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Performance Analysis Of PV Interfaced Neural Network Based Hybrid Active Power Filter

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ABSTRACT
This paper presents a comparative analysis of neural network controlled PV interfaced hybrid active power filter designed for harmonic compensation for nonlinear load.The neural network has been chosen for reference current generation because of its fast adaptiveness, simple calculation and high accuracy to eliminate harmonics.This paper shows a novel approach to interface PV array to hybrid active power filter to keep the capacitor voltage stable. To obtain efficient output from PV Array Maximum power point tracking (MPPT) is employed in it. MPPT is able to extract maximum possible power from PV Array of change in atmospheric condition. Simulation and analysis of hybrid active power filter and PV Array is done under nonlinear load, sudden change in load and unbalanced load conditions. The detailed simulation results have been presented to validate the proposed methodology.
Keywords-MPPT, ANN, HAPF, THD,NN

I. INTRODUCTION

An unrelenting proliferation of nonlinear loads in industrial, commercial and residential applications requires the supply of reactive power, harmonic power, and power losses pertaining to the former too [1]. These nonlinear load demands reliable power supply and voltage stability. These sensitive electronic instruments produce harmonics, undesired power losses and created a power quality issue due to voltage instability and unreliable power supply. This is necessary to compensate harmonics from the system and Total harmonic distortion (THD) below 5% as specified in the IEEE 519 harmonic standard [2]. The requirements for the power quality become more and more important to keep the safety of electrical devices and customer satisfaction [3]. To improve the power quality use of filters is very popular. In this paper hybrid active power filters (HAPF) is proposed which is the combination of active as well as passive filter. HAPF having the advantages of both and it eliminates the short comes.

By using this filter can improve the performance but for accurate operation in numerous techniques have been developed and studied in the control of the hybrid active power filter. For harmonic current tracking and reference current generation hysteresis current control, PI and dead beat control, etc. Hysteresis current control method has been used because of its simplicity and fast response but it has the drawback that it depends on widely varying switching frequency. The conventional PI control has many advantages such as simple structure and ease of use [4]. The conventional PI control method has the major disadvantage that it is not flexible. Some other strategies like Fast Fourier Transform (FFT), Kalman filter, and Artificial Neural Network (ANN) are applied for efficient reference current generations. Fast Fourier Transform sometimes provides incorrect results if the signal is contaminated by noise or the DC component is of decaying nature. The Kalman filter is used for estimating the harmonic components by utilizing a smaller number of samples, simple and clear observation. It takes shorter time for estimation of harmonic current compared to FFT. The kalman filtering technique is a recursive scheme [5]. In neural network (NN) approaches back propagation, radial basis neural network and ADALINE are used mainly. Back propagation algorithms are well known for supervised learning in neural networks to minimize the error function [6]. Back propagation provides local minimum entrapment and it requires too much data for the training of the ANN and leads to inaccurate results in the presence of random noise. The combination of ADALINE with LCL filter is also introduced for efficient reference current generations. Filter inductance is replaced by a third order LCL filter for better switching ripple attenuation can be achieved during operation [7]. To generate reference current fuzzy logic are also introduced. Fuzzy logic cannot provide accurate results at dynamic condition because the membership function and the parameter of single fuzzy logic controller are established based on experience and fixed during the whole control process[8].Combination of Neural network with fuzzy is also introduced to reduce harmonics and improve performance of system. This combination removes all the drawback of fuzzy controller [9]. The proposed controller is self-adapting, fast and simple in architecture and use of Photo voltaic array for stable DC voltage generation connected to the capacitor of the filter is improved the performance of filter. Basically for DC voltage generation battery, capacitor and AC source is converted into DC by using rectifier. So system becomes very complex and does not provide accurate results. So Photovoltaic array with MPPT followed by DC-DC converter is introduced to minimize all above problems.

II. PROPOSED SYSTEM

Figure 1 shows the block diagram of the proposed system. In this system three phase source is connected to a nonlinear load(rectifier unit with RL load) that injects harmonic in the supply system. To compensate this harmonic hybrid active power filter with PV array is proposed. To improve the performance of the filter, adaptive linear neural network (ADALINE) is employed in controller to generate an accurate reference current and to charge the capacitor of filter the PV array is connected. To control the output of PV array MPPT technique is proposed in this system.

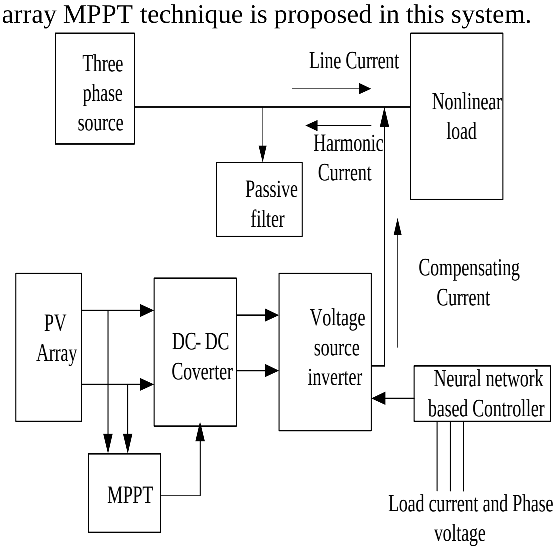

Fig.1 Proposed system

In the process of the system, neural network based controller continuously senses the three phase voltage and line current. These three phase voltage and line current are compared to the fundamental value of voltage and current and generates an error current. This error current is known as reference current. Now this reference current goes to the active power filter and on the basis of this reference current compensating current generated by the filter. Finally, this compensating current mitigate the harmonics from the system. Another technique to charge the capacitor of hybrid active power filter which consist PV array with maximum power point technique followed by DC-DC Converter. Here PV Array converts solar energy into the electrical energy by using photovoltaic effect. Maximum power point tracking technique is extracts the maximum possible power from PV Array in any changing atmospheric condition. Output of MPPT is a pulse which goes to the converter an then DC-DC Converter reduces the oscillation from the output of PV Array and generate efficient DC Output. Finally a ripple free output voltage is generated which is used to charge the capacitor of the filter at very short time duration.

III. REFERENCE CURRENT GENERATION

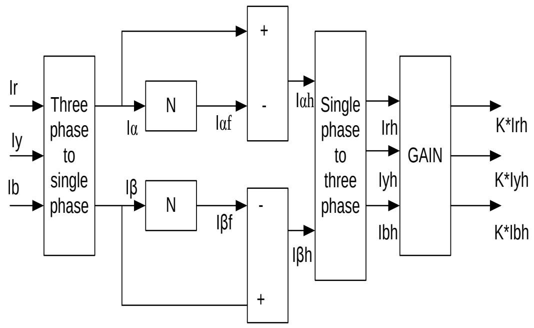

Fig. 2 Block diagram of NN based controller of HAPF.

The block diagram of proposed NN based controller is shown in Figure 2. The three -phase source currents i_r, i_y, and i_b are first transformed into two phase currents i_α and i_β using equation (1). The fundamental components of these two phases currents $i_{\alpha f}$ and $i_{\beta f}$ are extracted by proposed Adaptive Linear Neural Network (ADALINE). The two phase harmonic currents $i_{\alpha h}$and $i_{\beta h}$ are then obtained by subtracting the extracted fundamental currents $i_{\alpha f}$and $i_{\beta f}$from the two phase source currents $i_\alpha$and i_β , respectively. Finally these two phases harmonic components are transformed into three phases system using equation (2). These three phase harmonic currents after being multiplied by a gain K are used in generation of switching signals for PWM inverter.

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_r \\ i_y \\ i_b \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_{rh} \\ i_{yh} \\ i_{bh} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{\alpha h} \\ i_{\beta h} \end{bmatrix} \quad (2)$$

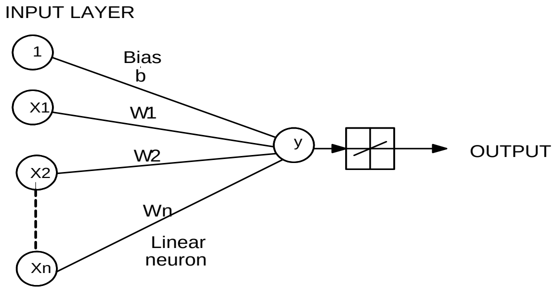

Fig.3.Internal blocks of proposed neural network

Figure 3 shows the architecture of proposed ADALINE neural network. It is a two layers (input and output) network having n-inputs and a single output. The basic blocks of this network are input signal delay vector, a purlin transfer function, weight matrix and bias. The input output relationship is expressed as-

$$y = \sum_{n=1}^{61} w_n . i_n + b$$

Where 'b' is bias, 'w' is weight, and 'i' is the input to the NN. This output 'y' is fed to the purlin transfer function, whose input output relationship is shown in Figure 4.

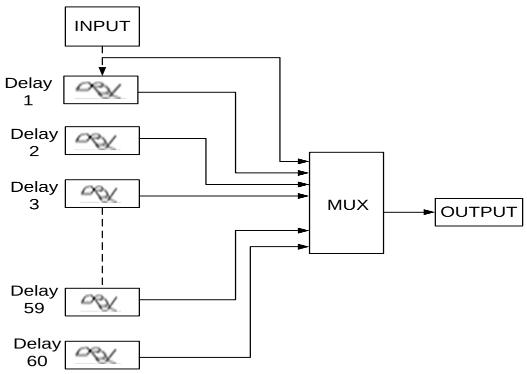

Fig.4. Internal structure of delays block

The input to the network is a time-delayed series of the signal whose fundamental component is to be extracted. The length of this delay series is 61, which has been decided considering expected maximum distortion and unbalance in 3-phase input signal. Fig. 4 shows the internal structure of delay block. The proposed NN receives 61 samples of input signal at a time and produce single output. The input is sampled at 6 KHz i.e. 120 samples per fundamental cycle of voltage. Target data (alpha and beta axis fundamental current) required for training the proposed NN was generated using current decomposition technique as presented in [10]. The weight adjustment is performed during the training process of the ADALINE using Widrow-Hoff delta rule. The mean square error between desired output and the actual output was reduced to $3.2e^{-5}$ by repetitive training with the learning rate of 0.0006.

IV. STABLE VOLTAGE GENERATION

Figure 5 shows the block diagram of the stable voltage generation system to charge the capacitor of HAPF. In this system PV array is used for voltage generation. PV cell is basically is the P-N junction diode which works in photovoltaic principle. The PV cell converts the solar energy into electrical energy. This paper presents a PV array which is the series and parallel combination of 300 PV cells.

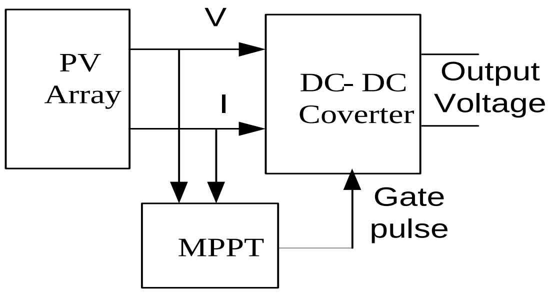

Fig.5. Block diagram of stable voltage generation system for HAPF

Output of PV cells is totally depends upon the temperature and environment condition. So to improve the performance of the system Maximum power point tracking technique is also connected which is able to extract the maximum possible power from a PV cell at any atmospheric condition. MPPT accepts as input the output of PV array voltage and current. In this paper perturb and observe method is used.

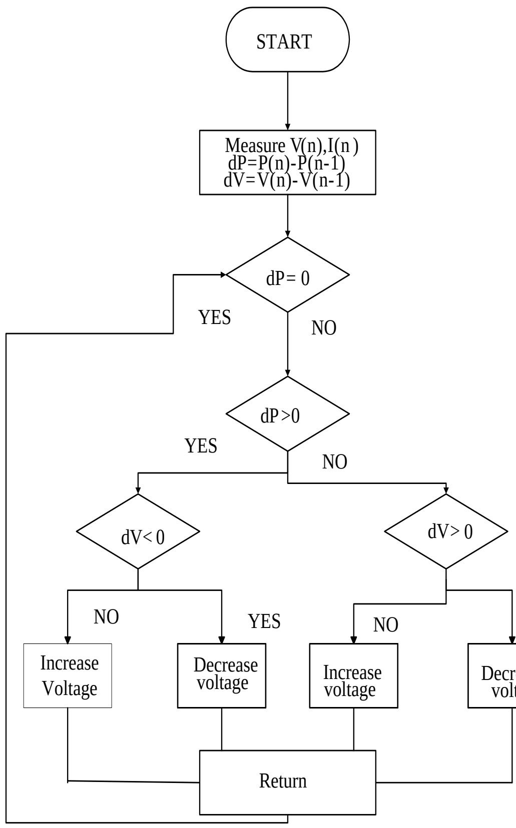

Fig.6. Flowchart of perturb and observe method

Figure 6 shows the flowchart of Perturb and observe method. In this algorithm a slight perturbation is introduced in the system. This Perturbation causes the power of solar module varies. If the power increases due to the perturbation, then the perturbation continues in the same direction. When the peak power is reached the power at the MPP is zero and next instant decreases and hence after that the perturbation reverses. When the stability condition is arrived the algorithms oscillates around the peak value [11-13]. Finally MPPT generates a gate pulse which is used to trigger the switches connected in DC-DC converter.

dP/dV>0: The PV panel operates on a point close to MPP.

dP/dV<0: The PV panel operates a point further away from MPP[14].

In this paper Buck converter is proposed to step down and used to reduce oscillation from the output of PV Array. Finally a ripple free and stable voltage is provided to the Filter.

V. SIMULATION RESULT

The Hybrid Active Power Filter and proposed controller are simulated in MATLAB software. This section is divided into two parts 1. Capacitor charging voltage from PV array 2. Performance analysis of HAPF at different load

5.1 Capacitor charging voltage from PV array- Figure 7 shows the waveform of output voltage to charge the capacitor of HAPF. It also shows that output voltage takes very less time to reach the maximum value that's all because of the use of MPPT. Output voltage of PV array is 600 V, output current of PV array is 0.85 A and output voltage of converter is 400 V.

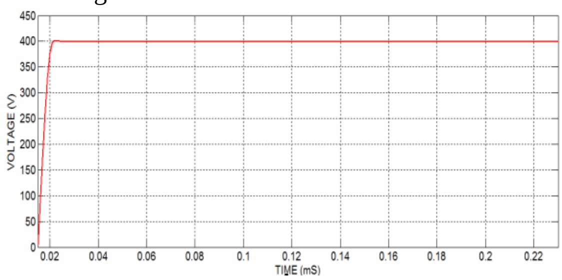

Fig.7.Capacitor charging voltage from PV array and MPPT

5.2 Performance analysis of HAPF at different load- Performance of neural network based HAPF is analyzed by changing the type of load. So this paper presents three load conditions 1. RL load 2. Unbalanced load 3. Dynamic load

5.2.1 RL Load condition- The HAPF is simulated with RL Load and sinusoidal balanced source voltage in a steady state condition. Nonlinear Load parameters are Load resistance = 160Ω, Load Inductance = 70 mH, Filter Capacitance = 1800 μF, Phase Voltage= 240 V(rms), 50 Hz. figure 8a represents the waveform of three phase load current and figure 8b shows the waveform of three phase source current for RL load. Both waveforms are distorted till 0.04mS after than it will become smooth because filter starts at 0.04mS. It is clear from the waveform that neural network extracts an instantaneous fundamental component embedded in the highly distorted waveform accurately. Figure 8c shows the spectrum of THD for RL load condition. THD value is 4.98%, which is less than 5%.

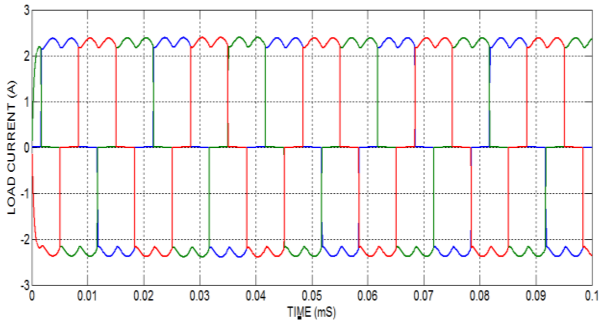

Fig.8a. Waveform of load current for RL load

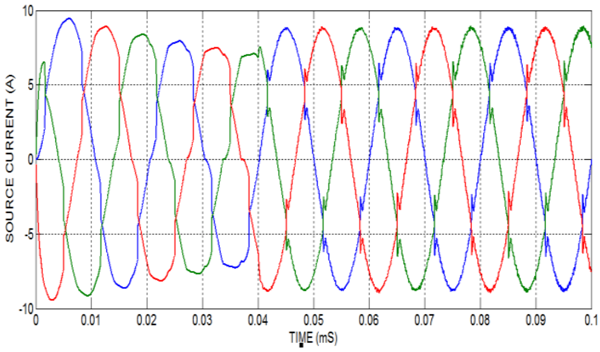

Fig.8b. Waveform of source current for RL load

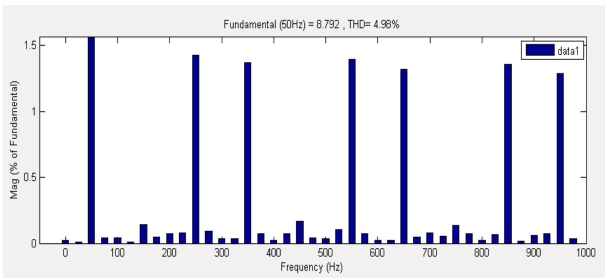

Fig.8c. THD spectrum of RL load

5.2.2 Unbalanced load condition- The HAPF is simulated with unbalanced load condition. In this condition value of first load resistance is 80Ω, value of second load resistance is 60Ω, filter capacitance is 800μF and source voltage $240V_{(rms)}$ 50Hz. Figure 9a and 9b show the waveform of load current and source current. From figure 9a and 9b distorted waveform is shown till 0.04mS after than it will become smooth because filter starts at 0.04mS. Waveforms are demonstrating that HAPF is able to deal efficiently unbalanced load condition also.Figure 9c shows the spectrum of THD which represents that value of THD is 4.60%.

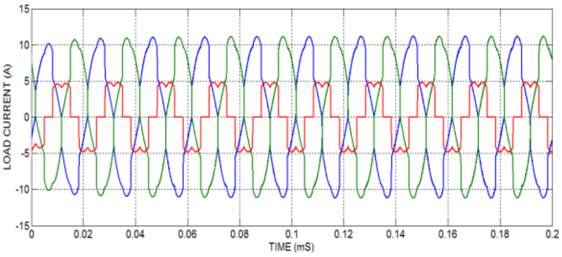

Fig.9a. Waveform of load current for unbalanced load

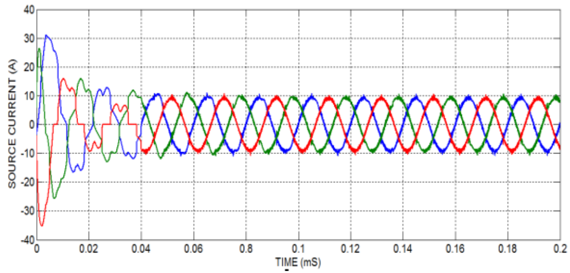

Fig.9b. Waveform of source current for unbalanced load

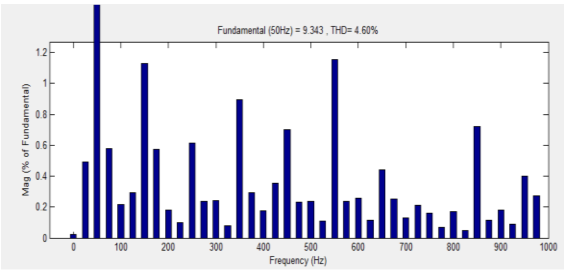

Fig.9c. THD spectrum of unbalanced load

5.2.3 Dynamic load condition- Now Performance of HAPF is analyzed for dynamic load condition. In This condition two impedances are connected in parallel at load side which is the combination of series connected resistor and inductor. The magnitude of this R_1= 80Ω, L_1= 130mH, R_2= 260Ω, L_2= 50mH, Filter capacitance = 2200µF and balanced source voltage is 240 $V_{(rms)}$ 50 Hz. Waveforms are demonstrating that HAPF is able to deal efficiently dynamic condition also. Figure 10a and at 10b demonstrate the waveform of load current and source current. Waveforms are distorted till 0.04mS after than it will become smooth because filter starts at 0.04mS and then at time 0.1mS suddenly load is increased, but the waveform is smooth, so waveform represents that neural network is able to deal with any kind of dynamic condition. Figure Fig 10c show the THD value reduced to 4.85%.

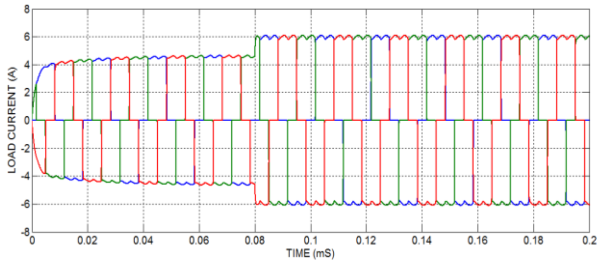

Fig.10a. Waveform of load current for dynamic load

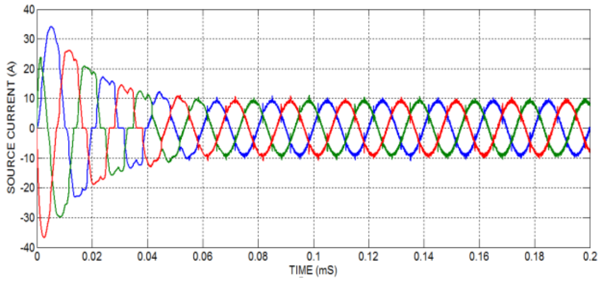

Fig.10b. Waveform of source current for dynamic load

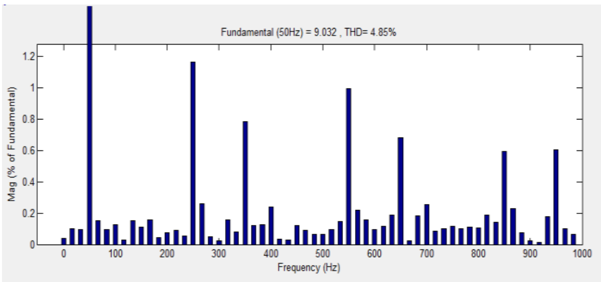

Fig.10c. THD spectrum of dynamic load

VI. CONCLUSION

All conditions are simulated in MATLAB. Simulation results show that Adaline based hybrid active filter is able to deal at any load condition and THD value goes below 5%. PV array with MPPT followed by DC-DC converter provides stable voltage which helps filter to work properly. The validity and effectiveness of the methodology proved by simulation results which are shown in paper.

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