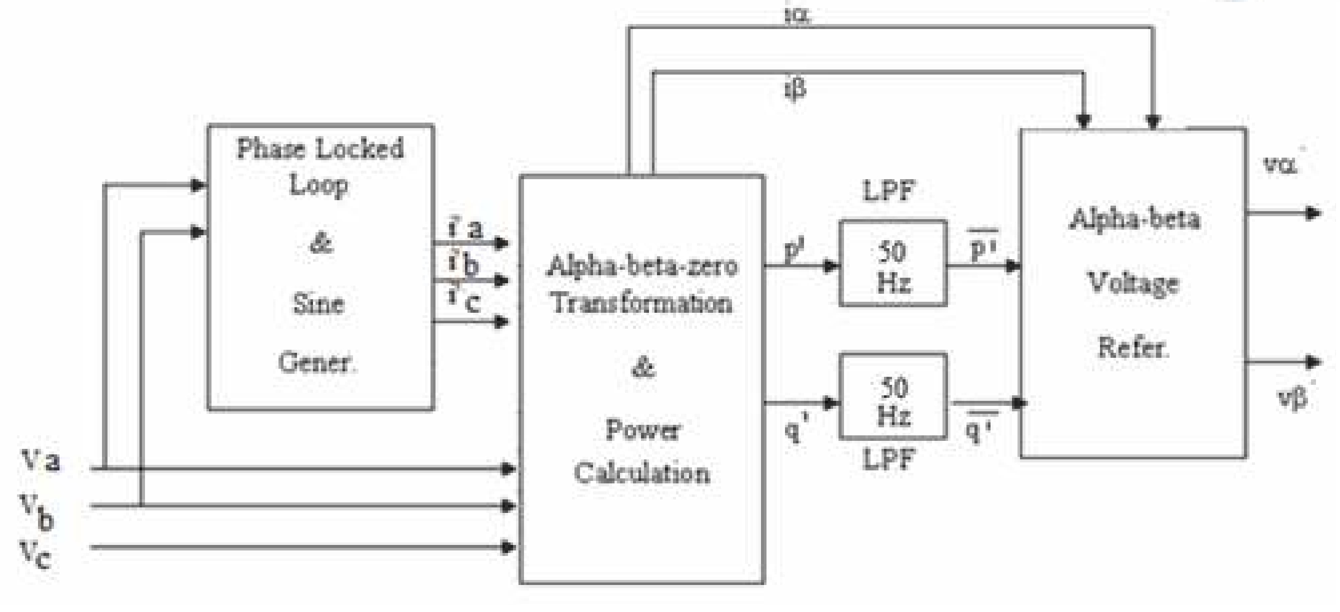

Fig. 3 Block Diagram of the Fundamental Positive-Sequence Voltage Detector for Sinusoidal Current Control Strategy

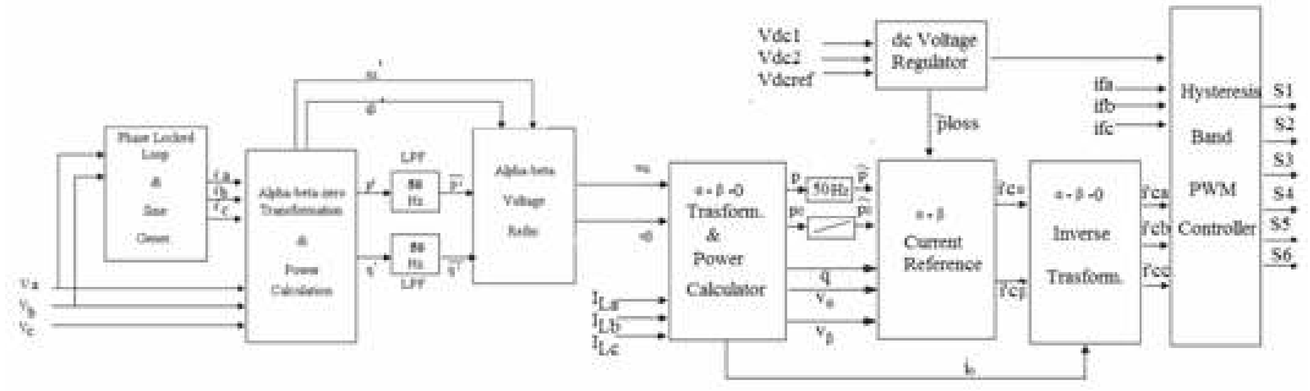

Fig. 4 Control Block Diagram of the Shunt Active Filter Controller for Sinusoidal Current Control Strategy

Sinusoidal current control strategy (modified constant source instantaneous power control strategy) applied in Active filter is simulated in MATLAB environment using SIMULINK and SimPowerSystem toolboxes.

The total simulated model of the sinusoidal current control strategy of has been modeled using SIMULINK and shown in fig. 5.

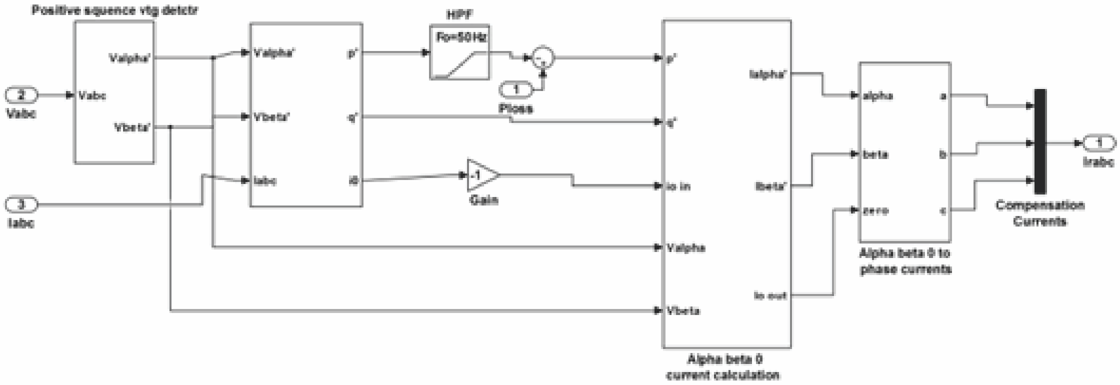

Fig. 5 MATLAB/SIMULINK Model of the Shunt Active Filter using Sinusoidal Current Control Strategy

3.2 Algorithm of ANN for Current Controller of Shunt Active Power Filter for sinusoidal current control techniques

The artificial neural network has to be first generated and then trained before implementing it in the shunt active power filter. Following steps are involved in developing the neural network.

Step 1: The required inputs are fed to the neural network. In the case of shunt active power filter, the inputs are three phase source current and three phase voltage and the error, which has been calculated in the dc voltage control loop.

$P = 7 \times 1$

Where, P is a vector matrix of 7inputs.

Step 2: Next, the targets are decided. Targets are the desired values of the variables to be optimized in ANN tuning method. The reference currents are the target variables.

$t = 3 \times 1$

Where, t is a vector matrix of 3targets

Step 3: The weights and biases are then initialized to any random values.

$$[w]^0 = [b]^0 = [randomvalues]$$

where, $[w]^0$ and $[b]^0$ are the weights and biases row matrices respectively. The number of layers selected is 2. The output vector matrix $[O]$ is obtained from these layers as these get the inputs. The output from the layers is obtained using suitable transfer function.

Step 4: The training of neural network generated from the data available in step 1 and step 2 is carried out by setting the goal parameter to a minimum. The error data in the form of error vector matrix *(E)* is generated to ensure the desired convergence has reached. When either the prescribed goal or the number of epochs during training of network is met, the training stops.

$$E = \frac{\sum_{i=1}^{n} (t_i - o_i)^2}{n}$$

Where, E is the error data matrix generated using mean squared error as objective function, $n$is the total number of outputs and n is the number of iterations.

Step 5: The target when achieved after the training of network yields the optimized values of the output which in the case of current controller of shunt active power filter is the reference or compensation current.

Step 6: These optimized values of reference currents or compensation currents are incorporated in the shunt active power filter developed in Chapter III for simulation of the performance of the supply system when the system is subjected to various loads.

Step 7: The results obtained are examined and compared with the results achieved from conventional control method on the basis of the THDs of source current and source voltage as well as response time for compensation or compensation time.

The Active power filters are complex closed loop systems having a feedback for calculating the reference current, thus feed-forward back propagation method for training the neural network is selected. The linear method could not produce the optimized results while, feed-forward back propagation method reproduced optimized values of reference current. Here the mean square error i.e. MSE has been used as an optimization function for current controller. In this research work the off line training of the network has been carried out using the feed forward back propagation method because online training of the network is a very time consuming and slow computational method. Following ANN parameters provided in Table 1 have been used to generate the trained network.

Table 1

PARAMETER VALUES FOR ANN BASED TUNED CURRENT CONTROLLER

Variables	Value
No. of Layers; output calculated from input using following transfer functions	2; a) 1st layer: hyperbolic tangent sigmoidal function b) 2nd layer: linear transfer function
No. of Neuron3s	21
Training Method	Levenberg-Marquardt back-propagationMean
Optimization function	Square Error (MSE)
Learning Method	Gradient Descent Weight and Bias

4. RESULTS & DISCUSSION

4.1 Simulation of Uncompensated System

In this paper the MATLAB/SIMULINK models of the uncompensated systems i.e. without active filters have been dealt with. The load have been connected to the 50 Hz balanced, supply system. Further, the loads under consideration for 50 Hz is three phase 6-pulse current source bridge converter. Simulations have been done for 15 cycles and results analyzed on the basis of THD of source current and voltage

Modeling and simulation for uncompensated system with balanced supply condition for 50 Hz supply for load have been done. fig. 6 presents the waveforms of source current and source voltage for Load . After simulating in MATLAB/ Simulink, it has been observed that THD of source current is 45.29% and THD of source Voltage is 27.75%. By observing these data, we can easily understand that they are out of the limit of IEEE 519-1992 limit. We have seen that supply has been polluted when Load 1 is connected to balanced uncompensated supply system.

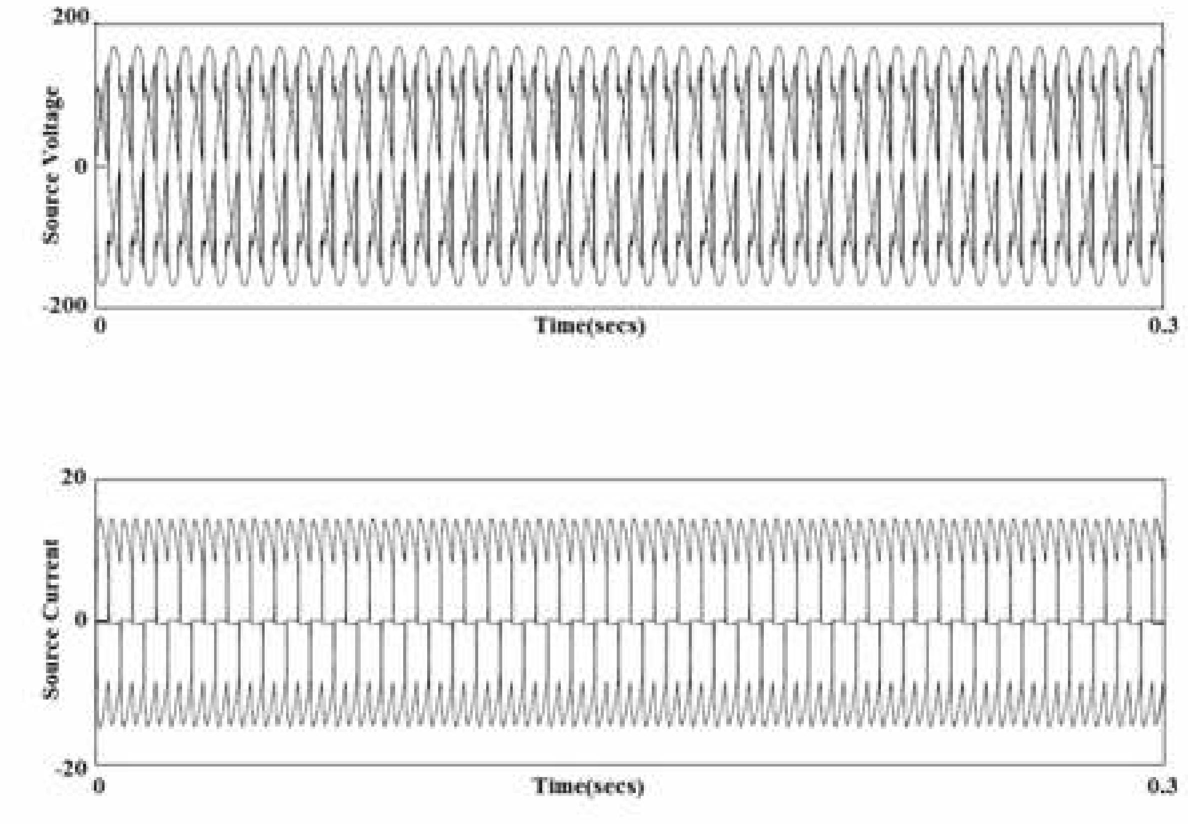

Fig. 6 Waveforms of source voltage, source current of Load for balanced supply condition

4.2 Simulation Of Compensated System

. Shunt active filter fulfills the demand of the load by providing the compensation current and the requirement of essential voltage for active filter has been completed by the two dc capacitors. There reference signals have been generated and the hysteresis band controller provide the necessary gating signals.

4.2.1 Simulation of Active Power Filter with Sinusoidal Current Control Strategy with 6-Pulse Current Source Converter Bridge

THDs of source current & source voltage have been found 1.39% and 4.15% respectively after making observations from the simulation results shown in fig. 7. The waveforms for source voltage and source current have become sinusoidal at t=0.08 sec. Compensation time is 0.08 sec. The waveforms of compensation current, dc capacitor voltage and load current have been shown in fig. 7. Waveforms show the variations in dc capacitor voltage.

4.2.2 Simulation of Shunt Active

Power Filter based on Sinusoidal Current Control strategy Using ANN For all three loads connected together at different interval

From the simulation results shown in fig. 8, it has been observed that that the THD of source current & source voltage was 1.75% and 4.08 % respectively. The compensation time was 0.070 sec. At t=0.070 sec, we can see that the waveforms for source voltage and source current have become sinusoidal.

From fig. 8, we can see the waveforms of dc capacitor voltage and load current. The variation in dc voltage can be clearly seen in the waveforms. Due to that, the source voltage variations can also be clearly seen in the waveforms. As per requirement for increasing the compensation current for fulfilling the load current demand, it releases the energy and thereafter it charges and tries to regain its set value. If we closely observe, we can find out that the demand of load current are being fulfilled and after the active filtering the source current and voltage is forced to be sinusoidal.

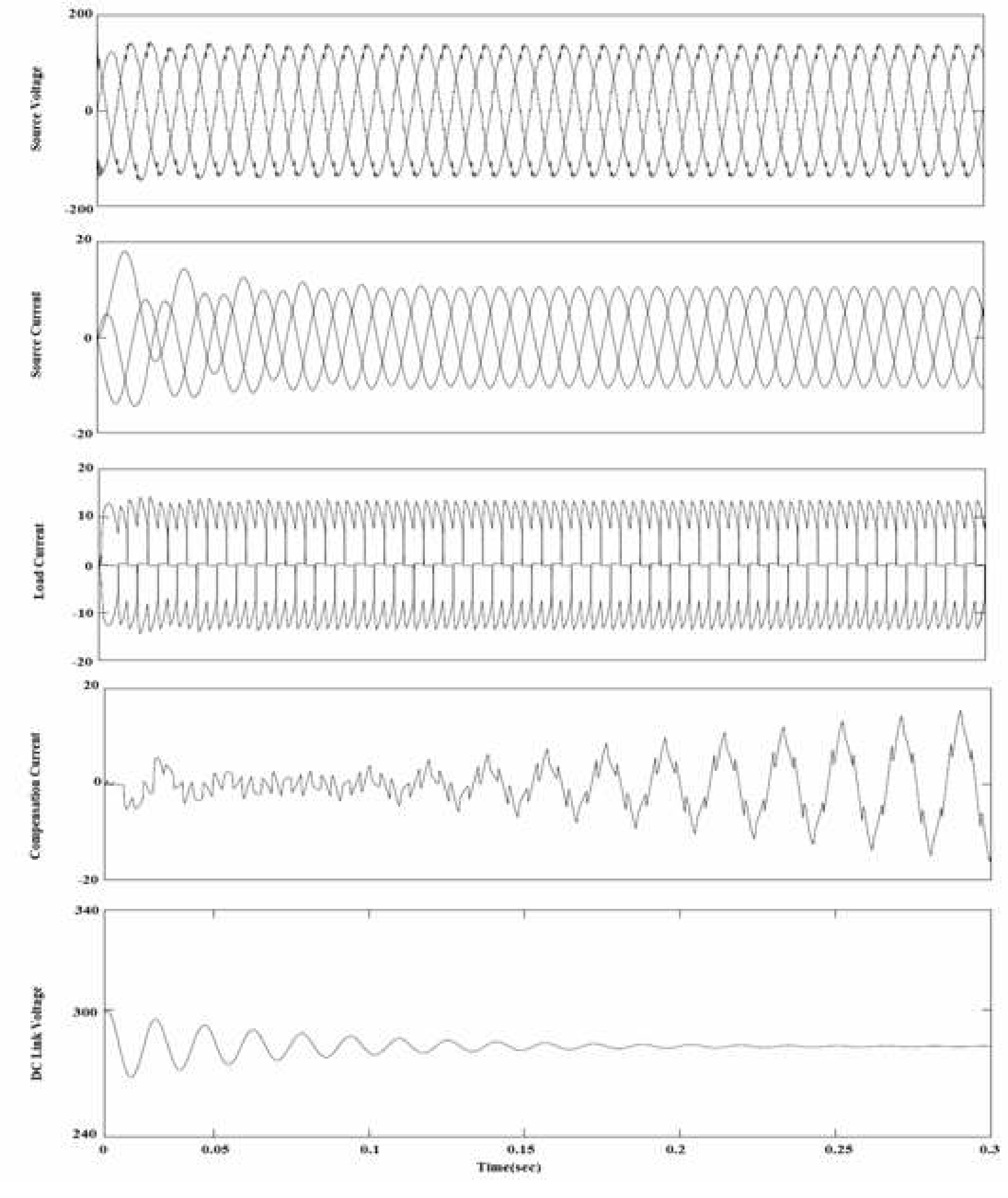

Fig. 7 Source Voltage, Source Current, Load Current, Compensation Current (Phase b) and DC Link Voltage Waveforms of Active Power Filter using Sinusoidal Current Control Strategy for Load for Balanced Supply

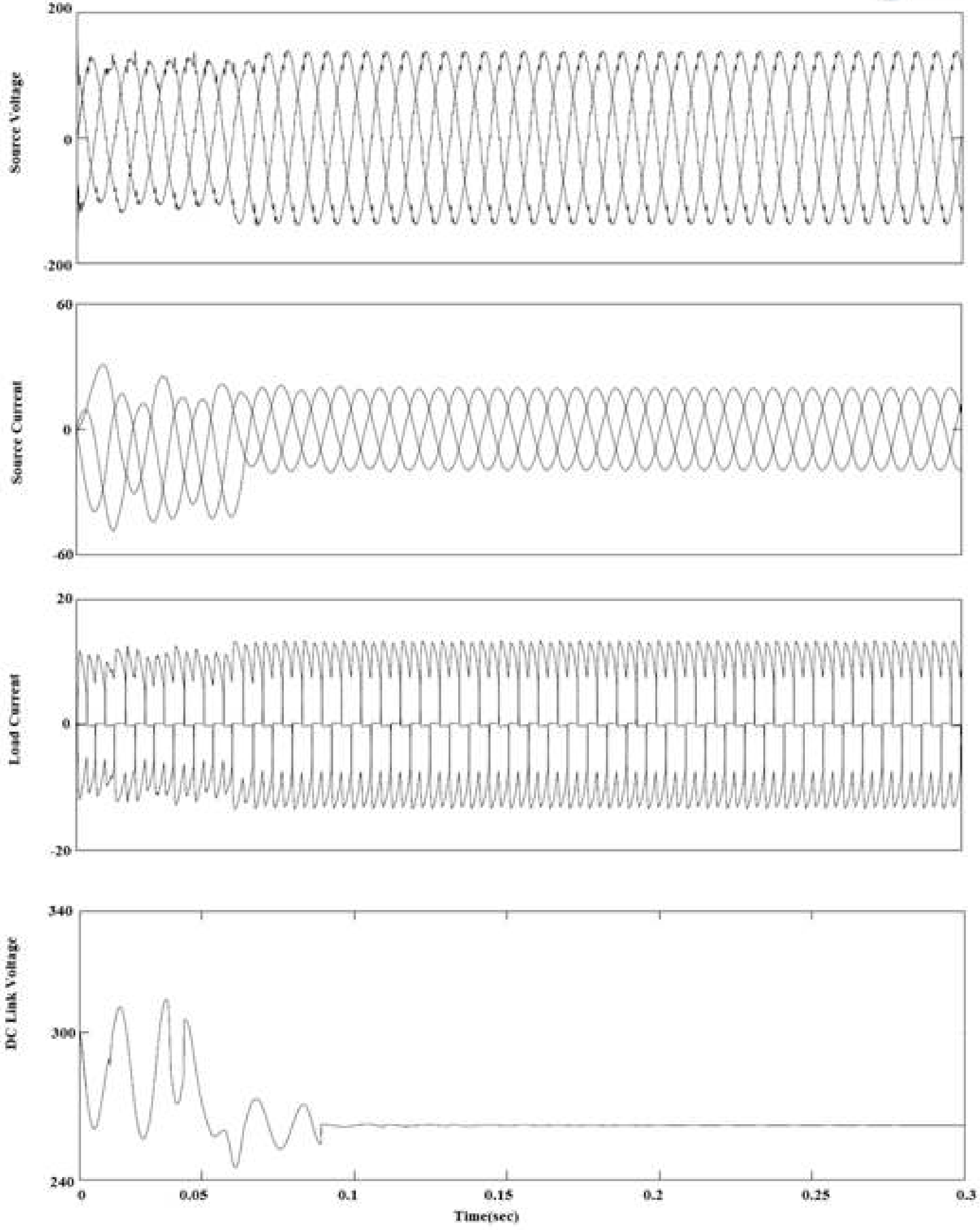

Fig. 8 Source Voltage, source current, load current and DC link Voltage waveforms of Active power filter using Sinusoidal Current Control strategy using ANN for balanced supply system

5. CONCLUSION

In this paper, one advanced artificial intelligent techniques i.e. Artificial Neural Network (ANN) has been used along with conventional Sinusoidal current control technique. The simulations load connected balanced supply have been carried out in MATLAB environment and results have been checked to be well within IEEE 519-1992 Standard. The waveforms of source are examined to be sinusoidal under load conditions. These results have validated the developed simulation model of the shunt active filter.

Following are the criteria or factors on which the exhaustive comparison has been carried out.

The total harmonic distortion (THD) for source current & source voltage have been calculated.

The compensation time i.e. the time when the THD of source current & voltage reduce and become within the IEEE 519-1992 Standard.

The results of AI techniques have revealed one fact that AI technique has been satisfactorily and successfully implemented in reducing the THD of source voltage and current during various load conditions.

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