ISSN PRINT 2319 1775 Online 2320 7876

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Shunt active Power Filter Performance Evaluation Using Artificial Neural Networks

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ABSTRACT: In order to reduce the harmonics of the distribution system, this research examines a 3-, 3-wire ShuntActive Power Filter (SAPF) with smart controllers based on Artificial Neural Networks (ANN). A feed forward-type (trained by a back propagation method) ANN-based is built in order to enhance the performance of the traditional controller based on hysteresis controller and benefit from smart controllers. The suggested method primarily relies on the capacitor energy concept to maintain the DC link voltage of a shunt connected filter and, as a result, shortens the transient reaction time when the load abruptly changes. The proposed control method is often suitable for any other active filters of any kind.

The suggested scheme's complete power system block set model was created in the MATLAB environment. Simulated actions are taken By utilising MATLAB, it is seen that the ANN driven filter reduces the%THD from 29. 71% to 2. 27%. The results of the simulated experiments also demonstrate the effectiveness of the innovative control approach in minimising harmonics, in addition to how simple it is to compute and use.

KEYWARDS: Shunt Active Power Filter, Total Harmonic Distortion (THD), Nueral Network Controller, Distribution System.

INTRODUCTION

The AC power system has seen many challenges concerning reactive power and unbalance from the very basic. It has devolved with the increased role of power electronic solid-state converters as some of these converters not only enhance reactive currents, but also produce harmonics in the source current [1]. These power electronic converters are operated in variable frequency AC motor drives, large power supplies, standby inverters and UPS, battery chargers, etc., which produce harmonics with large harmonic spectra. The current quality problem aggravates under unbalance. The increased reactive power, harmonics, and imbalance cause an addition in instability, voltage distortion and line losses when harmonics travel upstream and generate drop across the

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impedance, which subverts the power system. Different compensation solutions, e. g., passive filter, active power, and filter have been recommended and applied [2]. Conventionally, shunt passive filers are used to eliminate the specified harmonics but their application provides limited-fixed reactive power compensation [3]. Furthermore, passive filters do not offer any solution for unbalance, and variable reactive power compensation. Since these passive filters are designed for a set of loads with no probabilities of their design up gradation, their application provides fixed compensation, and it may create resonance thereby amplifying the current at certain harmonic frequencies [4]. The suitable solution for all the above-mentioned problems can be seen by a shunt APF [5]. Recent technological developments of switching devices and availability of inexpensive controlling devices, e. g., DSP-field-programmable-gate-array-centered system, accomplish an active power line conditioner, a natural option to compensate for harmonics [6].

The dynamic performance of an active power filter is largely dependent on how quickly and how exactly the harmonic components are extracted from the load current [7]. Several harmonic extraction methodologies are available, and their reactions have been discovered. Suggested methods include traditional $d-q$ and $p-q$ theory-based methodologies and application of adaptive filters, wavelet, genetic algorithm (GA), artificial neural network (ANN), and so forth, for quick assessment of the compensating current [8].

A Large number of modern methodologies have developed, offering solutions to several challenging control problems in industry and manufacturing areas. Unlike their conventional counterparts, these intelligent controllers can learn, remember, and make conclusions. Artificial-intelligence (AI) methods, particularly the Neural Networks, are having a major impact on power electronics applications. Neural- network-based controllers offer rapid dynamic response in order to maintain the stability of the converter system over a wide operating range and are counted as a novel instrument to design control circuits for Power Quality devices. The main objective of designing the controller for the SAPF for effective control, obtain the reliable control algorithms, and quicker response to create the output signals.

The article is primarily focused on a system which uses the ANN system and the results for the same are discussed. In this paper, a shunt APF with a hysteresis band control is utilized to compensate the non-linear loads.

CONFIGURATION OF SHUNT ACTIVE POWER FILTER(SAPF) AND ESTIMATION OF COMPENSATING CURRENT

Fig. 1 shows a shunt active power filter, it consists of the 3-phase source, universal bridge, load along with active filters. A SAPF is to produce the compensation current. The non-linear load is the sum of source current and the harmonic current. Objective is to get the balanced supply current without harmonic and reactive components. The suitable current is injected by the SAPF corresponding to the load current. The SAPF is designed with ANN controller. The proposed controller accounts for THD and DC voltage control, the controller have rapid dynamic response in case of load current deviation. The proper operation of the controller results in the generation of gate signals for 3-phase inverter which in turn is responsible for generating compensating currents. These compensating currents on injection through the 3-phase inverter results in harmonic compensation of source currents and improvement of power quality on the connected power system [9].

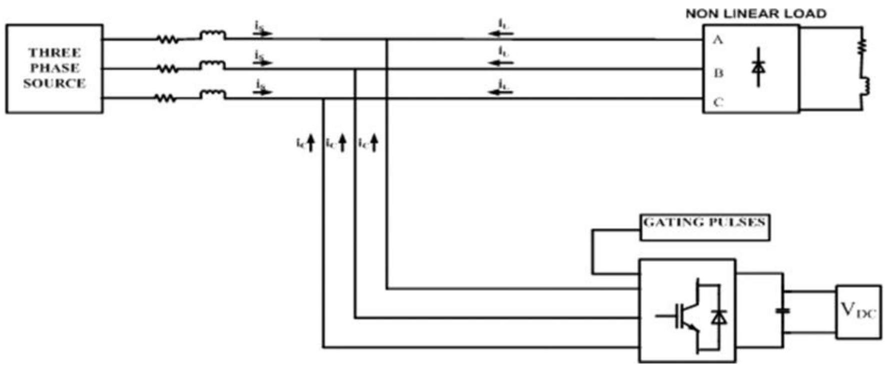

Fig. 1: Configuration of Shunt Active Power Filter

Design of ANN Controller

An Artificial neural network (ANN) is a model (mathematical) inspired by biological neural networks. An ANN consists of an interlinked collection of artificial neurons, and it develops information using a connectionist method to calculation. It resembles the brain in two facts: 1) The data is accumulated by the network through the learning process and 2) Interneuron connection strengths are employed to store the data. These networks are categorized by their topology, the manner in which they communicate with their surroundings, the manner in which they are guided, and their capability to process information. ANNs are applied to solve artificial intelligence problems without necessarily creating a model of a real dynamic system.

The rapid spotting of the disturbance signal with high accuracy, fast processing of the reference signal, and high dynamic response of the controller are the prime prerequisites for desired compensation in case of APF. The conventional controller fails to achieve satisfactorily under parameter variations nonlinearity load disturbance, and so forth.

For improving the performance of the suggested Shunt Active Power filter, a single layer feed forward network (trained by the back propagation algorithm) is seen. This network consists of two layers and their corresponding neuron interconnections. ‘2’ neurons in input layer to receive the inputs. The hidden layer comprises of 21 neurons to which each of the processed input is fed. The output layer comprises of ‘1’ neuron whose output is to be calculated as reference current. Activation functions are assigned for each of the layers to train them. The input layer is given the Tan- Sigmoidal function as activation function and the output layer is being given the Pos- Linear activation function as activation function.

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Fig. 2 shows the internal blocks of proposed neural network [9]. The large data of the DC-link voltage for 'n' and 'n-1' intervals from the conventional method are gathered and are stored in the MATLAB workspace. This data is used for training the ANN. The data stored in workspace is being retrieved using the training algorithm used. The neurons in the input and output layers are almost a fixed quantity to obtain the provided input. The accuracy of the ANN operation mostly depends on the number of hidden neurons.

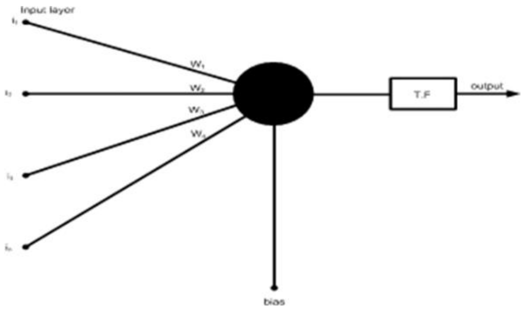

Fig. 2: Internal blocks of proposed neural network

B. 1. Algorithm for ANN:

Step 1: Normalize the inputs and outputs with respect to their maximum values. It is shown that the neural networks work better if the inputs and outputs lie between 0-1. There are two inputs given by $\{P\}_{2X20}$ and one output $\{O\}_{1X20}$ in a normalized form.

Step 2: Enter the number of inputs for a fed network.

Step 3: Enter the number of layers.

Step 4: Create a new feed forward network with 'tansig and poslin' transfer functions.

Step 5: Train the network with a learning rate of 0. 02.

Step 6: Enter the number of epochs.

Step 7: Enter the goal.

Step 8: Train the network for the given input and targeted output.

Step 9: Generate simulation of the given network with a command 'gensim'

The Neural Network is created with the set number of neurons in each layer using the above algorithm. At each training session, 500 iterations are done and 6 such validation checks are taken out in order to minimize the scope of error occurrence. The main aim of this is to bring the performance to zero. The Learning rate is the

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major consideration in the training of the Artificial Neural Network (change of interconnection weights). It should not be too low that the training gets too delayed. It should not be excessive because the oscillations occur about the target values and the time needed to converge is too high and the training gets delayed. For the considered controller, Neural Network is trained at a learning rate of 0. 02. The compensatory output depends on the input and its evolution.

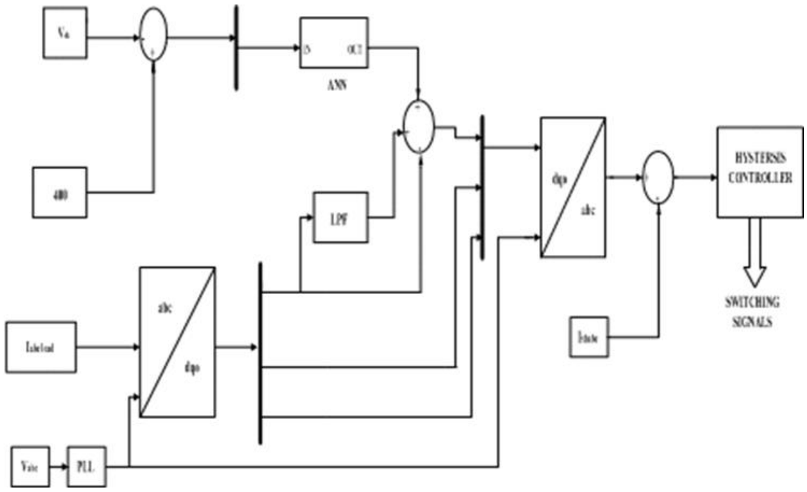

Fig. 3. Control scheme for ANN controller

Fig. 3 shows proposed control scheme for ANN, in which the load currents, PCC voltages and DC bus voltage of shunt active filter are sensed. The constant DC voltage is maintained by the DC voltage loop. The input of ANN controller is the difference between V_{DC} and a reference value. The output of ANN is responsible for harmonic mitigation. A phase-locked loop (PLL) synchronizes on the positive- sequence component of the current I. The output of the PLL (angle θ ωt) is used to compute the direct-axis and quadrature-axis components of the three-phase currents [10]. The output signals of ANN controller and direct axis component of current from d-q-o transformation are compared which produces direct axis component of reference signal. The signals from d-q-o frame are again converted to a-b-c frame are compared with a filter current (I_{shabc}), which results in generation of reference compensation current, which is given as input to the hysteresis controller [11].

Fig. 4 shows the operating principle of hysteresis band controller is to produce triggering signals required for switching ON/OFF of IGBT's shunt active filter. The objective of this controller is to control the compensation currents by forcing it to follow the reference ones. The switching strategies of the three-phase inverter will keep the currents into the hysteresis band [12]. The real load currents are sensed, and their non active components are compared with the reference compensation currents. The hysteresis comparator outputs signals are used to turn on the inverter power switches.

RESULTS AND DISCUSSIONS:

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FOR UNCOMPENSATED SYSTEM

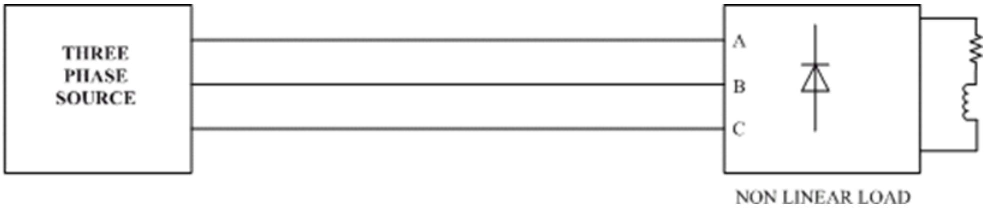

Fig. 5: Uncompensated system

Fig. 5 shows the simulation circuit for 3-phase 3-wire distribution system with a 3-phase voltage source connected to nonlinear load. Table. 1 shows the various parameters of the considered system. Fig. 6 shows Wave forms of source current and load current of uncompensated system [13]. It can be observed from Fig. 6 that instead of the actual sinusoidal waveform, a huge distortion in the source current can be observed. A delay can be observed in the output wave form, it is caused due to an inductor because an inductor opposes the sudden change in the current, though the supply wave form changes instantaneously it takes time for the inductor causing the delay in the wave form. Fig. 7 shows the FFT analysis of source current. From the FFT analysis of the output waveform without filter shown in Fig. 7, the %THD is about 29. 71.

Table 1 System parameters

System parameters	*Values Used*
Source Impedance	*L=0. 01e-3mH*
Load	R=10Ω, L=30e-3 mH
Active filter	*R=0. 1* Ω, L=3e-3 mH

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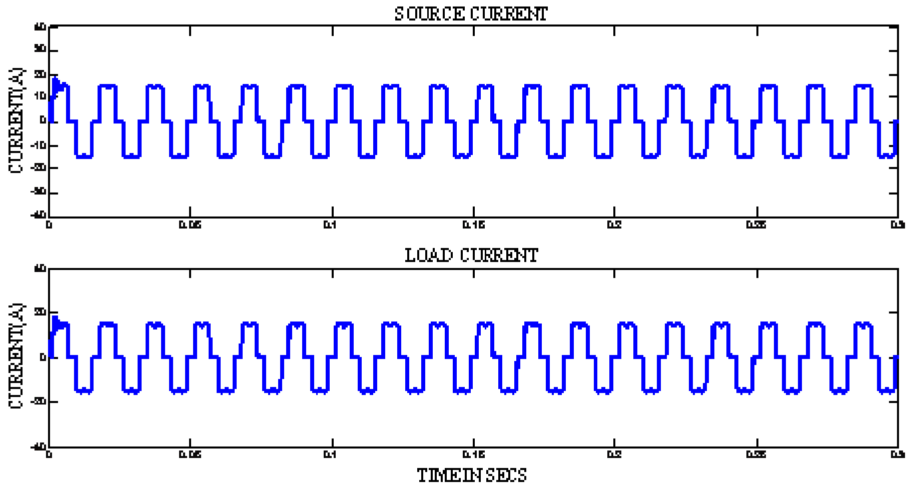

Fig. 6 Wave forms of load current and source current of uncompensated

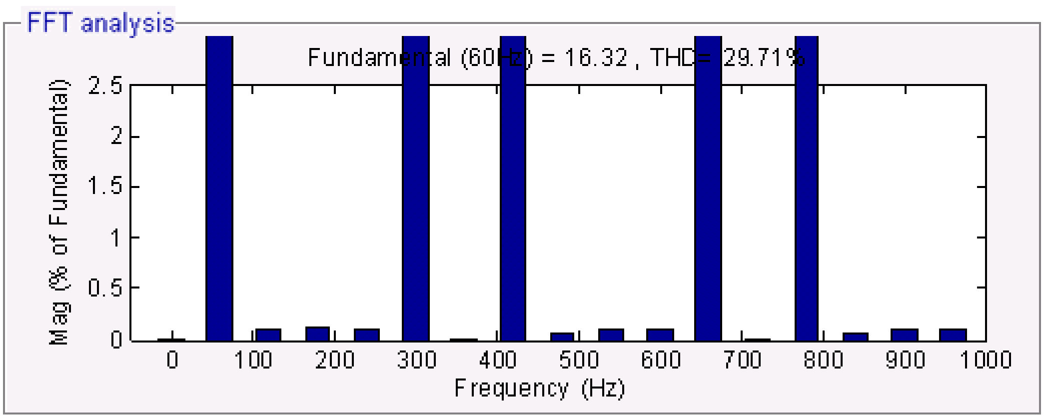

Fig. 7 FFT analysis of source current

FOR SHUNT ACTIVE FILTER WITH ANN CONTROLLER

Fig. 8 shows simulation circuit of Shunt Active Filter. Fig. 9 shows the Simulation results of Shunt Active Filter with ANN Controller. From Fig. 9, it can be observed that after Shunt Active Filter with ANN Controller runs, it reduces the much delay and waveform appears sinusoidally with fewer distortions when compare uncompensated system and it also observed that the harmonics of the source current are eliminated by injecting the capacitor current which happens because of maintaining the capacitor voltage near to constant. Capacitor voltage takes 0. 08sec to reach the steady state. Fig. 10 shows FFT analysis of source current with ANN controller. From Fig. 10, it can be seen that the current total harmonic distortion reduces to 2. 27% from 29. 71%.

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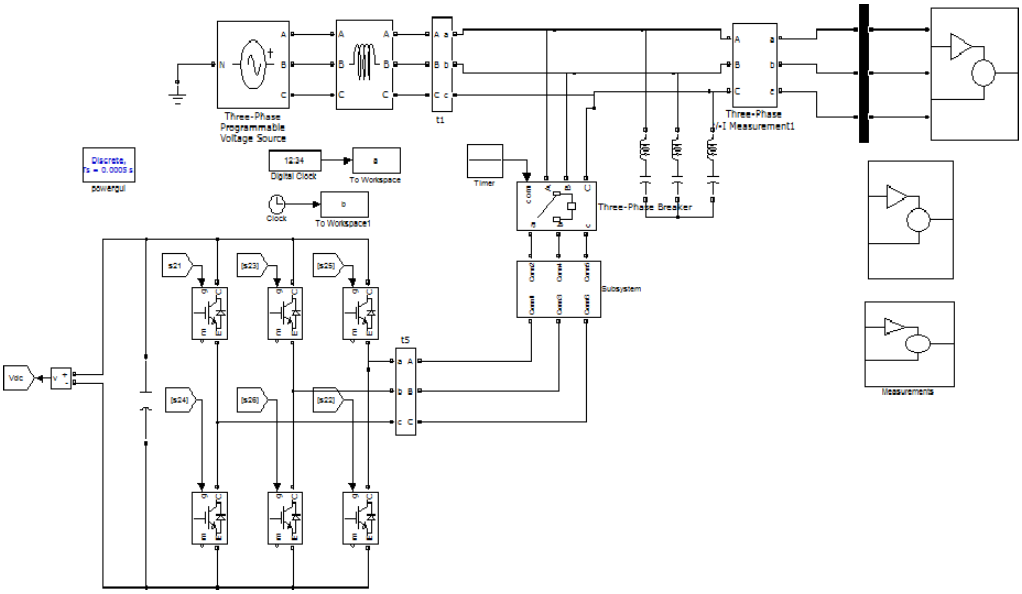

Fig. 8 Simulation circuit of Shunt Active Filter

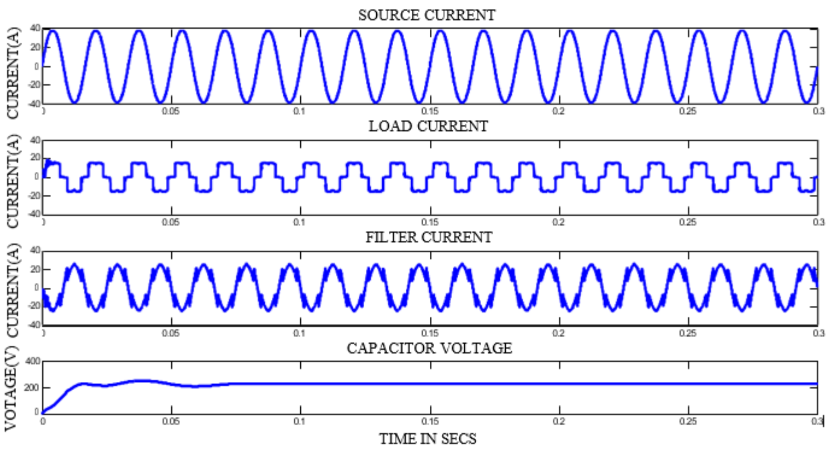

Fig. 9 Simulation results of Shunt Active Filter with ANN Controller

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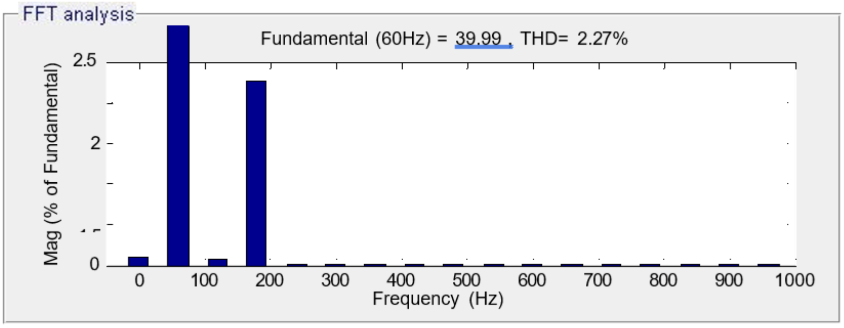

Fig. 10 FFT analysis of source current with ANN controller Table 2 Comparison of simulated results

Table 2 Comparison of simulated results

	SIMULATED RESULTS APF	
	Uncompensated System	**ANN**
Settling Time (V_{DC}) in Sec.	**--**	**0. 08sec**
%THD	**29. 71**	**2. 27**

CONCLUSION

The suggested Shunt Active Power Filter with ANNcontroller to reduce harmonics of the three-phase distribution system has been thoroughly examined in this work.

The acquired outcomes demonstrate the ease of use and potency of the suggested intelligent controller under nonlinear load situations. The findings show that an ANN driven active filter effectively decreases the current total harmonic distortion. The modelling and practical findings further demonstrate that the new control approach is quite successful in minimising harmonics, as well as being simple to calculate and use.

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