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Model reference adaptive sliding mode control using RBF neural network for active power filter

Yunmei Fang [a], Juntao Fei [b,*], Kaiqi Ma [b]

[a] College of Mechanical and Electrical Engineering, Hohai University, Changzhou 213022, China
[b] College of IOT Engineering, Hohai University, Changzhou 213022, China

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ABSTRACT

In this paper, a model reference adaptive sliding mode (MRASMC) using a radical basis function (RBF) neural network (NN) is proposed to control the single-phase active power filter (APF). The RBF NN is utilized to approximate the nonlinear function and eliminate the modeling error in the APF system. The model reference adaptive current controller in AC side not only guarantees the globally stability of the APF system but also the compensating current to track the harmonic current accurately. Moreover, a sliding mode voltage controller based on an exponential approach law is designed to improve the tracking performance of DC side voltage. Simulation results demonstrate strong robustness and outstanding compensation performance with the proposed APF control system. In conclusion, MRASMC using RBF NN can improve the adaptability and robustness of the APF system and track the given instructional signal quickly.

Introduction

With the energetically promotion of modern power electronic technology, the applications of different kinds of power electronic devices increase rapidly. The factors of harmonic, reactive power and unbalance in power grid degrade the quality of electric energy and reduce the capability and longevity of equipments in power system. What's worse, they may even jeopardize the safe operation of the electric power system. APF becomes one of the research hotspots because of its good capability to solve all the problems mentioned above and owns a great many advantages compared with traditional passive filter.

Research results indicate that intelligent control techniques can play a positive role in improving the performance of APF system. Neural network has learning ability to approximate any nonlinear smooth function over the compact input space. By properly choosing neural network structures and training the weights, researchers may use neural networks for special tasks. Han et al. [1] developed an ADALINE-based harmonic estimation algorithm for a hybrid APF with resetting filter. Bhattacharya and Chakraborty [2] utilized a NN predictive current controller in a three-phase APF system. Singh et al. [3] designed a DC side voltage approximation fuzzy controller. Cirrincione et al. [4] and Hamad et al. [5] exploited adaptive voltage control technique in APF and obtained accurate tracking capability of certain frequency and ideal control target.

The applications of neural network in different controlled systems mainly fall into the following two aspects. The first aspect, NN is used as a controller or in combination with other algorithms to constitute a new intelligent control system. It is easy to discover in [6–9] and [11–14] that NNs were suitable to control uncertain nonlinear dynamical systems with unknown control coefficient matrixes, input nonlinearities, unknown control direction. In addition, Wen and Ren [10] investigated a NN state observer-based adaptive control for a class of nonlinear systems with unknown control direction and Abdeslam et al. [12] put forward harmonic detection method based on NN for APF system and made several comparisons with other methods. The other aspect is system identification based on NN, such as the estimation of system parameters and the modeling of system. Nonlinear function or uncertainties can be approximated to any desired accuracy by different NN algorithms with a sufficiently large number of neurons in [15–18]. Kamble et al. [20] employed a sliding mode controller into a three-phase three wire shunt APF to enhance the robustness of the control system.

In [19], a PI–fuzzy controller is proposed to improve the voltage tracking performance for the DC side capacitor voltage control and a model reference adaptive controller is derived based on Lyapunov analysis for the AC side current compensation. In this

* Corresponding author. Tel.: +86 0519 85192023.
E-mail address: jtfei@yahoo.com (J. Fei).

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paper, the NN-based control algorithm in [18] is successfully extended to the current control of a single-phase APF. Adaptive NN control strategy instead of the adaptive control with PI–fuzzy compound controller in [18] is utilized to ensure real-time tracking of the reference current and strengthen the system robustness. NN is utilized to approximate nonlinear model and improve the current tracking performance and a sliding mode voltage controller based on exponential approach law instead of PI–fuzzy compound controller in [18] is proposed for the DC side voltage control. The main advantages of the proposed approach can be emphasized as:

(1). Model reference adaptive control technique has been combined with the NN control to achieve the desired elimination of harmonic current in APF system. It is the first time to combine RBF NN algorithm, MRAC and sliding mode control in APF system. Combination of these methods has a general sense and can be extended to other power electronic converter topology.
(2). RBF NN is proposed to approximate the unknown dynamic model term and model reference adaptive controller is equipped to eliminate the effect of the modeling error for control system. So the proposed control system can efficiently promote the application of APF, reduce total harmonic distortion (THD) and strengthen the quality of power supply.
(3). The key property of this method is that the weights of neural network can be adjusted on-line, and the asymptotic stability of the system can be guaranteed. Sliding mode control improved the tracking performance of DC side voltage, which can also enhance the robust performance of the APF system.

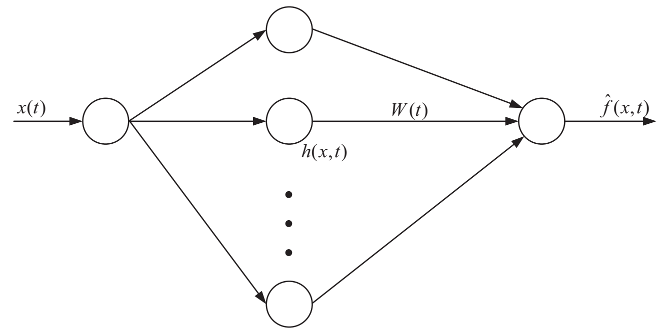

Fig. 2. RBF neural network structure.

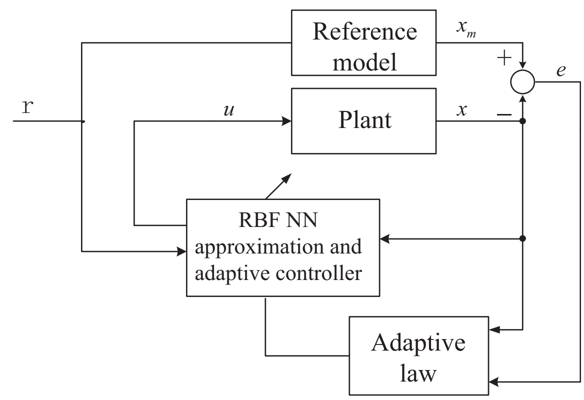

Fig. 3. Model reference adaptive control diagram using RBF neural network.

Dynamic model of active power filter

In the paper, a typical double-loop control system for the single-phase APF is shown in Fig. 1. The system working mechanism can be described. A sliding mode controller is proposed in the outer capacitor voltage loop to make the capacitor voltage to approximate constant value. The RBF neural network-based model reference adaptive current controller is designed in the inner loop to adjust the compensating current i_c to follow the harmonic current.

According to circuit theory and Kirchhoff's voltage law, the following voltage balance equation can be deduced from the APF main circuit of Fig. 1.

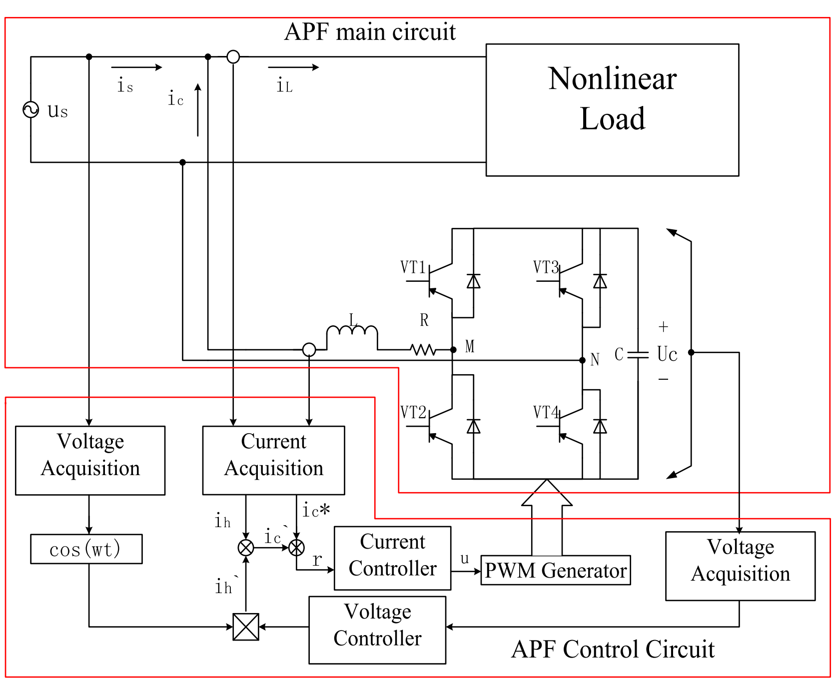

Fig. 1. Control system structure of shunt APF.