A Novel ANN based Harmonics Mitigation and Monitoring Approach of Shunt Active Power Filter

M.Manimegalai, K.Sebasthirani

Abstract: ***A new approach to monitor the power quality terms like harmonics, voltage sag or swell, flicker etc., in the distributed power system using shunt active power filter (SAPF) and controlling the filter using Artificial Neural Network (ANN) has been proposed in this paper. Harmonics are identified and mitigated using MOSFET based SAPF and controlled by ANN. Power quality has been monitored in the online for the domestic electronic applications. Comparing to PI controller ANN has better performance. Performance of the proposed technique has been shown in the Simulation results based on the parameter Total Harmonic Distortion (THD). Simulation has been done in MATLAB simulink. Online Monitoring has been carried out using PHP and SQL server.***

Keywords: Shunt Active Power Filter (SAPF), Artificial Neural Network (ANN), Total Harmonic Distortion (THD), Hypertext Preprocessor (PHP), Structured Query Language (SQL).

I. INTRODUCTION

Today's demand in electricity consoled by large scale generation of electricity including power plants using fossil fuel, nuclear power plants for higher performance, hydro dams using electric power, wind farms etc. This heavy production of electricity suffers by power quality in the transmission line. "Power Quality" term defined as perfect sinusoidal noise free wave shape of power created by the electrical system, and the power should be always stable when considering voltage and frequency.

Voltage stability is the most critical issue in power quality maintenance. Stability in voltage had been corrected by regulation of power supply, which is distorted by comparing reactive power and the time constant of the excitation system. As the study in practical issue shows that how harmonics affect the power quality in negative way. PQ disturbances mainly considered based on the duration of the fluctuation occurs in the system.

PQ issues generated when emission by newly entered equipments, interaction between equipments and power carrier line communication, devices immunity and weakening of transmission grid. These issues can be solved by following steps,

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- Continuous monitoring
- Detection and identification of issue
- Find out causes
- Prevention and correction of causes.

PQ can be monitored in two ways,

- Local Monitoring
- System Monitoring

Local monitoring concentrates on the single customer power quality whereas system monitoring done on the electrical system globally. There are many methods can be used to monitor the power quality like, phasor measurement sensor to capture the incorrect behaviors across interconnected power systems, wide area monitoring system (WAMS) , generation capacity as Spinning Reserve(SR), use of Zigbee communication protocol. These methods are affected by real time issues like, rain, thunder, starting of system with heavy load etc. In order to maintain the system with real time problems, online power quality monitoring will be proposed. In this method any user of the particular home can enter and login into system, and can see how much electricity passed into the appliances if any deviation or harmonics present, it will automatically trigger the AHM system for the compensation of the harmonics. User will get a alert message that there is a problem in power quality.

Sources affecting quality of power given below in the following diagram,

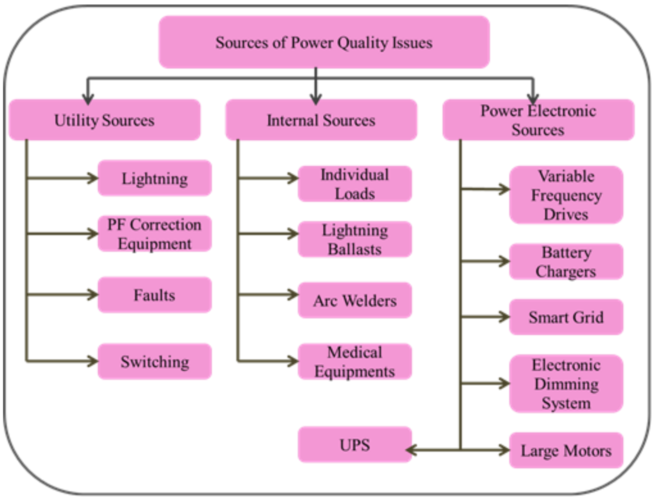

Fig. 1 Causes of Problems Affecting Power Quality

Evaluation of quality of power problems was shown in figure 2.

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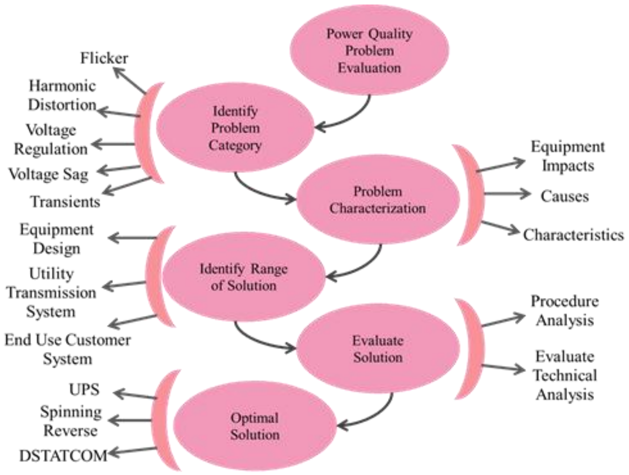

Fig. 2 Flow chart for evaluating issues of power quality

Classification of power quality problems according to IEEE standard shown in following figure,

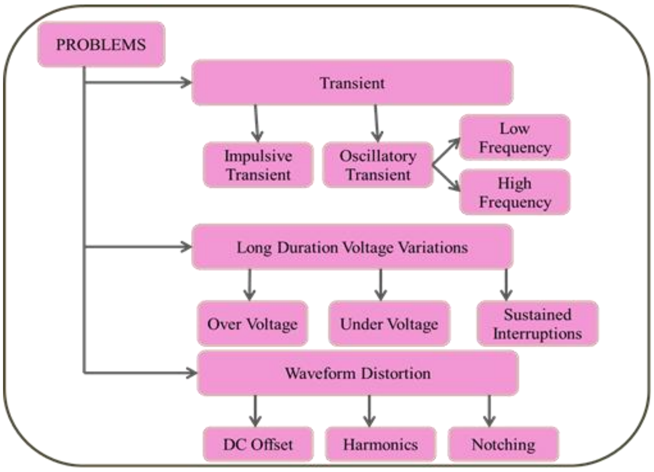

Fig. 3 Classification of Power Quality Issues

Proposed system has following sections for real time monitoring,

1. Three phase source voltage given as input.
2. Using Active Power Filter for the generation of current to compensate harmonics.
3. Controlling the inverter operations using ANN
4. Monitor the power quality through website

Flow of proposed system shown in following figure,

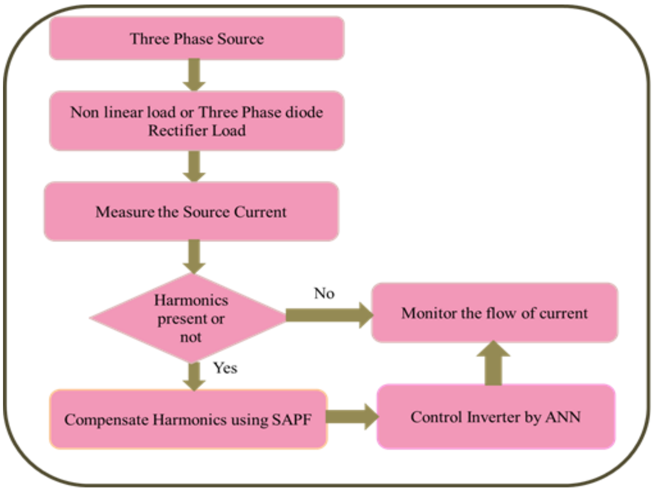

Fig. 4 Proposed system flow diagram

Let us see detailed description of these modules in following sections.

II. MONITORING POWER QUALITY

Harmonic in power flow described as waveform distortion caused by nonlinear loads. Variation of frequency of power is defined as fluctuation in the fundamental frequency of electrical system from the required normal value between 50 Hz to 60 Hz.

If $\quad f = nf_{fund}$ (1)

This may belongs to dc if the value will be,

$f = 0$ (2)

This is called inter harmonic distortion if it will be,

$f = nf_{fund}$ (3)

And finally, this can be sub harmonic if the values between,

$f > 0$ and $f < nf_{fund}$ (4)

Where, n will be positive integer, f is frequency, f_{fund} = fundamental frequency of electrical system. Harmonics are based on the distortion in the frequency which is represented in the form of waveform.

III. HARMONIC MITIGATION USING SAPF

Harmonics are mitigated by Active Power Filter in shunt mode which can be controlled by Artificial Neural Network (ANN). There are three types of filters for the purpose of harmonic mitigation, active, passive and hybrid filters. Among three, active power filter in shunt mode effectively eliminate the harmonic, by production of compensation in current, which is equal in magnitude but opposite direction to the harmonics. And it won't affect the stability of power system. Shunt active power filter designed by the static compensator (STATCOM), compensation of reactive power can be achieved by the STATCOM. Following figure shown the basic principle of active power filter,

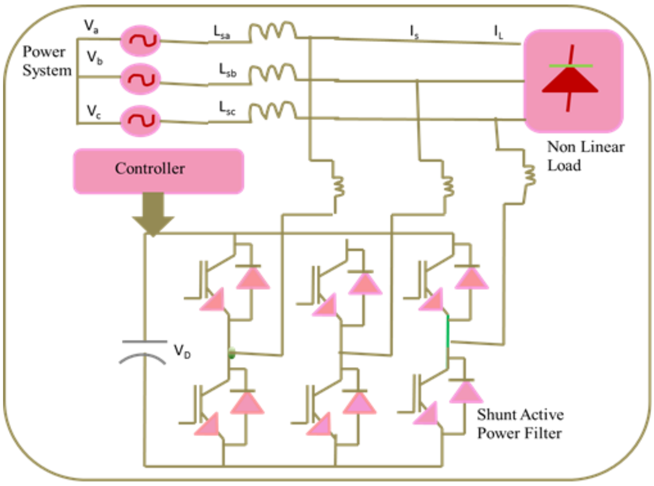

Fig. 5 Topology of Active Power Filter in Shunt Mode

The non linear current passed in three phase, expressed as follows,

$$i_L(t) = i_{\alpha 1}(t) + i_{\beta 1}(t) + i_{hL}(t) \quad (5)$$

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Here $i_{\alpha 1}(t)$, $i_{\beta 1}(t)$ is the fundamental frequency in phase current. The harmonics are represented by the i_{hL} . If the system in three phases and three wires, without neutral, the sequence zero components can't exist.

The voltage passed in source and load current of single phase can be expressed in following equations,

$$V_s(t) = V_m \cos\omega_s t \tag{6}$$

$$I_{\alpha 1}(t) = I_{\alpha 1} \cos\omega_s t \tag{7}$$

The compensating current given by shunt active power filter is given as,

$$i_c(t) = i_L(t) - i_{\alpha 1}(t) = i_L(t) - I_{\alpha 1} \cos\omega_s t \tag{8}$$

By calculation of $i_{\alpha 1}(t)$ and $i_L(t)$, by current sensors compensation current can be easily calculated by the equation 4.

IV. ARTIFICIAL NEURAL NETWORKS

In proposed method, shunt active power filter is stabilized using ANN by back propagation algorithm. ANN is defined as the artificial neurons which simulates biological brain system. Basic principle shown in the following figure,

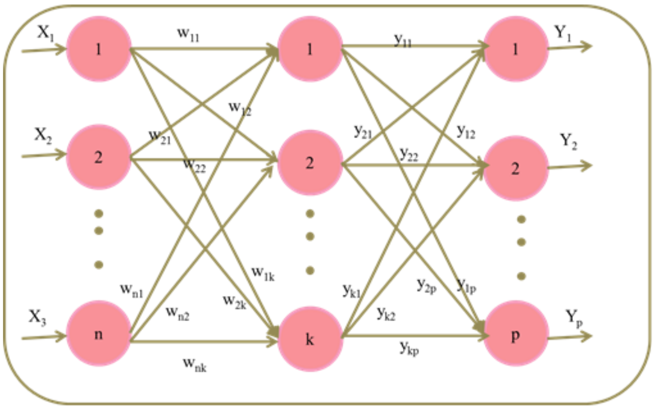

Fig. 6 Multilayer Artificial Neural Network

There are many techniques have been used for controlling SAPF, within that ANN has the advantages as approximate function mapping, high degree of fault tolerance with less computation cost.

In the control strategy, DC capacitor was monitored and referred with the reference value. The given diagram shows the working principal of Shunt active power filter with ANN controller.

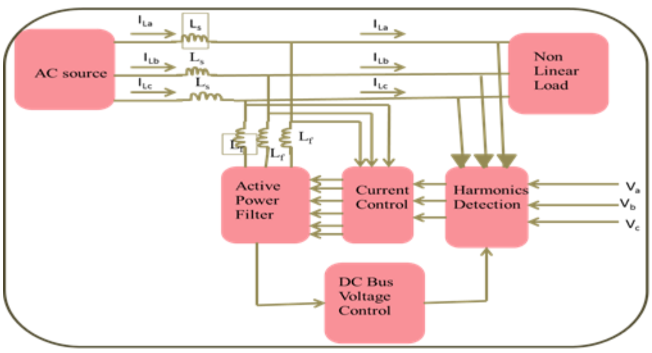

Fig. 7 Closed ANN Controlled Shunt Active Filter

Input vector in the ANN expressed by the equation and is given to the state exchanger.

$$u = [\, V_{dc}^{*} V_{dc} \,]^T \tag{9}$$

Two states are generated by the generator block, X_1 and X_2 as follows,

$$X_1 = V_e(k) \qquad X_2 = {}^{\delta X_1}/_{\delta k} \tag{10}$$

Where $V_e(k) = V_{dc}^{*} - V_{dc}(k)$ and z(k) is the output error represented as,

$$z(k) = V_0(k) - V_0(k-1) \tag{11}$$

The output $V_0(k)$ is fed back to the output state to estimate $I_{\alpha 1}$.

Controlling signal is generated by the Neuron cells through interrelated gathering as,

$$u(k) = u(k-1)\sum_{i=1}^{2} W_i(k) x_i(k) \tag{12}$$

Here W_i is the weight of the system. Neuron at k^{th} instant gained by training neuron using hebb's rule [11], is given as follows,

$$W_i(k+1) = (1-c)W_i(k) + \eta r_i(k) \tag{13}$$

$$r_i(k) = z(k)u(k)x_i(k) \tag{14}$$

Here

r_i - Progressive signal

η – Hebb's studying ratio

c- Constant

Substituting (9) and (10) to the equation (8), then

$$\Delta W_i(k) i(k) = W_i(k+1) - W_i(k) \tag{15}$$

$$= -c[\, W_i(k) - \eta z(k)u(k)x_i(k) /c \tag{16}$$

Weight at the k^{th} step is given in $\Delta W_i(k)$. Based on the Hebbs assumption, weights of the neurons are tuned. Weights are represented by,

$$W_1(k+1) = W_1(k) + \eta I^z(k) + x_1(k) \tag{17}$$

$$W_2(k+1) = W_2(k) + \eta I^z(k) + x_2(k) \tag{18}$$

Estimation of the compensating current done by the, control parameters whenever the ANN[12], starts working. These control parameters are initialized by the offline training of ANN.

Working of ANN shown as flowchart given below,

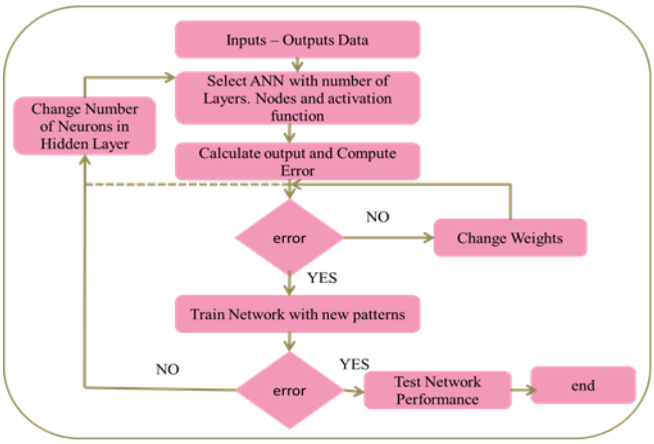

Fig. 8 Flowchart for training ANN's Controller

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For fine tuning neural network and back propagation algorithm is used. This algorithm explained in the next section.

V. BACK PROPAGATION ALGORITHMS

Neural network in the feed forward manner in multiple layers was trained by the back propagation algorithm, for the input patterns with known classifications [13]. For the given input pattern output response calculated, this response will be compared to the known output value and the error value [14], was estimated. The calculated error is called as mean square error [15].

Steps involved in the error calculation of back propagation algorithm is explained in the below figure.

Step 1: Initializing the weights into random values.
Step 2: Pass input values into the first layer
Step 3: Find output from the neuron using

$$Y_{ij} = f\left(\sum_{k=1}^{N_{j-1}} Y_{(j-1)k} W_{ijk}\right)$$

Step 4: Calculate error value by

$$\delta_{ij} = Y_{ij}\left(1 - Y_{ji}\right)\sum_{k=1}^{N_{j+1}} \delta_{(j+1)k} W_{(j+1)ki}$$

Step 5: Based on the error value calculated weight adjusted from kth neuron in layer (i-1) to every neuron in layer i

Finally root mean square value error is estimated as

$$E_p = \frac{1}{2}\sum_{j=1}^{N_M}\left(T_{pj} - O_{pj}\right)^2 \qquad (19)$$

By comparing the error find out in the back propagation algorithm, the current generated for compensation in the shunt active power filter is corrected and harmonics was compensated.

VI. RESULTS AND DISCUSSION

In a three phase voltage system with the voltage of 440 V simulated for the implementation of proposed system. An active filter with shunt mode was designed and experimented in MATLAB/SIMULINK. Table 1 shows the specified simulation parameters with balanced load. Non linear load specified by diode rectifier feeding R-L load. Simulated system shown in Figure 9.System is controlled by ANN. Supply voltage considered 440v with source inductance.

Table. 1Simulation Parameters

Parameters	Value
Sending end voltage	440 Vrms
Filter inductor	1mH
Load impedance	R=1Ω ,L=35mH
DC Link Voltage	304.4V
DC link Capacitor(C)	2200µF
Carrier Frequency	10KHz

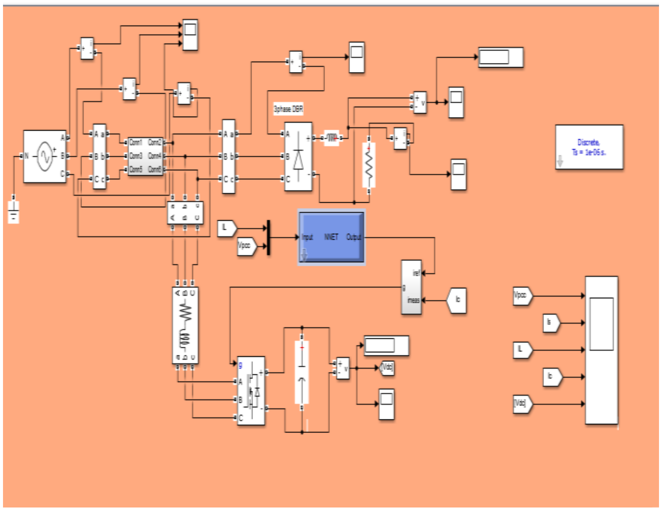

Fig. 9 Three phase ANN controlled Shunt active power filter

ANN subsystem given in following figure,

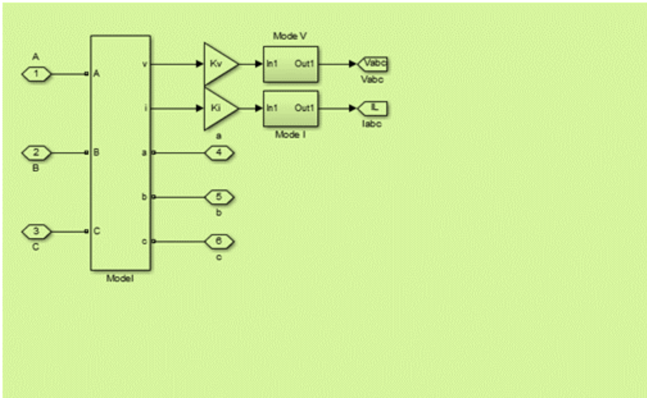

Fig. 10 ANN Subsystem

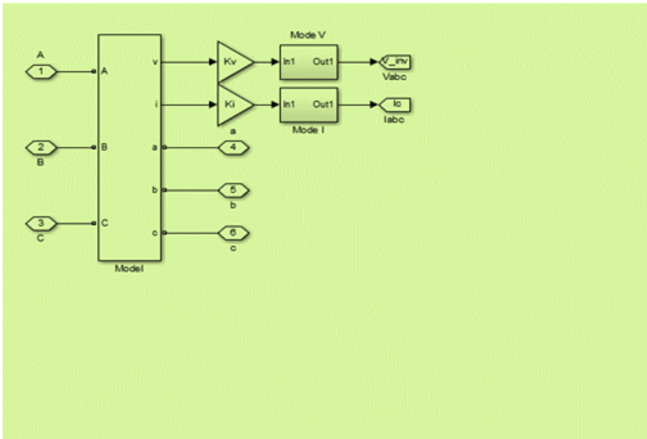

Fig. 11 Phase Measurement of V - I

Input source current represented in the following figure as waveform. Source voltage, Load current, current to compensate harmonics in opposite direction and DC link voltage represented in subsequent figures.

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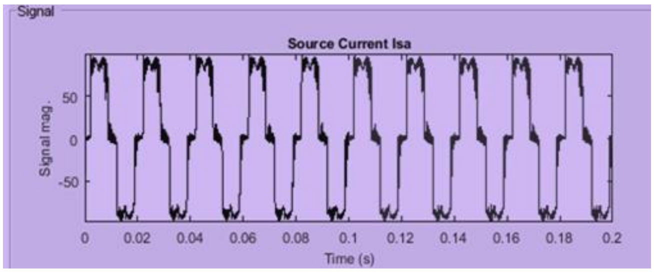

Fig. 12 Source Current Isa before Compensation

The value of Total Harmonic Distortion (THD) of source current before compensation was high, comparing to before the applying active power filter.

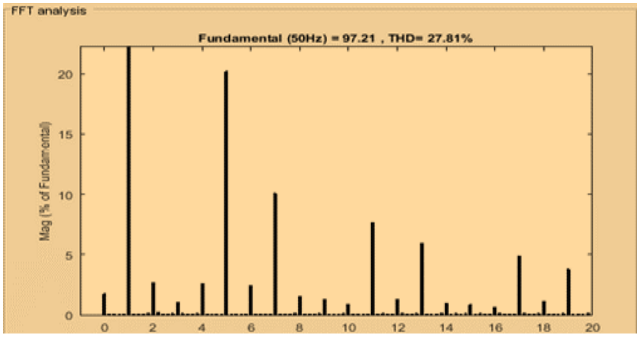

Fig. 13 THD of Source Current Isa before Compensation

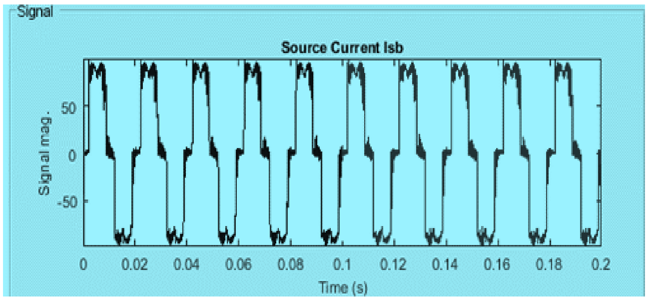

Fig. 14 Source Current Isb before Compensation

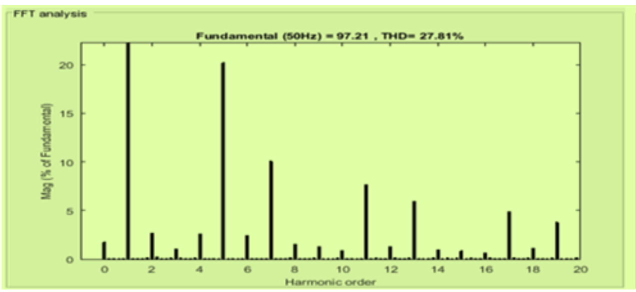

Fig. 15 THD of Source Current Isb before Compensation

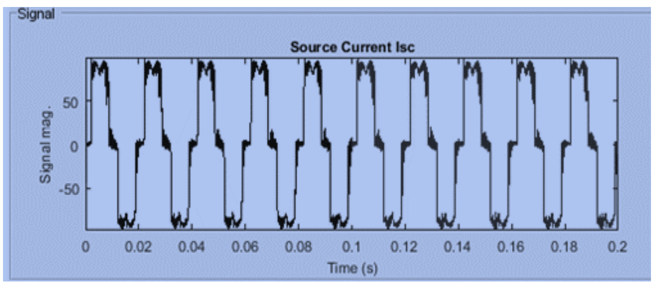

Fig. 16 Source Current Isc before Compensation

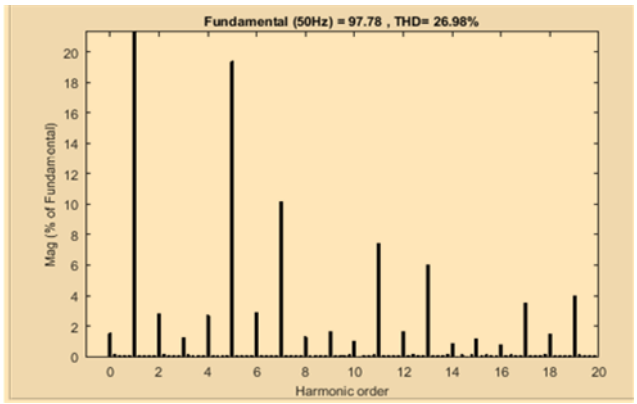

Fig. 17 THD of Source Current Isc before Compensation

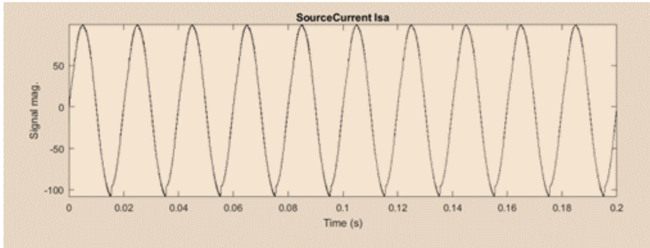

Fig. 18a Source Current Isa after Compensation

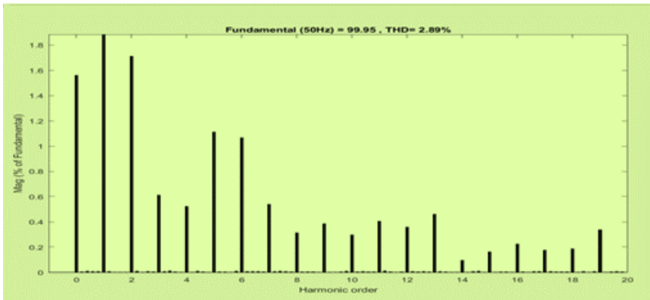

Fig. 19a THD of Source Current Isa after Compensation

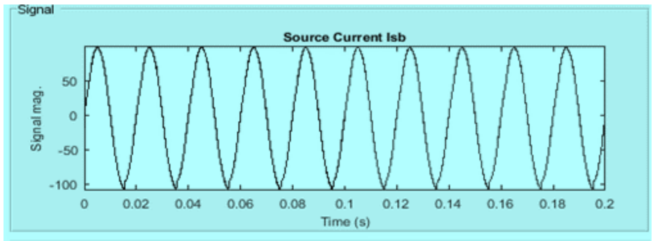

Fig. 18b Source Current Isb after Compensation

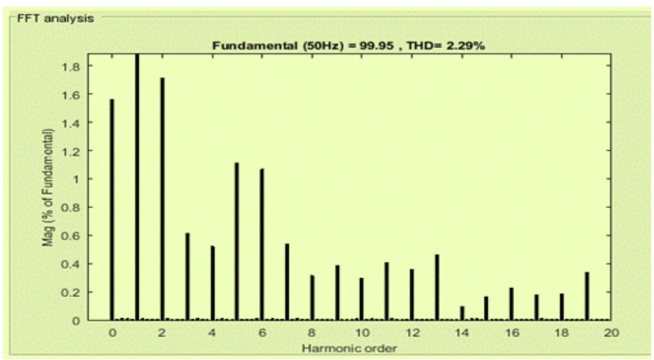

Fig. 19b THD of Source Current Isb after Compensation

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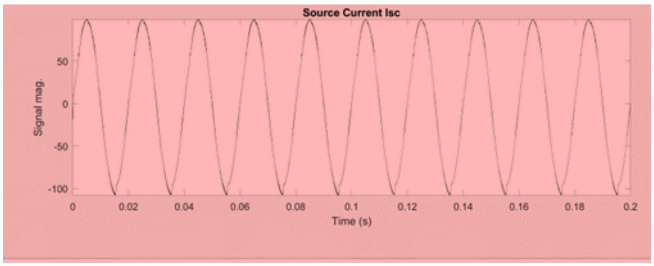


Fig. 20 Source Current Isc after Compensation

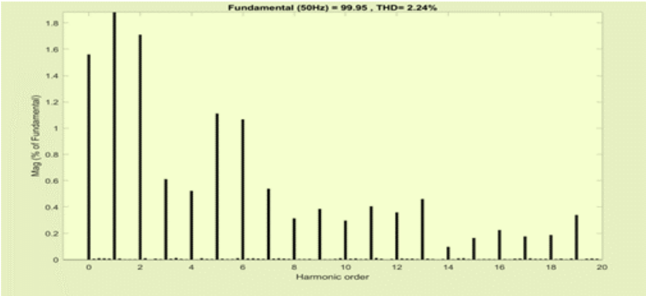


Fig. 21 THD of Source Current Isc after Compensation

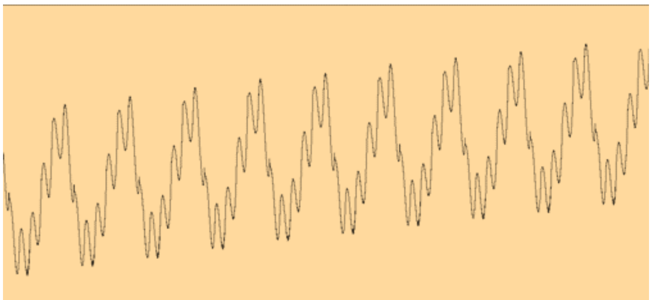
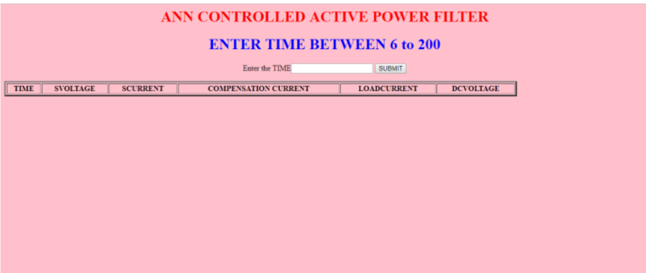


Fig. 22 DcLinkVoltage

Monitoring the power quality, the web page was created by PHP language. Information generated in the simulation was stored in the SQL server. Using PHP required data will be retrieved.



ANN CONTROLLED ACTIVE POWER FILTER

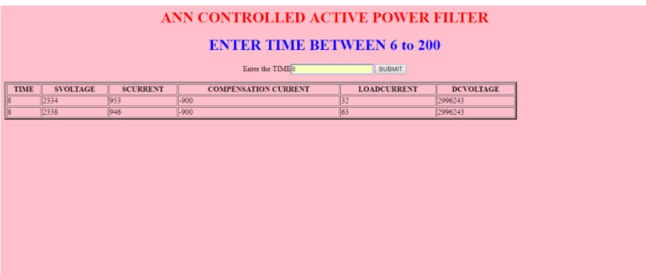
ENTER TIME BETWEEN 6 to 200

Enter the TIME SUBMIT

TIME	SVOLTAGE	SCURRENT	COMPENSATION CURRENT	LOADCURRENT	DCVOLTAGE

Fig. 23 Homepage of WAMP server

User need to enter the required time information in the specified field, corresponding signal information displayed in the table format.



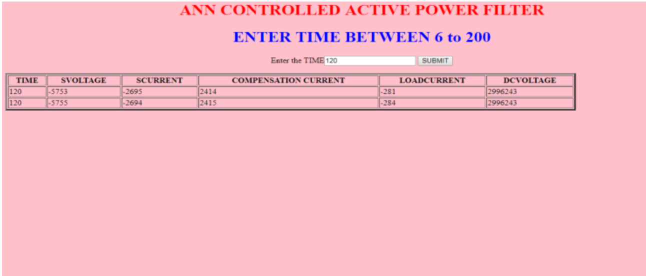
ANN CONTROLLED ACTIVE POWER FILTER

ENTER TIME BETWEEN 6 to 200

Enter the TIME 8 SUBMIT

TIME	SVOLTAGE	SCURRENT	COMPENSATION CURRENT	LOADCURRENT	DCVOLTAGE
8	2334	953	-900	32	2996243
8	2338	946	-900	63	2996243

Fig. 24.1 Extracting signal information from database



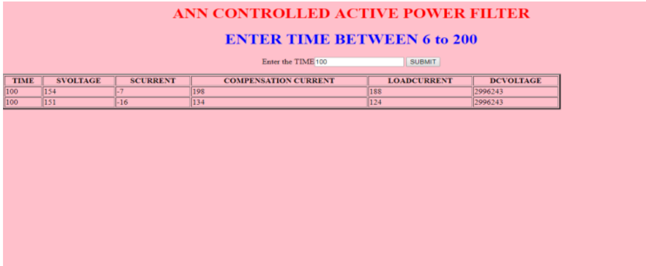
ANN CONTROLLED ACTIVE POWER FILTER

ENTER TIME BETWEEN 6 to 200

Enter the TIME 120 SUBMIT

TIME	SVOLTAGE	SCURRENT	COMPENSATION CURRENT	LOADCURRENT	DCVOLTAGE
120	-5753	-2695	2414	-281	2996243
120	-5755	-2694	2415	-284	2996243

Fig. 24.2 Extracting signal information from database when time = 120



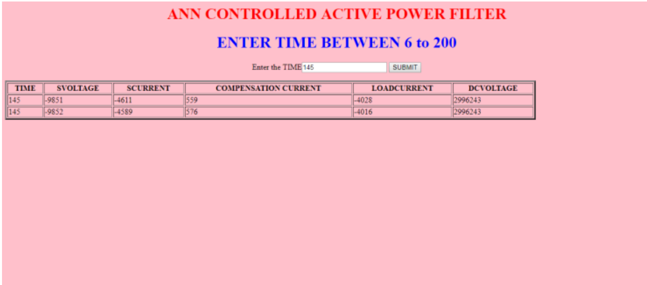
ANN CONTROLLED ACTIVE POWER FILTER

ENTER TIME BETWEEN 6 to 200

Enter the TIME 100 SUBMIT

TIME	SVOLTAGE	SCURRENT	COMPENSATION CURRENT	LOADCURRENT	DCVOLTAGE
100	154	-7	198	188	2996243
100	151	-16	134	124	2996243

Fig. 24.3 Extracting signal information from database when time =100



ANN CONTROLLED ACTIVE POWER FILTER

ENTER TIME BETWEEN 6 to 200

Enter the TIME 145 SUBMIT

TIME	SVOLTAGE	SCURRENT	COMPENSATION CURRENT	LOADCURRENT	DCVOLTAGE
145	-9851	-4611	559	-4028	2996243
145	-9852	-4589	576	-4016	2996243

Fig. 24.4 Extracting signal information from database when time =145

Using this proposed method, the power quality will be monitored at anytime from anywhere by the user.

VII. CONCLUSION

Active power filter to mitigate harmonics, by injecting current in equal magnitude and opposite direction was simulated and performance can be evaluated. Main purpose of this proposed method lies in the controller using ANN which is used to determine source current referred by APF system. The proposed method also handles design and controlling of APF system. The performance of proposed system evaluated, by comparing ANN with fuzzy logic controller. The ANN controller can be used to eliminate the complicated calculations proposed in this system which is observed. The proposed method implemented in the MATLAB Simulink software. The shunt active power filter controlled by Artificial Neural Network has a better performance to the ANN controller in steady state except one thing which is settling time that is very less in the fuzzy controller. In future work, the system performance compared with the controller using fuzzy logic by reducing the settling time.

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