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Implementation of Artificial Neural Network Controlled Shunt Active Power Filter for Current Harmonics Compensation

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Abstract: A pure sinusoidal voltage is a conceptual quantity produced by an ideal AC generator. The nonlinear loads cause the current to vary disproportionately and the current taken by them has a non-sinusoidal waveform. The aim of this project is to present harmonic cancellation using shunt APF with an application of neural network (NN). Shunt active power filter (SAPF) is commonly used as an effective method in compensating harmonic components in non-linear loads. This active filter concept uses power electronic equipment to produce the current components that cancel the harmonic current components from the nonlinear loads. For the extraction of sequence currents and to improve the performance, the back propagation algorithm is used. This is a multi-layer feed-forward neural network. The back propagation method is for obtaining the source currents at the fundamental frequency. The Active Power Filter reference compensation currents are then determined by subtracting the fundamental components from the load currents. Thus proposed is an algorithm for maintaining ideal phase source currents when the source voltages are amplitude-imbalanced. Hence this method can be used when the loads may be balanced/unbalanced, linear/non-linear and any distortion the source current must be sinusoidal.

Keywords: sinusoidal supply, neural network, back propagation, compensation, Point of common coupling, load

I. MOTIVATION

Modern power electronic devices such as fluorescent lamp, static power converter, arc furnace, Adjustable Speed Drives, electronic control and Switched Mode Power Supplies are drawing non-sinusoidal current which contain harmonics.

The harmonic related problem is mitigated by using active power quality conditioner. The active power quality conditioner can be connected in series or parallel and combinations of both (unified power quality conditioners) as well as hybrid configurations. The series active filter operates as a harmonic isolator and voltage regulator between the nonlinear load and distribution system. The series active filter injects voltage component in series with the supply voltage and therefore can be regarded as controlled voltage source, compensating voltage sags and swells on the distribution side. The injected harmonic voltages made the source voltage to be incremented or decremented to maintain pure sinusoidal voltage across the load. Hybrid active filter is a combination of passive and active power line conditioner. The hybrid series filter is controlled to act as harmonic isolator between the source and non-linear load by injection of controlled harmonic voltage source. Unified power quality conditioner is the integration of the series and shunt filter. The series active power filter has the capability of voltage regulation and harmonic compensation at the utility-consumer point of common coupling. For the compensation of reactive-power and negative-sequence current, the shunt active power filter absorbs current harmonics and regulate the dc link voltage between both active power line Conditioners.

Power system current harmonics are the major problems in the load side , due to presence use of non-linear loads. So the shunt active power line conditioner is an attractive choice to solve the current harmonic as well as reactive-power problems.

METHODS FOR ELIMINATION OF HARMONICS

The existence of harmonics, as informed will cause distorted current and voltage waves. There are a few techniques which can be used to eliminate Harmonic like L-C filter and Zigzag transformer. These techniques facing many disadvantage either the controller or the system such as fixed compensation, resonance, heavy weight, interference , voltage sag and flicker. There are some advantages of implementing shunt active filter on grid power system since it can be installed at housing estate or others system that using single phase grid power system.

- ✓ It is applied either near the harmonic source or at the point of the common coupling (PCC).
- ✓ The objective of SAPF is to detect the current harmonics and to cancel them, leaving the fundamental current only to be supplied by the power system.
- ✓ The power converter is controlled to generate a compensation current, which is equal but opposite the harmonic and reactive currents generated from the nonlinear load.

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✓ A voltage source inverter having IGBT switches and an energy storage capacitor on DC bus is implemented as a SAPF.

II. SHUNT ACTIVE POWER LINE CONDITIONER

Shunt active power line conditioner uses power electronics to produce complementary harmonic components that compensates the harmonic components produced by the non-linear load in the electrical system. This filter used for elimination of harmonics consists of a power converter unit and control unit, which controls the injection of the filter into the ac network based on the measured load harmonics. Therefore, this device senses voltage and current harmonics and generates offsetting harmonics to cancel out the superfluous harmonics caused by the nonlinear load in source. So in the system there should be a feedback mechanism by virtue of which the source provides clean waveforms for the load. Some of the merits of using active power line conditioner are harmonic reduction, reduction of neutral return current, Power factor improvement, regulation of Voltage, automatically adjusts to changes in the ac network and load fluctuation, resonance between filters and network impedance will be reduced.

III. APPROACH USED IN THIS PAPER

In this project, the parallel or shunt active power line conditioner configuration is chosen shown in figure (1). The parallel connection between active power line conditioner and the load at the Point of Common Coupling (PCC) is shown in Figure (1). A Pulse Width Modulation (PWM) based two-level voltage source is used for the power circuit, inverter is in use, which operates in a current control mode. For the faster response the compensation of current is performed in time domain approach (specification). The purpose is to inject the compensating current at the parallel point such that the source current becomes sinusoidal, since this shunt active power line conditioner is used for cancelling current harmonics.

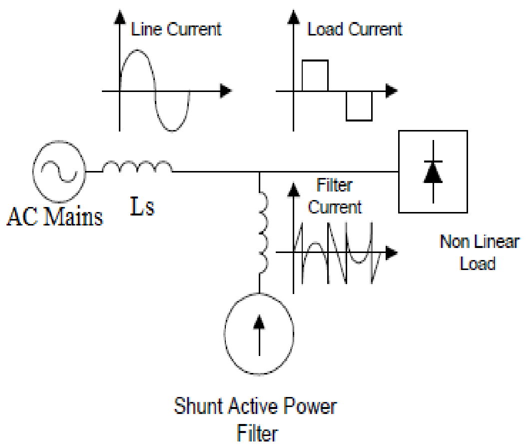

Figure 1: Schematic Diagram of Shunt Active Power Line Conditioner.

IV. NEED OF FEEDBACK MECHANISM

In this configuration, it is important to know the active power line conditioner is required to supply the compensating filter current at PCC. The active power line conditioner is required only to supply the reactive power of the load at ideal situation and hence the average dc-link capacitor voltage should be kept as constant. In practice, it is not possible as the losses of the inverter and interface inductor will make the dc charge stored in the capacitor to fall. However, it is important to keep the dc charge or voltage of the dc storage capacitor nearly constant so that the functioning of the system remains unaffected. By drawing active current from the source, the replenishment of losses through a feedback mechanism. Concerns to be meet controller

✓ To extract the required reference current, the efficient reference current extraction method is used

✓ The control strategy, taking into account transient and steady state

✓ For the power circuit, the high efficiency large capacity converter is used.

V. PROPOSED SYSTEM

This project proposes a new control strategy for single phase shunt active power filters (APFs) based on neural network is shown in figure 2. The proposed concept consists of the shunt active power filter connected to the single phase ac source. Because of power electronics load, the load taken is nonlinear load. Voltage controlled shunt active power filter is used. The gating signal for the shunt active power filter is produced by means of PWM technique. The point at which the system and shunt active power filter is connected called POINT OF COMMON COUPLING (PCC). Shunt active power filter is implemented with back propagation training algorithm as shown in Figure 6. As Back propagation algorithm performs better control under rapidly it is used to extract the load current, changing nonlinear load current. Back propagation algorithm is used as a training algorithm. It acts as a controller to produce the error signal. The gating signals of the shunt active power filter are varied to produce the compensation current in accordance with the error value. The THD value is reduced by harmonic distortion which provides better quality over the supplied power.

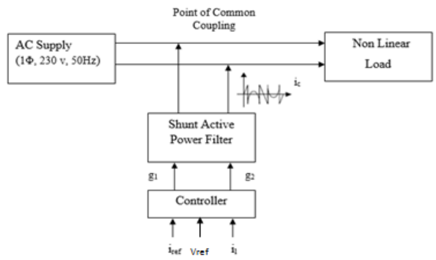

Figure 2: Block Diagram of Proposed System

The shunt active power filter is used to compensate the non linear current in the system. Since the system has to compensate one parameter so the number of input layer and output layer is one.

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So the total number of input layer and output layer is 2.
Hence the number of input layer is 2.
Calculation on weight:

Weight values = (input no*hidden layer no) + (hidden layer no*output no)
= (1*2) + (2*1)
= 4

Bias values = hidden layer number + output layer number
=2+1
=3

Total weight formula = Weight values +bias values
=4+3
=7

VI. EXISTING SYSTEM: PWM CONTROLLED SAPF

This shows the Simulink modelling of SAPF in which the gate signals are generated by the PWM controller as shown in figure 3. The PWM technique offers simplicity and good response. PWM methods offer a more flexible option but it is sensitive to the environments and easy to overload.

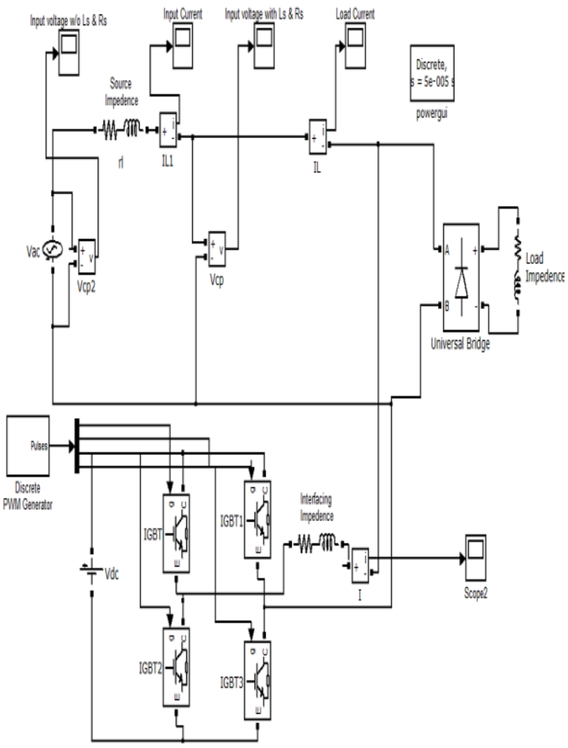

Figure 3: Simulink model of PWM controlled SAPF.

VII. RESULTS

The below figure 4 shows the waveform of source voltage (v_s) , source currents (i_s) load currents (i_L) and compensating currents (i_c) under unbalanced nonlinear loads.

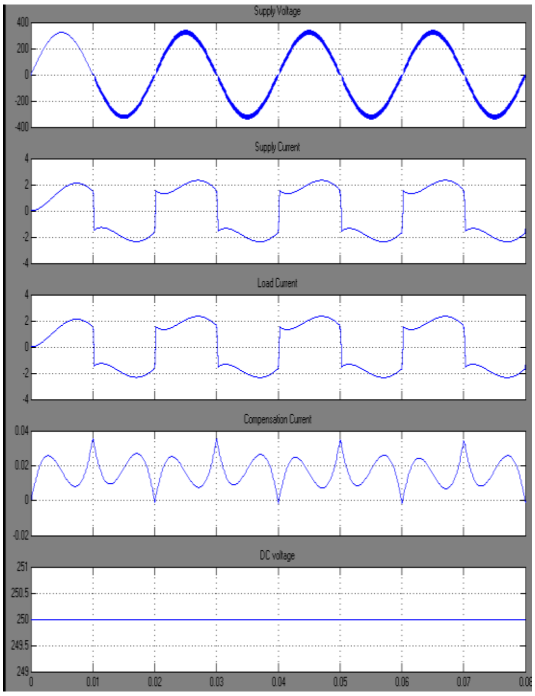

Figure 4: Performance Parameters of PWM controlled SAPF
a) V_S b)I_S c)I_L d)I_ce)V_{dc}

VIII. THD ANALYSIS:

Harmonic spectra of phase 'a' voltage at PCC (v_s), source current (i_s) and load current (i_L) are shown in figure 5 figure and figure 7 . THDs of the phase 'a' at PCC voltage, source current, load current are observed 5.99%, 35.43% and 35.41% respectively.

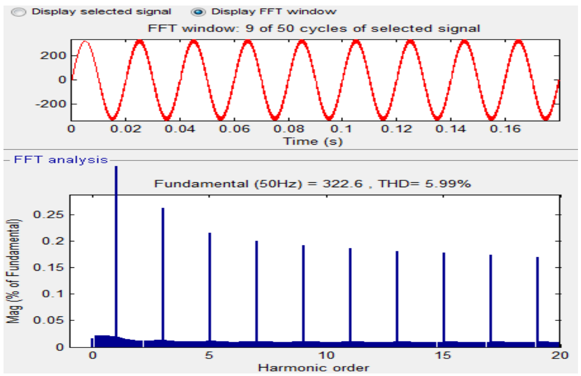

Figure 5: Waveforms and harmonic spectra for PCC voltage of SAPF with BP.

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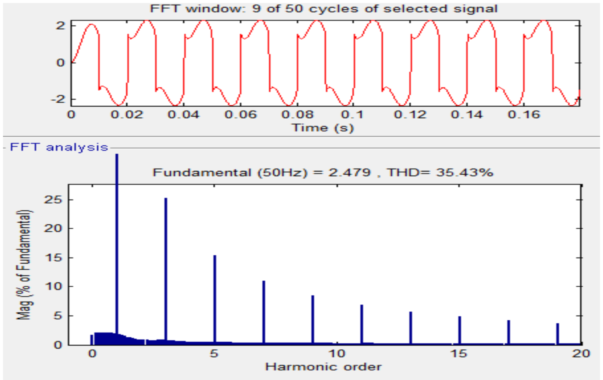

Figure 6: Waveforms and harmonic spectra for Source current of SAPF with BP

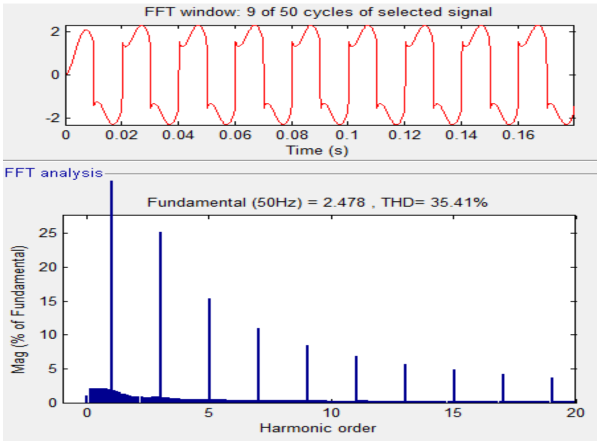

Figure 7: Waveforms and harmonic spectra for Load current of SAPF with BP

IX. PROCESS OF BACK PROPAGATON ALGORITHM

Neural subsystem for SAPF is shown in figure 8. It consists of input layer, hide layer and output layer. Back propagation also consists of weight calculation and adding of bias.

The extraction of reference and error calculation consists of two steps:

i. Angle calculation
ii. Extraction of reference current

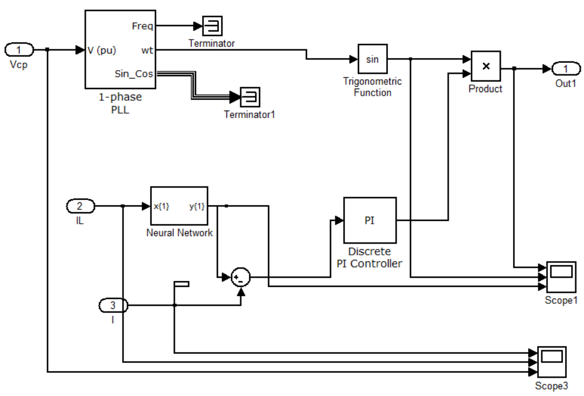

Figure 8: Simulation Diagram for Neural Subsystem.

X. ANGLE CALCULATION

The phase-locked loop is used for angle calculation. A phase-locked loop or phase lock loop (PLL) is a control system that generates an output signal whose phase is related to the phase of an input signal. The input to the PLL is REFEVCE VOLTAGE and it produces three outputs, out of which the angle of supply voltage is considered. The remaining outputs are terminated.

XI. EXTRACTION OF NEGATIVE SEQUENCE CURRENTS

For the extraction of sequence currents, a three-layer feed-forward back propagation neural network is used shown in figure 9. The name "back propagation" comes from its characteristic training method. For extraction of sequence currents, a three layer feed-forward back propagation neural network is used, it consists of five weights in layer1 with a bias and with weight bias in second layer. The transfer functions for all layers are purelin and tansig. The input and the output layer are formed as shown in figure 10.

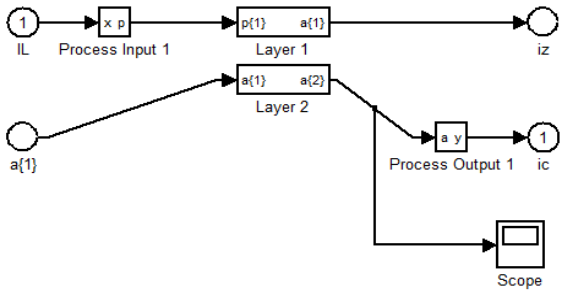

Figure 9: Simulation Diagram for Input Layer and Output Layer.

XII. TRAINING DATA GENERATION

For the extraction of sequence currents, the required inputs are reference currents, load current and the corresponding outputs. The required inputs and outputs are generated in MATLAB program. In the program the input currents are initialized to zero, and incremented in steps. By taking one thousand samples in a cycle and arranging them in a vector of three rows, outputs arranged in required vector size depends on the number of the outputs. The input vector size and output vector size must have same number of columns. The training data is generated for both balanced and unbalanced conditions. The number of data required depends on the network architecture and required error tolerance.

XIII. TRAINING THE NETWORK

The training of the network was done with MATLAB program. The training data required the number of epochs, error and mini gradient. The number of epochs depends on the error, and architecture of the network. First, the weights are initialized as a random numbers. After training the first data, the weights are adjusted to the required outputs. For both balanced and unbalanced conditions the training is done. After training, the network is simulated with trained inputs shown in figure 10. The architecture is suitable only if the network errors are within the predefined range, otherwise the network architecture must be changed. After successful training, the

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network can also give the required outputs with unknown inputs. After training, the architecture is converted to simulink block. Figure 11 shows the inside view of a layers.

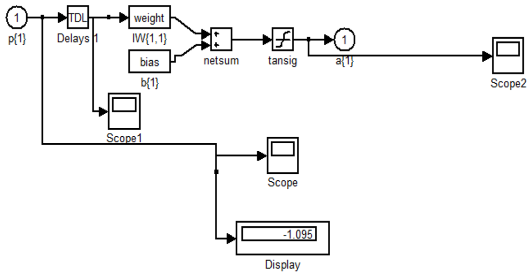

Figure 10: Overview of Simulation of Input Layer

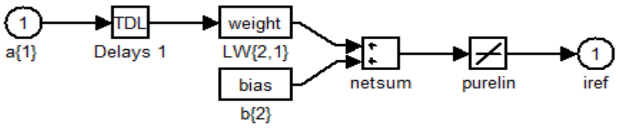

Figure 11: Overview of Simulation of Output Layer

Each neuron within the network is usually a simple processing unit which takes one or more inputs and produces an output. Every input has an associated weight which modifies the strength of each input at each neuron. Addding of all the inputs together and calculates an output to be passed on by the neuron .

In general, initial weights are randomly chosen, with typical values between -1.0 and 1.0 or -0.5 and 0.5. Initialization may bias the network to give much more importance to larger inputs.

Figure 12 and figure 13 shows the number of the neurons of a layer and weight corresponding to the SAPF.

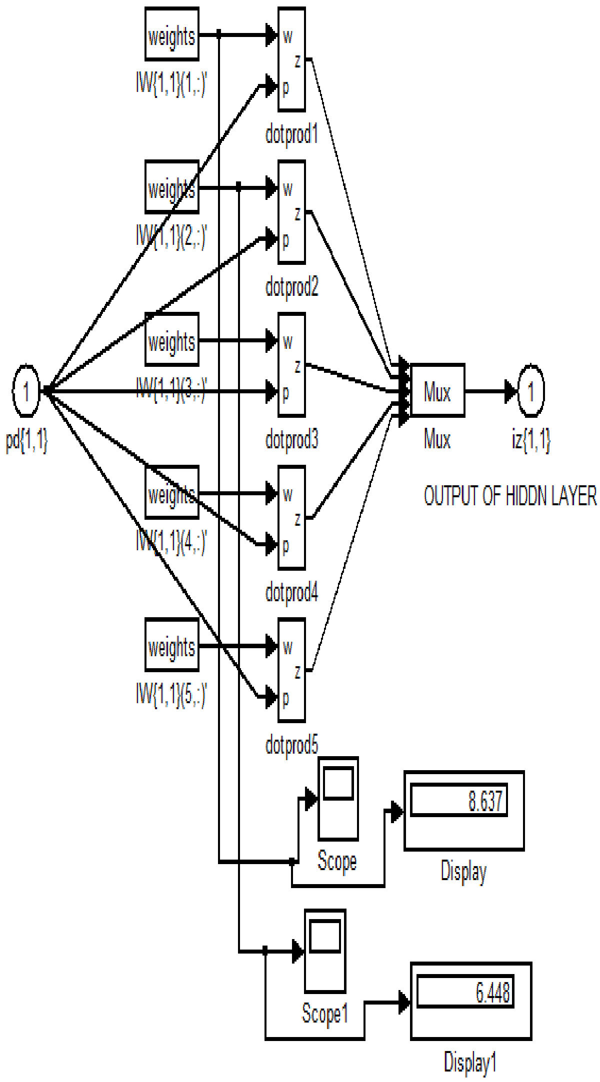

Figure 12: Simulation of Hidden Layer-1.

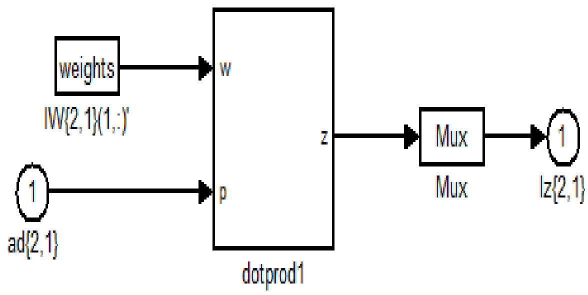

Figure 13: Simulation of Hidden Layer-2

XIV. SIMULATION MODEL OF SHUNT ACTIVE POWER FILTER

The Shunt active power filter has been developed by using MATLAB is shown in Figure 14. To operate Shunt active power filter, a single phase non linear load is used. The supply voltage is considered as 230v with source inductance.

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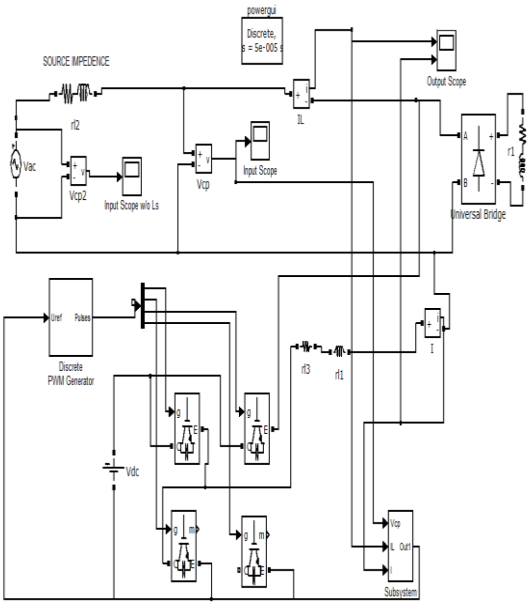

Figure 14: Simulation Model of Shunt Active Power Filter

XV. OUTPUT OF SAPF WITH BP ALGORITHM

BP ALGORITHM is used for the extraction of non linear load current. By comparing with the reference current, BP Algorithm produces the error value. According to this value, the gate signals are changed. This compensates the non linear current and reduces the low THD value. The below figure shows the waveform of source voltage (v_s), source currents (i_s) load currents (i_L) and compensating currents (i_C) under unbalanced nonlinear loads as shown in figure 15.

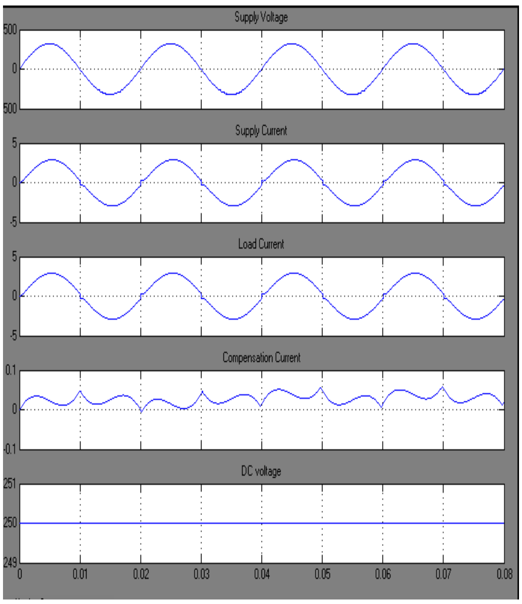

Figure 15: Performance Parameters of BP controlled SAPF a)V_S b)I_S\c)I_L d)I_ce)V_{dc}

XVI. THD ANALYSIS

Harmonic spectra of phase 'a' voltage at PCC (v_s), source current (i_s) and load current (i_L) are shown in figure. THDs of the phase 'a' at PCC voltage, source current, load current are observed 0.39%, 3.90% and 3.69% respectively shown in figure 17, figure 18,figure 19.

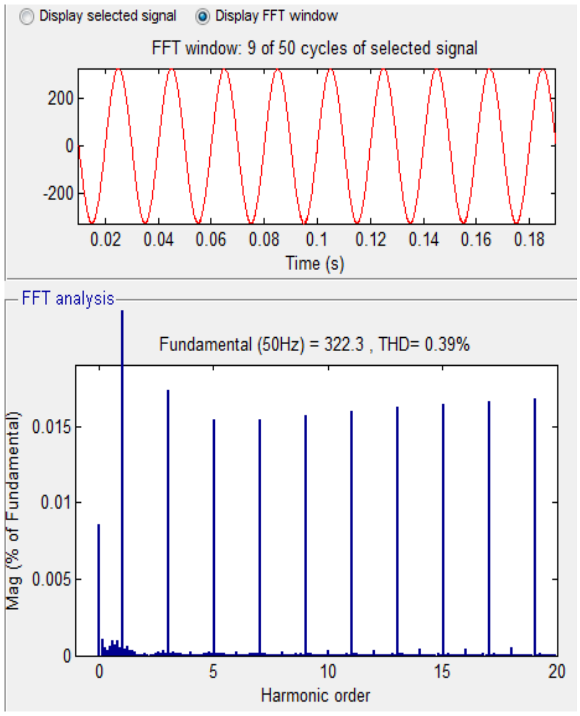

Figure 16: Waveforms and harmonic spectra for PCC voltage of SAPF with BP

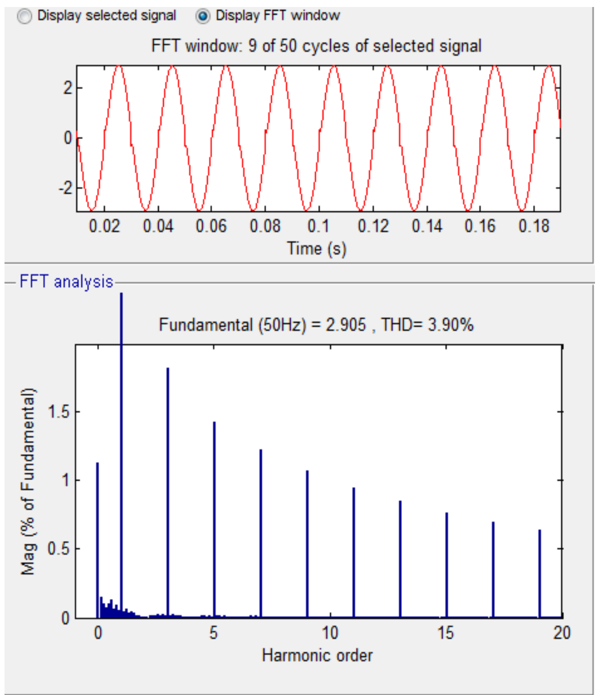

Figure 17: Waveforms and harmonic spectra for Source current of SAPF With BP

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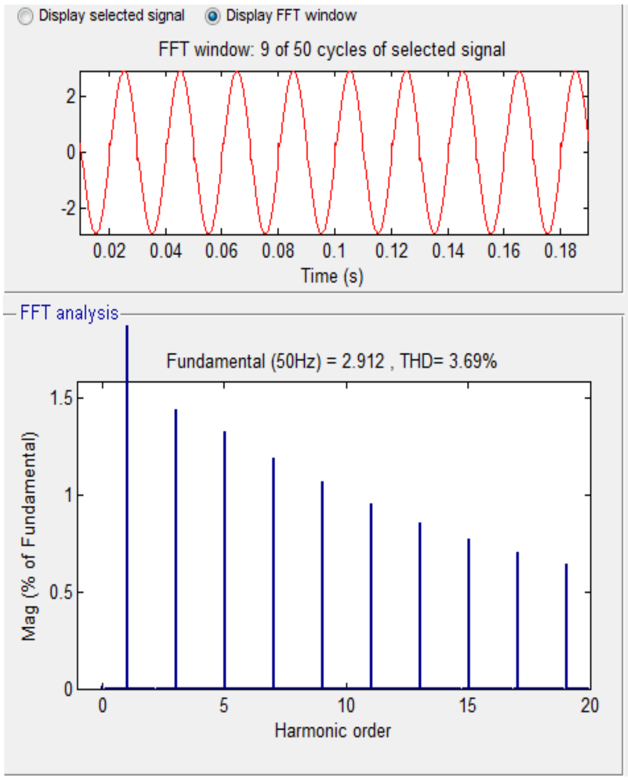

Figure 18: Waveforms and harmonic spectra for Load current of SAPF with BP

XIX.PARAMETERS USED IN SIMULATION

This table shows the parameters that are considered to simulate the PWM controlled SAPF and the Artificial Neural Network controlled SAPF.

PERFORMANCE PARAMETERS	SAPF With PWM controller	SAPF With BP controller
PCC voltage (V), %THD	5.99%	0.39%
Source current (A), % THD	35.43%	3.9%
Load current (A), % THD	35.41%	3.69%
dc bus voltage (V)	250V	250

Table 1: PARAMETERS USED IN SIMULATION

A) Analysis on the Performance of SAPF:

PARAMETERS	ANN CONTROLLED SAPF	PWM CONTROLLED SAPF
AC Supply Source, Single phase	230 V,50 HZ	230 V,50 HZ
Source Impedance	R_f =1 Ω ,L_s= 5 mH	R_f =1 Ω ,L_s= 5 mH
Non-linear: Single phase full bridge uncontrolled rectifier	R=110Ω and L= 40Mh	R=110Ω and L= 40Mh
Reference dc bus voltage	250 V	250 V
Interfacing inductor(Lf)	2.75mH	2.75mH
Phase and Frequency of PLL	*0^0, 50 Hz*	-
Gain of PI controller of PLL	k_p =180,k_i =3200, k_d=0.1	-
Gain of voltage PI controller	k_p=1, k_d =0.1	-
Learning rate (μ)	0.62	-

Table 2: Analysis on the Performance of SAPF>

XX.CONCLUSION

A pure sinusoidal voltage is a conceptual quantity produced by an ideal AC generator built with finely distributed. But the existence of harmonics, as informed will cause distorted current and voltage waves. The shunt active filter has been used to compensate a non linear current. In this report shunt active power filter was simulated using MATLAB/SIMULINK. The single-phase shunt APF for current harmonic compensation based on neural network was simulated. The output current of SAPF is altered by altering the gate signals. This gate signals are controlled by back propagation. As a result, the THD value for linear and nonlinear loads reduced.

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BIOGRAPHIES

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