Performance Improvement of Hybrid Active Power Filter under Unbalanced Voltage Condition using ANN

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***ABSTRACT:* This paper presents a harmonic current detection method using artificial neural network. The hybrid active power filter (HAPF) is designed for harmonic compensation method and then their consumption of power requirements compared with load. Harmonic suppression of the well-known p-q theory deteriorates in non ideal grid voltage conditions in previous stage. In this paper presents an Adaline neural network technologies are used to extract the fundamental current/voltage under distorted voltage condition. The harmonic currents are deduced and re-injected phase-opposite in the power distribution system network through an active power filtering scheme. The control strategies are involved in the voltage source inverter. The detailed simulation results have been validating to the proposed technologies using MATLAB/Simulink.**

KEYWORDS: Adaline Neural Network, THD, Hysteresis Current Controller, PI Controller.

I. INTRODUCTION

The increased use of modern power electronics technologies by industries has resulted in direct increase of harmonic distortion in the industrial power system in recent years. The improved efficiency and productivity provided by adjustable speed drive and uninterruptable power supplies (UPS),etc is offset by the fact that the utility grid is being disturbed by these equipments because of their rectifier front ends. Now a days, the amount of harmonic currents flowing into the grid is growing rapidly due to polluting loads [1].Some power-line-conditioner methods have been proposed in the literature to minimize harmonic-distortion currents [2].

Power quality problems are common in industrial, commercial and utility networks as power electronics appliances are widely used in these fields. These appliances generate harmonics and reactive power. Therefore it is very important to compensate the dominant harmonics and thus Total Harmonic Distortion (THD) below 5% as specified in IEEE 519 harmonic standard.[1]

To lessen the effect of harmonic distortion two different filters are provided namely Active and Passive filters. The passive filtering is the simplest conventional solution to eliminate the harmonic distortion and power factor improvement in the power system utilities. Although with various advantages such as simplicity of construction, easy to implement and cheaper, the passive filter suffer from many disadvantages such as tuning problems due to tolerance ,resonance ,fixed compensation characteristics for fixed value of L&C and their bulky size. To overcome this problem Active Power Filter (APF) is brought in effect [2] [3].

The shunt solution is the most widely used in low and medium-power application due to effectiveness, and harmonic-rejection capabilities. Shunt filters are usually applied to three-phase systems where a large capacity is required. The information regarding the harmonic currents and other system variables are passed to the compensation current/voltage reference signal estimator. The signal from compensation reference signal estimator drives the overall system controller. SAPF have been researched, developed and have gradually been recognized as a workable solution to the problems created by non-linear loads. The main function of shunt active filter is to sense the load currents and extracts the harmonic component of the load current to produce a reference. The reference consists of the harmonic components of the load current which the active filter must supply. This reference current is used to generate the switching signal which is used to switch the power switching devices of active filter in order to produce the harmonics required by the load. As a result, the AC supply will only need to provide the fundamental component to the load, resulting in a low harmonics.

II. HYBRID ACTIVE POWER FILTER:

2.1 Introduction:

Hybrid active power filter gives the efficacious combination of passive and active filter, which implies the advantages of both and eliminates the short-comes of each one. Accuracy of this hybrid active power filter is depending upon the calculation of harmonic current and generation of reference current. In this paper, a three phase three wire neural network controlled shunt hybrid active power filter is proposed [4] [5].

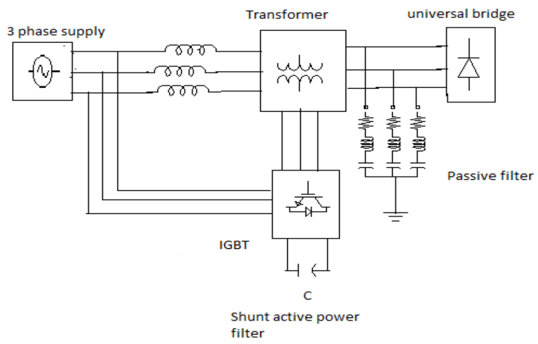

Fig.2.1Hybrid Filter Configuration

In the previous case, The control approach of detecting both source current, and load voltage harmonics is applied based on the synchronous rotating frame method or dq-transformation and pq theory transformation method [6]. In this paper, To make the shunt active power filter model by using ANN controller has been used to facilitate the calculation of reference currents. ANN controller is used to generate fundamental from non-ideal voltage source. The extracted fundamental currents are then subtracted from source current to evaluate the reference signal i.e. harmonic current. The proposed controller has self-learning with high accuracy and simple architecture and it can be successfully applied for harmonic filtering under various power system operating conditions. Therefore, presents a hybrid power filter using neural network-controller to control the harmonics under different non-sinusoidal and unbalanced source/load conditions for its performance.

If an unbalanced voltage/current harmonics is present in a three-phase supply system, a ripple occurs at the dc-bus voltage. This can interact with the bus voltage controller if the controller was not designed to handle a distortion in the dc-bus voltage [7]. The interaction can result in harmonics in the injected current. The bus voltage controller is usually a PI-controller with a randomly chosen sample frequency [8] ,[9–10].

2.2 Design of Hybrid Active Power Filter:

The structure of the proposed SHAPF is shown in Fig.3.1. It consists of a three-phase pulse width-modulation (PWM) voltage source inverter (VSI) connected in series with one or more passive filters. They are directly connected to the grid with the need of a transformer. The passive filter consists of simple *LC* filters per phase tuned near certain harmonic frequencies. Basically, the active power filter acts as a controlled voltage source which forces the system line currents to become sinusoidal.

The active filter is used only to compensate harmonics, while the reactive currents are damped by the passive filters. Therefore, it is considered as a voltage source proportional to the harmonic line currents ($V_{AF} = K\cdot I_{Sh}$), where K is the gain of the active filter [11].

When no active filter is connected ($K = 0$), the ratio between the harmonic components of the ac line current (I_{Sh}) and those of the nonlinear load (I_{Lh}) is easily obtained from considering the ac mains (Vs) as purely sinusoidal.

The requirement of reactive power is must for designing of hybrid power filter. The proposed control scheme generates the reference compensation current for the active power filtering with low order
harmonics and VAR being taken care of, by the passive tuned filter. As a result, no harmonic resonance occurs and no harmonic current flows in the supply. Following equations can be used for designing passive filter.

Let VAR requirement of load is (VAR)L so VAR supplied by passive filter is

$$(VAR)_{S=}\frac{(VAR)_L}{3}$$

Capacitance, inductance and resistance of the passive filter element can be calculated as

$$L = \frac{1}{W^2 C}$$

$$R = \frac{WL}{Q}$$

Where, Q is the Quality factor. Value of R, L & C varies with different values of VAR and Q.

After further analysis following equation is obtained:

$$B_P = \frac{1}{Q}$$

Where, BP is the bandwidth of the passive filter. With high value of Q the bandwidth is narrow therefore it is difficult to obtain the tuning.
Total impedance of system is given by the equation:

$$Z = \frac{Z_5 Z_7 Z_S}{Z_5 Z_7 + Z_5 Z_S + Z_7 Z_S}$$

Where, Z_5 & Z_7 are the 5th and 7th tuned passive filter impedances, and Z_S is the source impedance.

III. PROPOSED TOPOLOGY:

A system with a nonlinear three-phase load supplied by a voltage source is considered. **A** shunt active power filter is used to generate the compensation current. The nonlinear load current I_L is the sum of the source current $\boldsymbol{i_s}$ and the compensation current I_c. The target is to get a source current without harmonic. The compensation current injected by the shunt APF corresponds to the harmonic component of load current.

Active power filter has two different control schemes; one is neutral network controller that accounts for reference current generation and second PI controller for DC voltage regulation.ANN comprises three adaptive linear neurons to extract the fundamental components of the three phase voltages from non-sinusoidal supply. The capacitors are designed to limit the dc voltage ripple to a specified value. The performance of the active power filters is dependent to a great method, for the calculation of reference current.

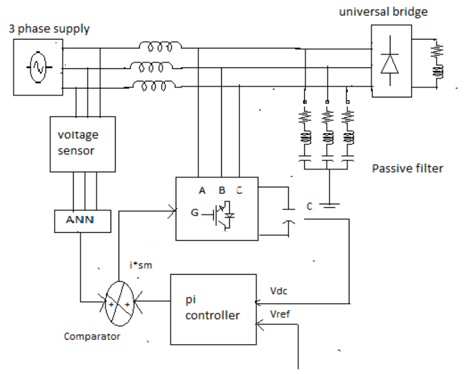

Fig.3.1.Block Diagram of ANN Based Shunt Active Power Filter

A shunt APF with a hysteresis band control is used to compensate for the nonlinear loads. The target is to control the compensation currents by forcing them to follow the reference ones. The switching strategies of the three-phase inverter will keep the currents in the hysteresis. Finally the proposed control allows an excellent filter dynamic response, and the compensation currents can be adapted quickly to any change of load current.

IV. REFERENCE CURRENT GENERATION:

For the proper response of APF the extraction of fundamental component of current from non-sinusoidal input, reference current generation is a essential task. The indirect method of current/voltage sensors is used. The three phase unit voltage vectors (v_{sa}, v_{sb}, v_{sc}) are obtained from the supply voltages.

Neural networks consist of a large class of different architectures. In many cases, the issue is approximating a static nonlinear, mapping $f(\mathbf{x})$ with a Neural network. The most useful neural networks in function approximation are Multilayer Layer Perceptron (MLP) networks. Here we concentrate on single layer perceptron networks .A SLP consists of an input layer, and an output layer. [12]

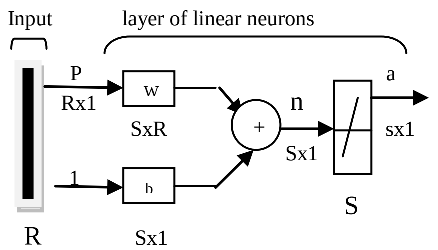

Fig.4.1.Single Adaline Network

The single ADALINE network has one layer of *S* neurons connected to *R* inputs through a matrix of weights **W**.

Where,

R =Number of elements in the input vector

S =Number of neurons in layer

This network is also called as MADALINE for Many ADALINEs. The figure 4.1 defines an *S*-length output vector **a**. The single-layer linear networks can only be trained by Widrow-Hoff rule. This is not a notable disadvantage; however, as single-layer linear networks are also as capable as multilayer linear networks. For every multilayer linear network, there will be an equivalent single-layer linear network.

In this case the weight matrix **W** has only one row. The network output is

$$\alpha = \mathrm{purelin}(n) = \mathrm{purelin}(W_P + b) = W_P + b$$

or

$$\alpha = W_{1,1}P_1 + W_{1,2}\ P_2 + b$$

There are many algorithms to determine the network parameters. In neural network literature the algorithms are called learning or teaching algorithms, in system identification they belong to parameter estimation algorithms. The output these ANN Controller, when multiplied with reference supply current (I*sm), result in three phase reference supply currents (I*sa, I*sb, I*sc). The reference supply currents and sensed supply currents (Isa, Isb, Isc) are the inputs for the pulse generator, which generates the firing pulses for the gating signals to the IGBT's of the active power filter.

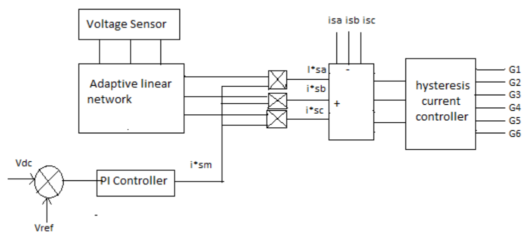

Fig.4.2.Block Diagram Of Reference Current Generation Strategies

A comparison of the average and the reference values of the dc bus voltage for the shunt AF results in a voltage error, which is fed to a proportional integral (PI) controller and the output of the PI controller is multiplied by the mains voltage waveform Vsa, Vsb, Vsc in order to obtain the supply reference currents isa*, isb*, isc*. Hysteresis current control is a method for generating the switch signals of voltage source inverter so that the generated output current follows a reference current waveform.

V. ARTIFICIAL NEURAL NETWORK :

Adaline neural network principles are similar to the perceptron network, but their transfer function is linear rather than hard-limiting. Adaline neural network allows their outputs to take any value, whereas the perceptron output is limited to either 0 or 1. Linearly separable problems can only be solved by both the ADALINE and the perceptron networks. However, the LMS (least mean squares) learning rule in ADALINE, which is much more powerful than the perceptron learning rule. The Widrow-Hoff or LMS, learning rule minimizes the least mean square error values and thus moves the decision boundaries so far from the training patterns.

- The structure of the network is first defined. Then, activation functions are chosen and the network parameters, biases and weights, are initialized.
- The associated parameters of the training algorithm like maximum number of epochs (iterations), error goal, etc, are defined.
- The training algorithm is called.
- After the neural network has been determined, the result is first tested by simulating the output of the neural network with the measured input data. This is compared with the desired outputs.
- Final validation of the neural network must be carried out with independent data.

VI. CONTROL STRATEGIES:

PI controller will eliminate steady state error and forced oscillations resulting in operation of P controller and on-off controller respectively. However, introducing integral mode 'I' has a negative effect on speed of the response and overall stability of the system. Thus, the combined PI controller will not increase the speed of response. It can be expected that the PI controller does not have means to predict what will happen with the error in near future. This problem can be solved by introducing the derivative mode 'D' which has the ability to predict what will happen with the error in near future and thus to decrease a reaction time of the controller.

PI controller algorithm involves two parameters, the Proportional 'P' and Integral 'I'. The Proportional part of the controller 'P' determines the reaction to the current error in the system, and the Integral part 'I' determines the reaction based on the sum of recent (past) errors.

Transfer function is defined as,

$$H(S) = K_P + \frac{K_i}{s}$$

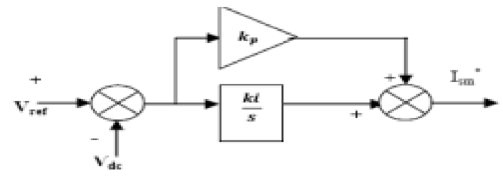

Fig.6.1. Dc Bus Voltage Controller

Where, Ki is the integration constant that determines it's settling time, and Kp is the proportional constant that determines the dynamic response of the DC-bus voltage control. The steady state DC-bus voltage error will be low and the DC-bus voltage regulation is dominant if Kp and Ki are large. On the other hand, if kp and ki are small, the real power unbalance gives little effect to the transient performance. Therefore, to satisfy both of the above mentioned control performances, the proper selection of kp and ki is essentially important. The computed reference currents are compared with the sensed three phase supply currents. The result is given to the hysteresis current controller which generates the switching signals for the switches of the shunt APF which injects the required current in to supply to follow its reference values [13].

VII. SIMULATION RESULT

The simulated waveform of shunt active power filter is shown in figure 7.1.

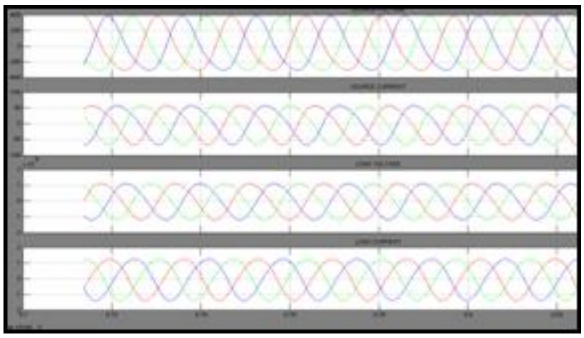

Fig.7.1.(a) 3-ph source voltages (b) 3-ph Source currents (c) 3-ph load voltage (d) 3-ph load current

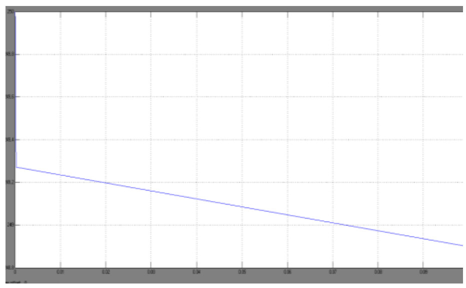

Fig.7.2.Dc bus voltage controller

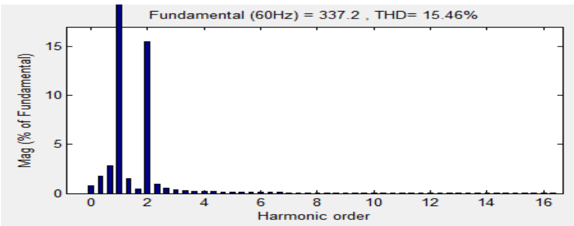

Fig.7.3THD of source voltage

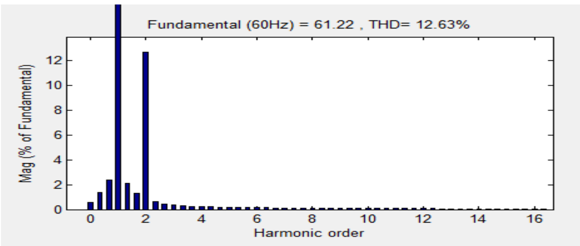

Fig.7.4.THD of source current

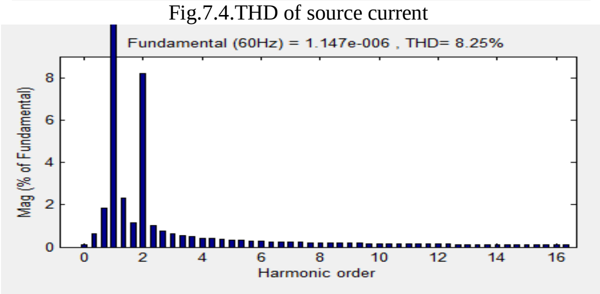

Fig.7.5.THD of load voltage

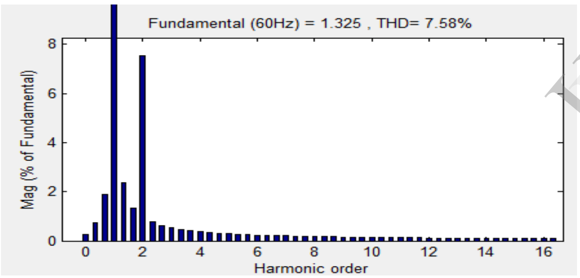

Fig.7.6.THD of load current

The waveforms are maintained sinusoidal in spite of such large variation in load. Figure.8.7 shows the filtering performance under unbalance load condition. In this simulation study, a single phase rectifier load is connected between phase ‘r’ and ‘b’ in addition to three phase rectifier. This creates an unbalance of 50% in line currents. In Figure 8.7 the source voltage is contaminated with 3rd and 5th harmonics with THD of 15%. The APF is starting at t = 0.05 sec. It can be seen that the proposed neural network controller keeps currents in each phase nearly sinusoidal and THD is less than 7% respectively.

VIII. CONCLUSION

In this work, a control method of hybrid active power filter has been carried out for the estimation of the reduction in size and cost of the active filtering unit with the passive tuned filters inserted for partial compensation with load. The estimation has been done for varying VAR compensation of the passive filters. As the HAPF is complex with cost effective parameter control, the hybrid active power filter has been preferable in the subject of harmonic solution. The performance of evaluation of active power filter has been done by proposed topology Adaline neural network (ANN) was verified through simulation studies with MATLAB. Proposed controller gives a better compensation of harmonic current. The conventional Hysteresis current controller for the reference current generation to three phase IGBT voltage source inverter. Further the strength of the active power filter based on the control strategies.

REFERENCES

[1] Roger C.Dugan, Mark F. Mc Granaghan, Surya Santoso and H.Wayne Beaty, Electrical power system quality”, McGraw-Hill.

[2] H. Adage, “Recent trends in active power line conditioners,” IEEE Trans. Power Electronics, vol. 9, no. 3, pp. 26'3May 1994.

[3] P.Santiprapan and k-l.Areerak, ‘performance improvement of harmonic detection using synchronous reference frame method,ISSN: 1792-4324.

[4] F. Z. Peng, 1998. "Application issues of active power filter,”IEEE Industrial application. Magazine 30.

[5] G. Bhuvaneswari and Manjula, G.Nair July 2007. “Three-Phase Hybrid Shunt Filters for Power Quality Improvement” Journal of Power Electronics,Vol.7, No.3.

[6] Rachid Demine 2010,“The harmonic detection method based on neural network applied to harmonic compensation, “International Journal of Engineering Science and Technology vol.2,No.5.pp.258-267.

[7] T. Green and J. Marks, Mar. 2005. “Control Power Appli techniques for active power filters,” IEE Proc.-Electr.., vol. 152, no. 2, pp.369–381.

[8] A. Chaoui, J. Gaubert, F. Krim, and G. Champenois,2007.“PI controlled three-phase shunt active power filter for power quality improvement,” Electric Power Components and Systems, vol. 35, no. 12, pp. 1331–1344.

[9] G. Chang, C. Yeh, and W. Chen, Jul. 2006 “Meeting IEEE-519 current harmonics and power factor constraints with a three phase three-wire active power filter under distorted source voltages,” IEEE Trans. Power Del., vol. 21, no. 3, pp. 1648–1654.

[10] P. Lohia, M. Mishra, K. Karthikeyan, and K. Vasudevan, Jul. 2008 “A minimally switched control algorithm for three-phase four-leg VSI topology to compensate unbalanced and nonlinear load,” IEEE Trans. Power Electron., vol. 23, no. 4,pp. 1935–1944.

[11] Victor Fabián Corasaniti Hybrid Power Filter to Enhance Power Quality in a Medium-Voltage Distribution Network IEEE transactions on industrial electronics, vol. 56, no. 8, august 2009.

[12] J.R.Vazquez & P.Salmeron, March 2003 “Active power filter control using neural network Technologies,” IEE Proc.-Electr.Power Appli., vol.150, no.2.

[13] Elsa Susan Daniel, “April 2013 Selective harmonic elimination using shunt hybrid active power filters operating at different switching frequencies ,International Journal of innovative research in electrical, electronics, instrumentation and control engineering vol. 1, issue 1.

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