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Active Power Filter Based On Ann For Distribution System Power Quality Improvement

Abhishek Dubey[1], Suchi Mishra[2] and Sachin Tiwari[3]

[1]Department of Electrical Engineering, Scope College of Engineering, Bhopal.

[2]Department of Electronics & Instrumentation, SATI, Vidisha.

[3]Department of Electrical and Electronics Engineering, Oriental Institute of Science and Technology, Bhopal.

Abstract— Nonlinear loads created by power electronics devices produce harmonic components in the current and voltage of the distribution system. Low power factor and imbalanced load are additional issues that the distribution systems face. This study offers a controller for an active power filter (APF) based on an artificial neural network (ANN). It uses a feedforward neural network that has been trained using the Levenberg-Marquardt method to generate pulses and a reference current for the inverter. The traditional and ANN-based controller models' experimentation by employing MATLAB/SIMULINK are reviewed. To keep the system balanced, the neutral current has been decreased.

Keywords — Feedforward network, APF, VSI, THD, ANN.

I. INTRODUCTION

The nonlinear loads that are present in power systems, such as static var generators, solid state switches, arc furnaces, switch mode power supply, electronic lighting ballasts, adjustable speed drives, resistive welders, and uninterruptable supply, cause distortion of the waveform. This, in turn, unbalance of system, causes problems with power factor, and reactive power. Harmonics that have been detected in the system have the potential to saturate the transformer, induce insulation failure, create severe dielectric loss, induce malfunctioning in electronic devices, induce heating of the neutral conductor, diminish the equipment's life expectancy, and interfere with the lines of communication. All of these issues may occur simultaneously. The goal of the IEEE standard 519-1992 is to decrease and attenuate harmonics to a level that has a total harmonic distortion (THD) of less than 5%. Both active and passive filters are used in order to correct for harmonics. A passive filter's disadvantages include its bulky size and the possibility that its frequency tuning may result in resonance. As a result, active filters are an excellent option. The imbalance of the load causes an excessive flow of neutral current. The presence of triplen harmonics in the stability of a three-phase system may be responsible for a number of undesirable effects, including the formation of standard mode reduced noise, the overloading of transformers, and voltage distortion. These issues can also be brought on by the realization that the transformers are operating at an excessively high capacity.

Current reference production of pulses to inverter for three phase three wire construction, [1]-[4] may be accomplished by making use of a wide variety of control strategies, any one of which may be selected in order to bring about the desired result. A few examples of these control systems include wavelet, the P-Q theory, the synchronous reference frame method, the fast Fourier transform, the recursive discrete Fourier transform, and the fast Fourier transform. There are additionally a lot more cases of these control systems. There is a possibility that some of these might be utilized in conjunction with systems that have three phases and four wires. On the other hand, the most majority of them are complicated, difficult to put into practice, and expensive, particularly for purposes which require lower to moderate amounts of power. For a three-phase four wire network, the mid-point capacitor design and a four switching leg architecture are the two potential designs that might be employed. [5] Both of these designs have their advantages and disadvantages. Both of these topologies have their advantages and disadvantages. Because the neutral current flows fully through it, the midpoint capacitor must have a rating that is greater than the remainder of the capacitors in the circuit in order to meet the requirements of the design. The value of the midway capacitor has to be higher by a factor of two in comparison to the value of the dc link capacitor. It is recommended that the four switching leg design be used, despite the fact that it calls for two more IGBTs together within the driver circuit. This is due to the fact that it provides the most switching options. This is due to the fact that the performance of this topology is superior to that of other topologies.

The PI controller that is employed in typical four switching leg architecture has high performance when the system is in steady state, but its performance is not sufficient when the system is subject to parameter fluctuation, non-linearity, or load change (transient condition). It is thus susceptible to parameter fluctuation since it needs a precise mathematical connection to be satisfied.

In recent years [6]-[10], the implementation of ANN as a tool for use in electrical systems has developed into an advanced technique. Parallel design enables the controller to compute quicker, does not need a perfect input output relation, and is capable of handling non-linearity. These benefits are made possible by the controller's capacity to learn on its own. Because of this, the controller is more reliable than a traditional one. Active power filter (APF) employing artificial neural network (ANN) controller of four switching leg architecture is constructed using MATLAB/SIMULINK, as described in this study. For the development of the reference current signal, a feedforward neural network that was trained using the LM method is employed. This is then followed by a hysteresis controller for the generation of gating signals. This is how the paper is structured: In part II, data is offered on the APF and its control system; in section III, content regarding the ANN-based controller is described. Part III concludes with a summary of the material presented. The conclusion on the ANN-based controller for the APF of the three-phase, four-wire systems is offered in section V, which follows the discussion of the simulation model presented in section IV and the comparison of the results achieved by the conventional controller and the ANN controller reported in section IV.

II. ACTIVE POWER LINE CONDITIONER

The block design of the APF for a three phase four wire system is seen in Figure 1. It is three single-phase nonlinear loads that are being supplied by the three-phase supply. In order to correct for harmonic currents, a

VSI with four legs is used. A dc link capacitor's principal function is to maintain a constant dc voltage with a little ripple while simultaneously functioning as a storage element that delivers real power across the load and the source if there is a transient. This dual role is essential to the operation of a dc link capacitor. When the system is at steady state, the supply of electricity and the load are in equilibrium [10]. But there will be a power imbalance while the transition is taking place. Because of this, the dc voltage value will now be different from the dc reference voltage. In order to strike a harmonious balance in terms of power among the power source and the load that it powers, a corresponding adjustment is made to the reference current. This allows the reference to be located. The control strategy for the four switching leg architecture consists of two stages: the first stage generates a reference current signal, and the second stage generates pulses that are sent to the inverter. The initial step is to identify the source voltage, which is then employed to produce the unit template once it has been discovered. In order to compensate for the harmonics that exist in the source current, this unit template multiplies with the final value of the PI controller, which results in the reference current. This reference current is then utilized for compensating for the harmonics. The variation in dc voltage that occurs between the voltage at the source and the voltage at the dc link is what determines the value of the input that is sent to the PI controller. The second step consists of comparing the current that was created as a reference with the current that was measured, and then the hysteresis controller generates pulses that are sent to the VSI.

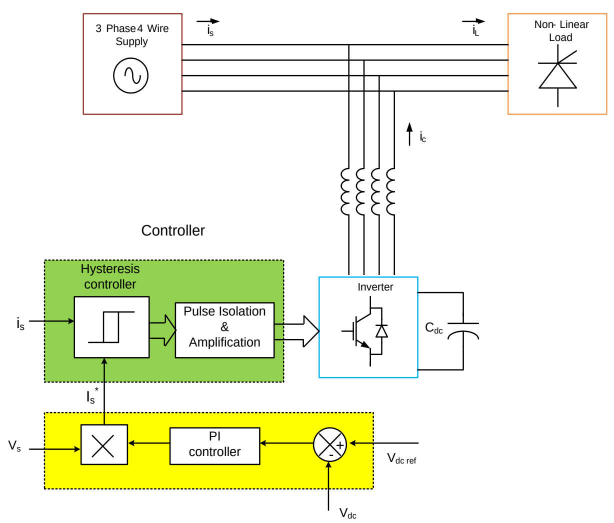


Fig.1. Block schematic for a three-phase, four-wire system with APLC

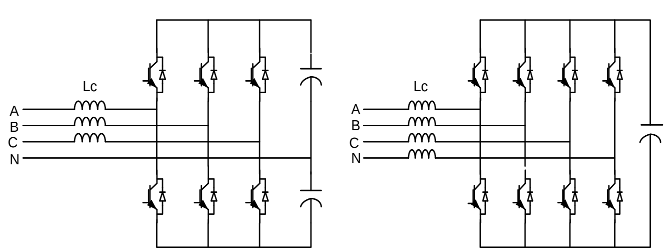


Fig.2. Mid-point capacitor VSI and a four-leg switching topology

Ua, Ub, and Uc are the unit templetes that are derived from the corresponding source voltages Van, Vbn, and Vcn. The current serving as a reference is produced by,

$$\begin{bmatrix} i_a^* \\ i_b^* \\ i_c^* \end{bmatrix} = C.\begin{bmatrix} U_a \\ U_b \\ U_c \end{bmatrix} \quad (1)$$

$$C = \left(K_P + \frac{K_I}{s}\right)e \quad (2) \qquad e = V_{dcref} - V_{dc} \quad (3)$$

'Kp' and 'KI' stand for the gains of the PI controller in this equation, whilst 'e' stands for the error of the inputs to the PI controller. The equation is what generates the current pulses that are used for compensating,

$$i_c = i_s^* - i_s \quad (4)$$

Where i_s* refers to the reference current, and i_s the source current that is being felt.

III. ANN CONTROLLER

The similarities between the artificial neuron and the real neuron are laid out for you to notice in picture 3. Weights, bias, and transfer function are the three primary aspects of a neuron that define its key properties. It is possible to specify the architecture of an ANN by the number of layers, the types of transfer functions, including the amount of neurons. The network is educated using a learning algorithm with the help of the data that was acquired.

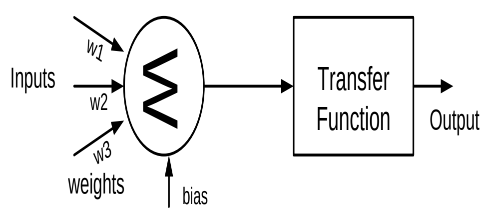


Fig.3. basic model of artificial neurons

The PI controller is designed to quickly react to deviations in dc link voltage from the reference value. This is its primary purpose. The primary benefits of artificial neural networks, such as parallel processing, rapid learning, self-organizing behavior, and nonlinear mapping, provide the system an advantage in terms of reliability and rapid dynamic reaction over conventional controllers. The PI controller that is shown in figure 1 has been switched out for an ANN controller. Adjustments are made to both the number of neurons and layers until the desired deseried output is achieved.

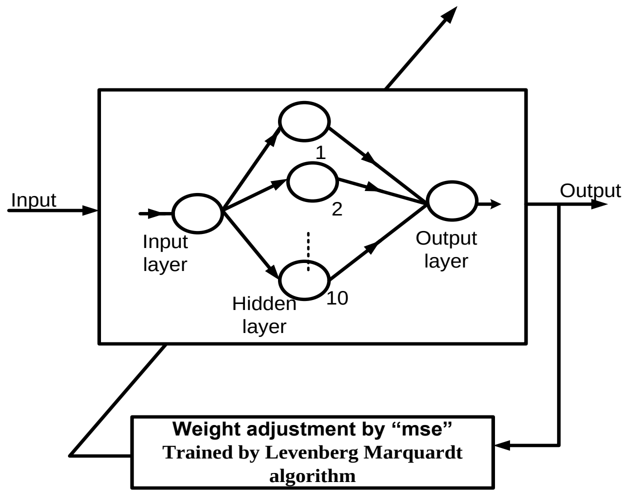


Fig.4. PI controller feedforward ANN

The ANN controller in this example has a feedforward design, as shown in figure 4. One neuron makes up the input layer, ten neurons that have a tansigmodial transfer function make up the hidden layer, and a single neuron with a purelin transfer function makes up the output layer of the network. The mean square error is used in order to make adjustments to the network's weights and bias, and the ANN gets trained offline by using the LM approach in conjunction with the data that was collected.

IV. EXPERIMENTATION

The following is a model for simulation of a PI and ANN-based system of controls for a four switching leg architecture.

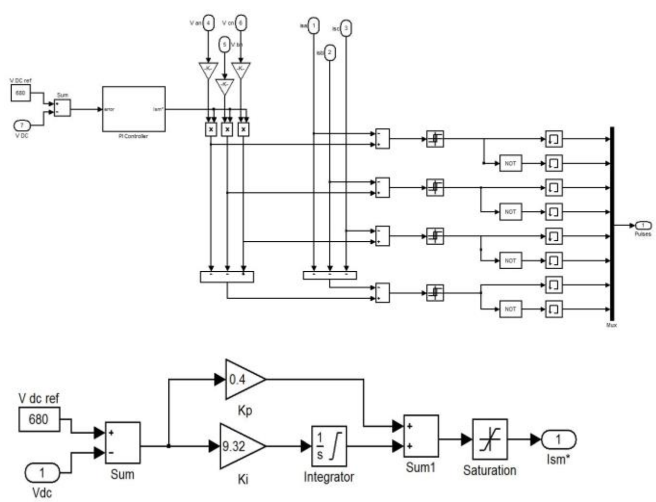


Fig.5. Traditional controller Simulink model with PI controller

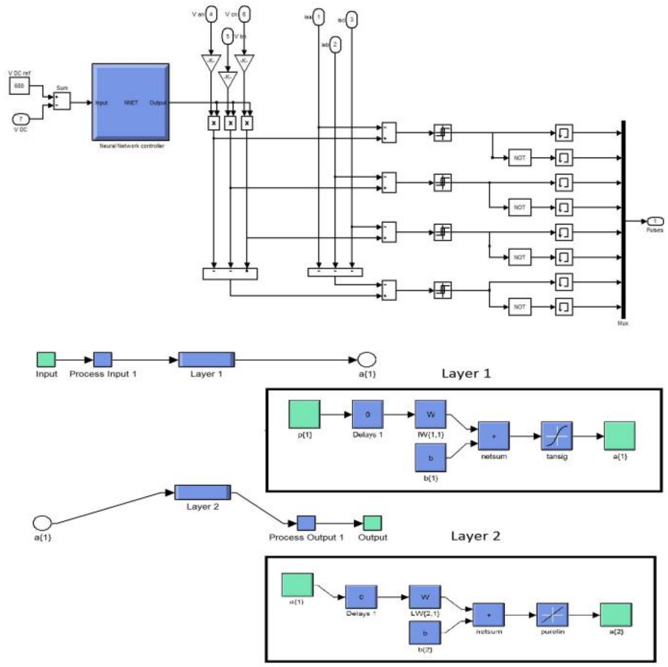


Fig.6. Architeture of an ANN-based controller in Simulink, including its inner blocks

The following table presents the results of a simulation run using a four-leg switching architecture with an ANN-based controller.

A. The steady-state performance of a balanced three-phase, nonlinear load**:**

Just the data from a single phase are provided for both controllers due to the load being balanced.

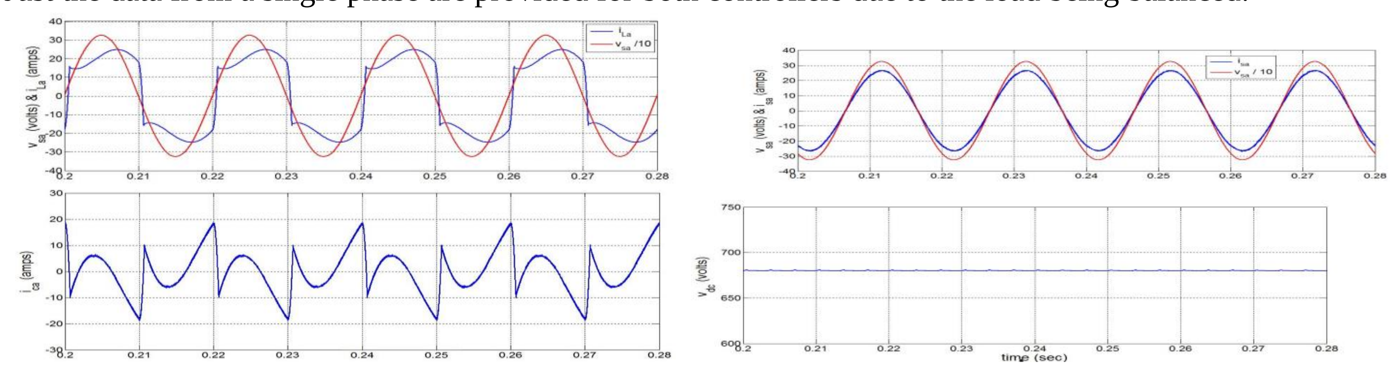
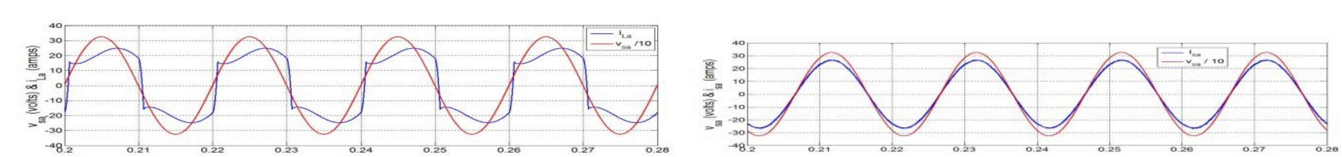


Fig.7. The outcomes of the experiment after steady-state compensating using the PI controller for phase A



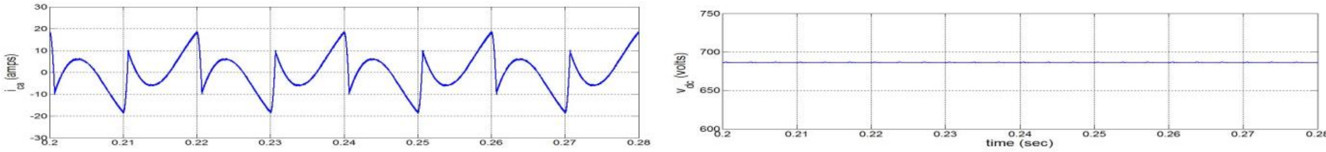


Fig.8. The simulation's outcomes after compensation in steady state utilizing phase A's ANN controller

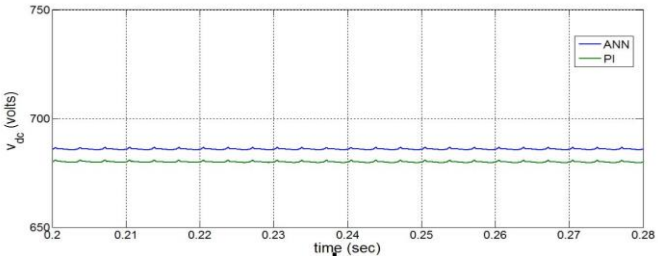


Fig.9. voltages of the DC links used by PI and ANN-based controllers

B. The results of a balanced, nonlinear, three-phase load in a transient condition**:**

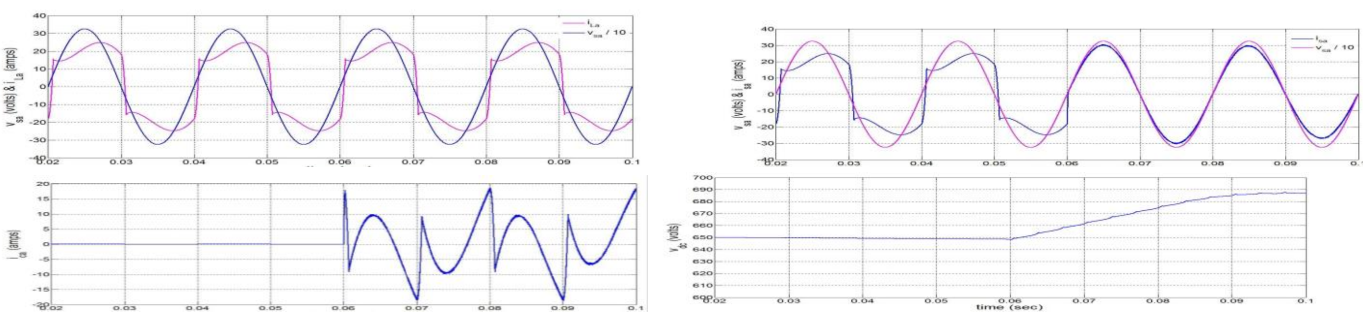


Fig.10. The reaction of the APLC to the PI controller when phase A is switched on

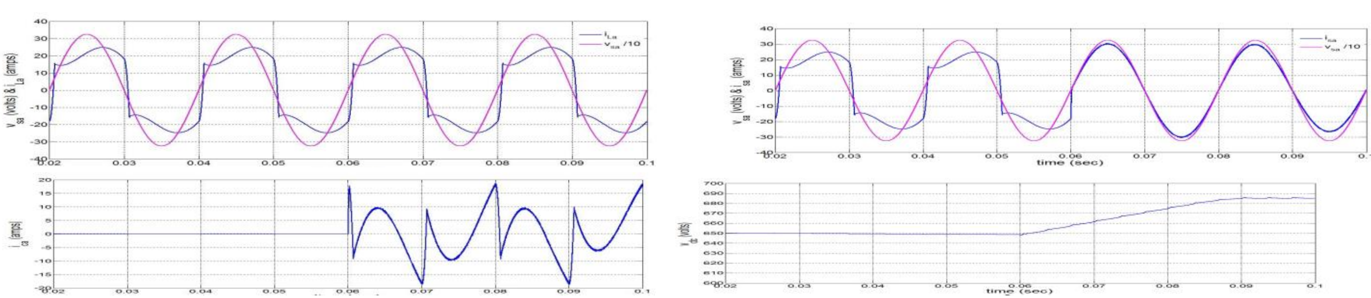


Fig.11. The phase A APLC's switch-in reaction to the ANN controller

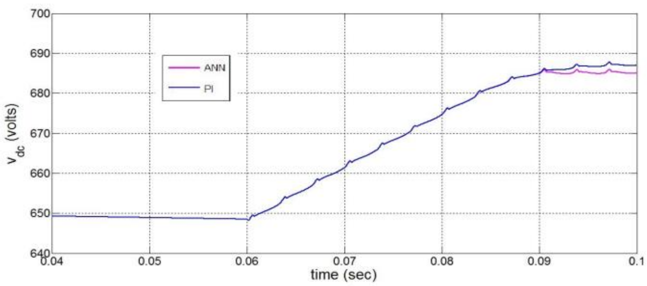


Fig.12. Response to the PI and ANN controllers' DC link voltages being switched on

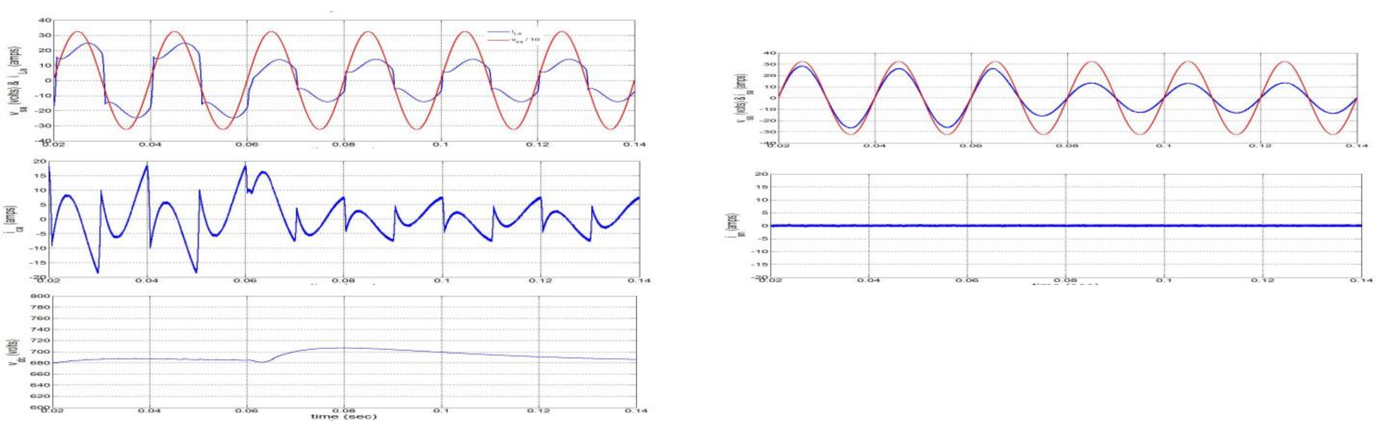


Fig.13. The response of the PI controller to a change in the load during phase A

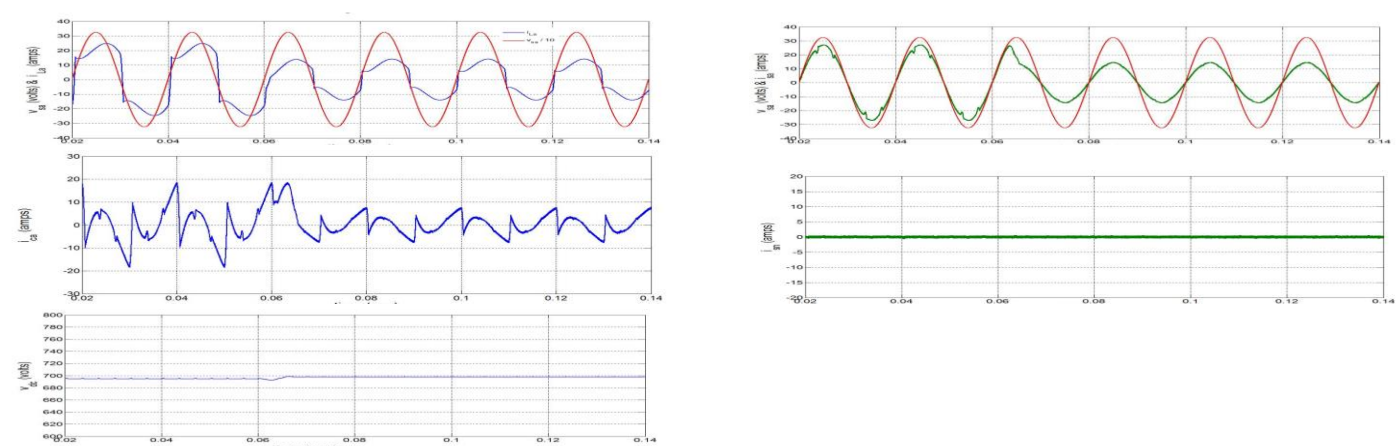


Fig.14. The response of the ANN controller to a change in the load in phase A

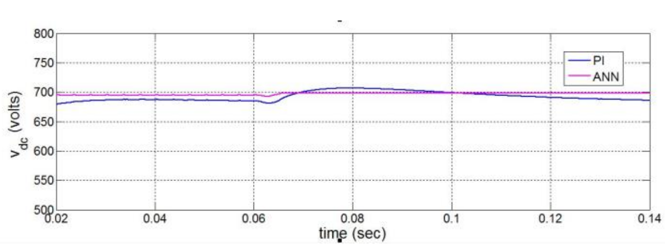


Fig.15. Alterations in the load responses and DC link voltages produced by the PI and ANN controllers

C. The outcomes of an imbalanced load applied to a three-phase four-wire scheme**:**

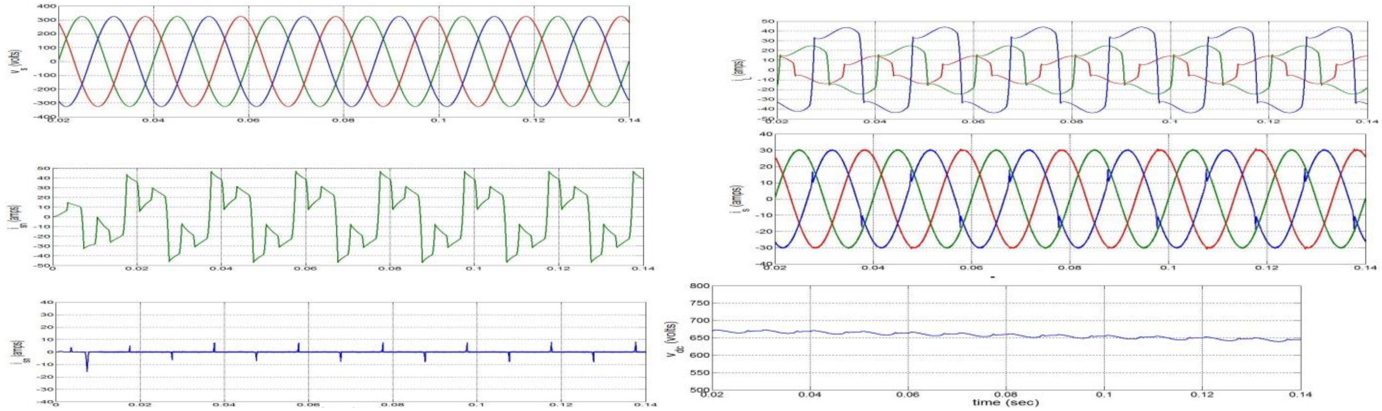


Fig.16. reaction in steady state to an uneven load using a PI controller

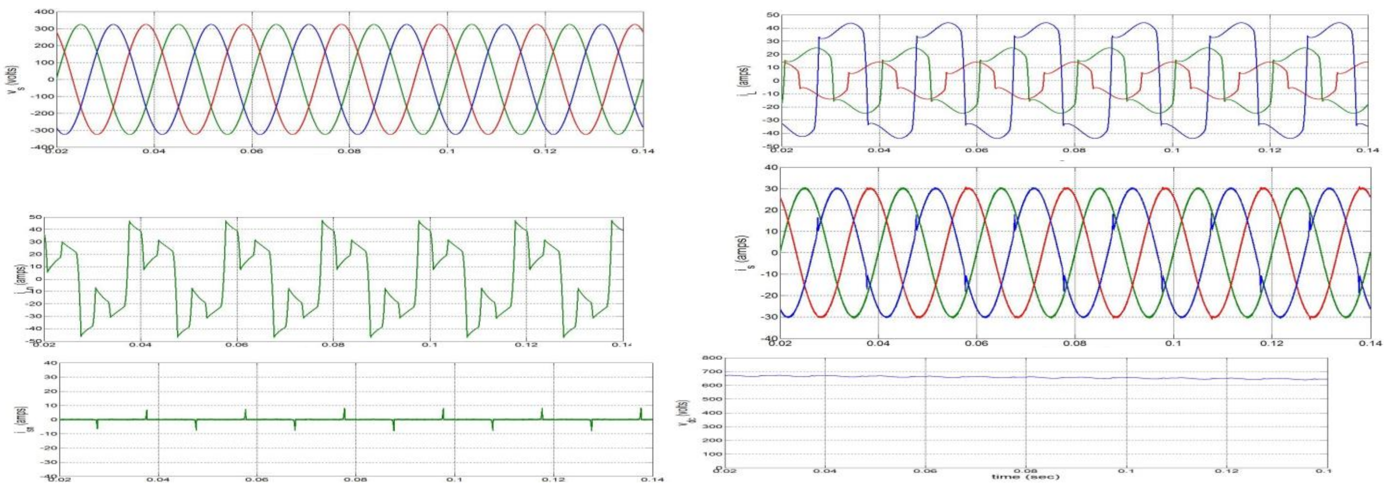


Fig.17. imbalanced load with an ANN controller exhibiting steady-state response

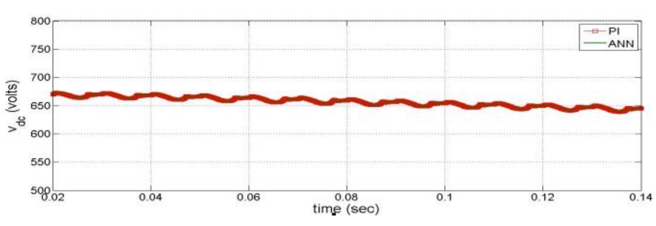


Fig.18. PI and ANN controllers provide a steady state response to an uneven load.

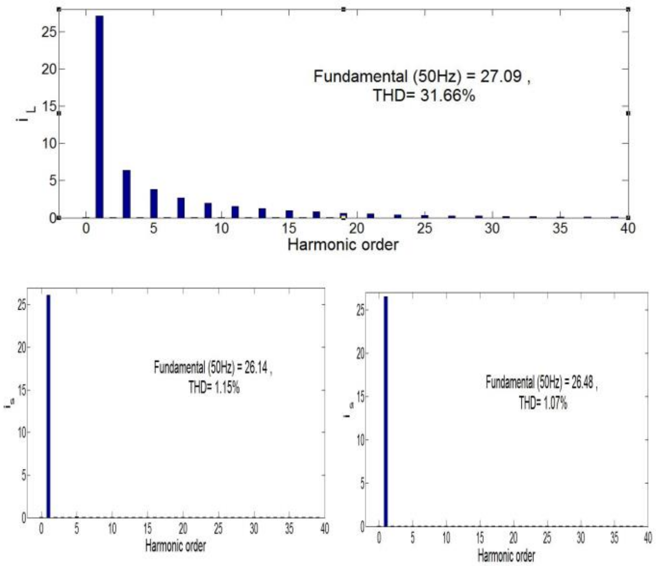


Fig.19. FFT analysis of the input level and output signal for the PI and ANN controllers.

The responsiveness of both controllers is satisfactory while the system is in steady condition. The pulses, on the other hand, are switched at a rate of 0.04 seconds during the transient period, and the switch-in response of ANN was swift while having a lower peak in comparison to PI controller as shown in figure 12. The ANN controller had a quick reaction and was able to keep the dc voltage level stable throughout the load shift that occurred at 0.06 seconds, as illustrated in figures 14 and 15. Figures 16, 17, and 18 illustrate the reaction of the two controllers to an uneven load. Because of the reduction in the neutral current, the system has been able to return to its previous state of equilibrium. The powerfactor is improved as a direct consequence of the generating voltage being in step with the current. As soon as the APF inverter begins supplying the system with compensating currents, the distorted waveform is transformed into a sine wave. The total harmonic distortion (THD) of a typical PI controller is 1.15 percent, but the THD of an ANN-based controller is just 1.07%. When all of these factors are taken into consideration, ANN-based controllers have a decent performance.

V. CONCLUSION

The model that was constructed has the capability of adjusting for harmonics and reactive power, in addition to minimizing neutral current, maintaining system balance, and getting very near to reaching power factor unity. A PI and ANN-based controller that handles a four-wire, a three-phase system's steady-state experiment results and transient experimental observations are reported here, along with those controllers' results for balanced and load imbalances. Though PI controllers could be used while the entire system is in a state of equilibrium, the performance of these controllers is poor when the system is in a condition that is characterized by continuous change. In comparison to the PI controller, the ANN-based controller displays much higher levels of performance; hence, the system can be relied upon and is long-lasting.

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