A FAST DETECTION OF HARMONIC COMPENSATION CURRENT FOR ACTIVE POWER FILTERS USING ADAPTIVE RBF NEURAL NETWORK AND HYSTERESIS CURRENT CONTROLLER

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ABSTRACT

This paper has proposed a new combination to control of the shunt active power filter (APF). The recommended system has better specifications in comparison with other control methods. In the proposed combination, the RBF neural network with three layer is used to cancel harmonics. The structure of this neural network and the adaptive adjusting algorithm are presented. In addition the hysteresis current control method determines the switching signals of the APF and we have used this method because of its simplicity, fast current control response and inherent peak current limiting capability. Generally, by using this combination (that has never been used), the compensation speed increased. The study has been carried out through dynamic simulation Toolbox. The results of simulation show that this approach can detect harmonic components at real time and omitting them with high precisions, little calculation and strong adaptive ability.

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 two. Over period of three decades, various types of reactive power compensators have been researched and developed for power factor correction, harmonic compensation and load balancing. Due to these disadvantages, the attention of researchers has been drawn to the power filters. Active power filters are inverter circuits, comprising of active devices. Different topologies and control techniques have been proposed for their implementation. [1]. About Active power filters, Series and shunt topologies have already been presented. Shunt active power filters are more suitable to compensate current harmonic components and the displacement power factor, while series topologies present better characteristics to compensate voltage distortions[2]-[6]. One of the most important issues in APFs is the extraction of reference signals in a fast manner. Several methods have been introduced in literatures to achieve this goal[7],[8]. In fact fast and accurate estimation of nonlinear currents is a prerequisite for satisfactory compensation of harmonics.Recently, Artificial neural networks have been applied with success in control of APF.The learning capabilities of ANNs allow online adaption to every changing parameter of the electrical network.In this paper also a shunt APF is applied for compensating the current harmonics based on the RBF neural network.The main feature of the employed RBF neural network is its adaptiveness.Furthermore the recommended current controller method which is used in this paper is also the hysteresis current control that the hysteresis band is defined for each phase. We have used this method because of its simplicity of implementation, fast current control response and inherent peak current limiting capability. Generally the APF controlling system consists of three steps: measurement of the load current or load voltage, calculation of reference current for filter and strategy of filter switching control in such a manner that the required reference current is produced. The structure of a shunt APF connected to a network is shown in Fig.1. The simulation results which are done by MATLAB/Simulink are presented to verify the validity and effectiveness of the proposed combination. It is notable that a three-phase diode rectifier with changeable RL load on its DC-side is considered as the non-linear load in the simulations.

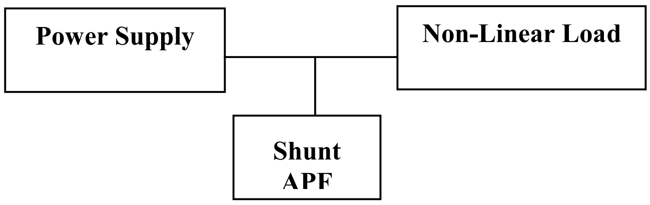

Fig. 1 The structure of shunt APF connected to a network

PROPOSED COMBINATION

As it mentioned *above RBF neural network and a hysteresis current control (a new combination) is employed to extract the reference signals and to control of the voltage source inverter (VSI) in the APF structure respectively. The proposed combination used in this paper is shown in Fig.2.*

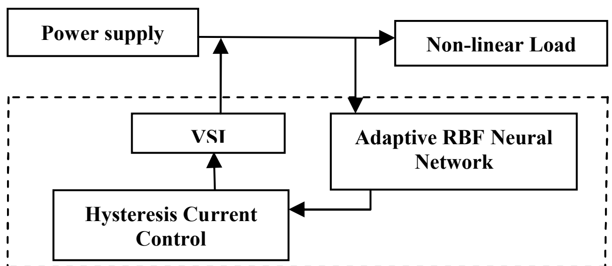

Fig. 2 The proposed combination

RBF NEURAL NETWORK MODELING

RBF Neural Network

One of the strongest neural networks used in estimation is RBF neural network consisting 3layers: the input, the middle and the output. One of the advantages of the RBF neural network is the fast training in comparison with other networks. There are several methods for reference current estimation in APFs. Most of these methods need more calculations in order to estimate the reference current and they mostly calculate the desired reference current with time delay [9]. In this paper the RBF neural network is used for fast reference current prediction.

The compensation current can be expressed as:

$$i_c(k+1) = f(x(k)) \tag{1}$$

where $x(k)=(x_1(k), x_2(k),\dots x_p(k))=(i_c(k),\dots, i_c(k- n_y+1), u(k- n_d),\dots, u(k- n_u- n_d+1))$, n_y and n_u are maximum lags considered for the output and input terms, respectively, n_d is discrete dead time . $p= n_{y+} n_u$.

Equation (1) can be approximated by RBF neural network, as shown in Fig.3.

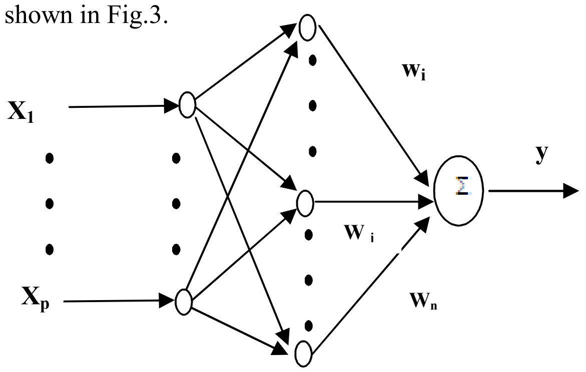

Fig. 3 The structure of RBF neural network

The basis function of neuron in hidden layer is chosen as:

$$\phi_j(x) = \exp[-\frac{\|x-c_j E\|}{2\sigma_j^2}], (j=1,2,...,n) \tag{2}$$

Where ϕ_j is output of the jth neuron in hidden layer. x is input vector. C_j , σ_j is the center and the width of the jth neuron, respectively.

The output of RBF network is expressed as

$$y = i_c(k+1) = \sum_{j=1}^{n} w_j \phi_j(x) \tag{3}$$

Where, n is the number of neurons in hidden layer. w_j is weight between hidden layer and output layer[10].

Adaptive Learning Algorithm

An adaptive learning algorithm have proposed to make the RBF neural network much simpler and tighter so that it can be used for real time application. The RBF network starts with one hidden neurons. Then neurons can be recruited or deleted dynamically according to their significance to the network performance so that the structure can be self-adaptive. The algorithm can be described as follows:

(1) Input a new observation (X_i , q_i), calculate ϕ_j and network output y_i. q_i is the desired output.

(2) Calculate error

$$\| e_i \| = \| q_i - y_i \| \tag{4}$$

(3) Calculate the distance d_j between X_j and the center c_j of the existing RBF hidden neurons.

$$d_j = \| X_i - c_j \| \qquad j = 1,2,...,m \tag{5}$$

Where, m is the number of existing RBF hidden neurons.

(4) Find d_{min}= min (d_j) ,

If $\| e_i \| > \varepsilon$ and $d_{min} > \lambda(i)$, a neuron should be generated.

Where, ε is desired accuracy of the network and $\lambda(i)$ is effective radius of the accommodation boundary, which is chosen as

$$\lambda(i) = \max(\lambda_{max}\gamma^i, \lambda_{min}) \tag{6}$$

Where, γ is decay constant . $0 < \gamma < 1$.

The parameters of generated neuron is chosen as

$C_k = X_i$

$$\sigma_k = \frac{1}{p}\left(\sum_{j=1}^{p} \| X_i - C_j \|^2\right)^{\frac{1}{2}} \tag{7}$$

(5) Adjusting weight by means of LLS method.

(6) If statisfies

$$\left\| \frac{w_k \phi_k(X_i)}{y_i} \right\| \le \delta \tag{8}$$

Then, the jth neuron should be deleted, where, δ is Predefined constant.

(7) Turn to procedure one, until all observation are finished[11].

HYSTERESIS BAND CURRENT CONTROLLER

The hysteresis band current control technique has proven to be most suitable for all the applications of current controlled voltage source inverters in active power filters. The hysteresis band current control is characterized by unconditioned stability, very fast response and good accuracy [12]. The hysteresis band current control scheme used for the control of active power filter line current is shown in Fig.4. The reference line current of the active power filter that we have received from RBF neural network, is referred to as I^*_C and the actual line current of the active power filter is referred to as I_C.

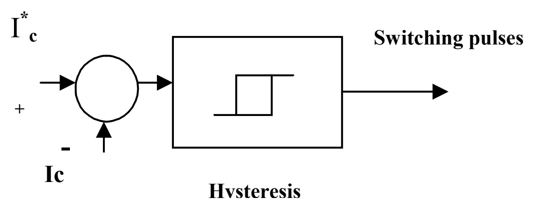

Fig. 4 Hysteresis band current controller

The hysteresis band current controller decides the switching pattern of active power filter [13],[14]. The switching logic is formulated as follows :

If i_{ca}<(i^*ca-HB), for leg "a"(SA=1), the upper switch is OFF and the lower switch is ON.

If i_{ca}>(i^*ca+HB), for leg "a"(SA=0), the upper switch is ON and the lower switch is OFF.

The switching function SB and SC, which are for phases B and C respectively, are determined similarly, with the corresponding reference, the measured currents and the hysteresis bandwidth (HB).The hysteresis band current control method is popularly used because of its simplicity of implementation, among the various PWM techniques. Besides the fast-response current loop and inherent-peak current limiting capability, the technique does not need any information about the system parameters, so in this paper we used this method for control of reference current signal of APF and by this combination(RBF and hysteresis) we have reduced delay for omitting harmonic current.

SIMULATION RESULTS

The simulation results using developed MATLAB model are presented and are validated by experimental results to depict the effectiveness of the proposed control method of APF.

The design specifications and the circuit parameters used in the simulation are indicated in TABLE I.

Table 1. Design Specifications and Circuit Parameter

Symbol	Description	QUANTITY
f	Fundamental frequency	60HZ
V_{ac}	Ac Supply Voltage	220V
V_{dc}	Inverter dc Voltage	700V
R	Changeable Rectifier Load Resistance(first load resistant begin with)	30Ω
L	Rectifier Inductance	1mH
L	Inverter Side Inductance	2mH
C_{dc}	DC link Capacitor	1500µf

The load is consisted of a three-phase diode rectifier which is connected to the grid via inductances. The resistor on the DC-side of the rectifier is changed at t=0.06 sec. The three-phase load voltages, the nonlinear load currents, the source currents and the compensation currents are shown in Fig.5-8, respectively. The reference current prediction using RBF neural network is faster than other methods because it needs simple calculations. The total harmonic distortion of the load current is 26.66% (Fig.9), The THD of the supply current is reduced to 2.17% after compensation(Fig.10). It can seen from the simulation waveforms that harmonic components decrease significantly and the whole system has well dynamic compensation characteristic.

All these results demonstrate that the proposed combination of the predictive RBF and hysteresis controller, cancels current distortions effectively.

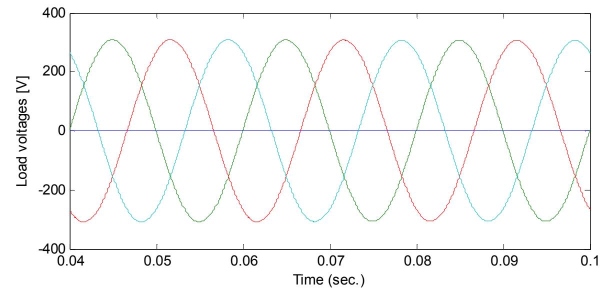

Fig. 5 Three-phase load voltages

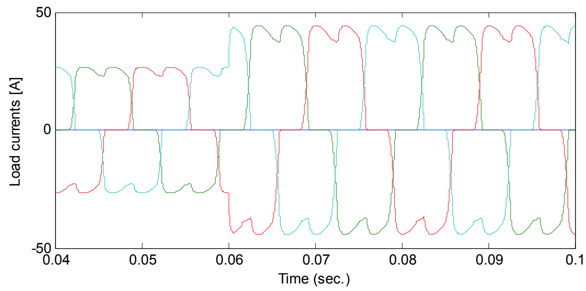

Fig. 6 Three-phase load currents

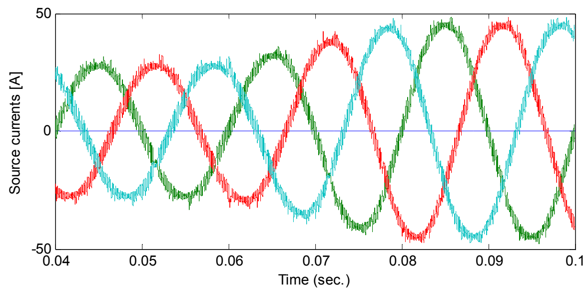

Fig.7 Three-phase source currents

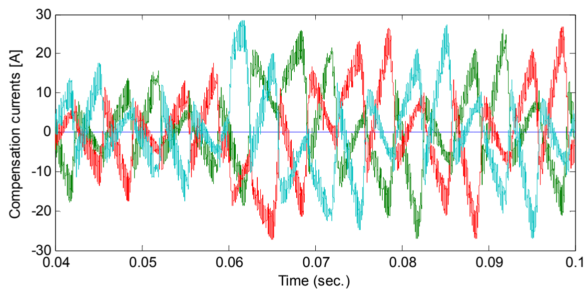

Fig..8 Three-phase compensation currents conclusion

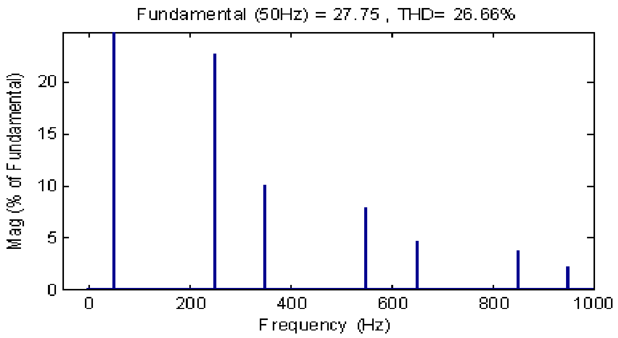

Fig..9 Harmonic spectrum of load current before compensation

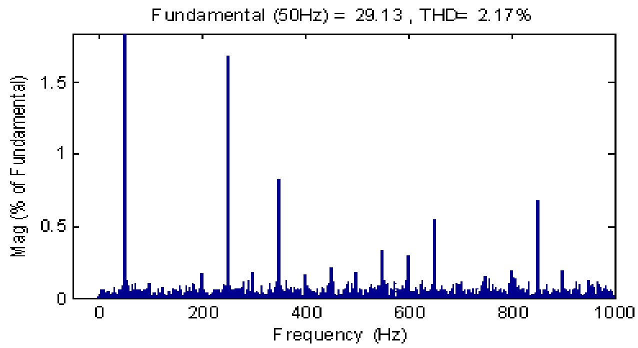

Fig..10 Harmonic spectrum of supply current after compensation

CONCLUSION

As we know one of the most important factors in Active power filters, is the fast estimation of reference signal and fast compensation. In this paper we have used a new combination that has never been used. In this combination, adaptive RBF neural network has been used for the reference current prediction, and hysteresis current control method has been proposed to control the switching pattern in the APF configuration. In this combination by using RBF neural network, because of its fast adaptiveness with changing of the load and its fast learning, also the simplicity of hysteresis and its simple calculation, the compensation has done in the fast manner and the speed of compensation has been increased. The validity and effectiveness of the proposed combination has been proved by the simulation results.

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