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Adaptive neural network control of active filters

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Abstract

This paper presents a new control design of shunt and series active filters for harmonic compensation in a power distribution system. The topology of the active filter is based on a 3-phase pulse width modulated (PWM) voltage source inverter (VSI) and a control circuit. The control circuit using two neural network controllers is proposed. One adaptive neural network (NN) controller is designed to estimate the harmonic components of the distorted load current and supply voltage. Another neural network controller that uses Levenberg–Marquardt backpropagation (LMBP) for its training is designed to generate accurate switch control signals for the PWM VSI. The resultant series active filter also has the capability to compensate for voltage sags in the distorted supply voltage. A power factor correction function is incorporated in the shunt active filter to achieve a power factor that is near to unity. Simulation results show that the active filters with neural network control can significantly reduce harmonic distortion in the load current and supply voltage and can adapt to variations in system operating conditions.

Keywords: Active filters; Adaptive control; Neural networks; Power quality

1. Introduction

Over the last years, the prolific use of non-linear power electronic loads, like static rectifiers, adjustable speed drives, dc/ac converters, etc., has indiscriminately increased the amount of voltage and current distortion in power distribution systems. These distortions, which are caused by harmonics, are one of the major power quality concerns in the electric power industry. Considerable efforts have been made in recent years to improve the management of harmonic distortion in power distribution systems [1]. The switching actions of power converters result in distorted input currents, which contain a fundamental and some other higher order harmonics. These power converters behave as current sources, injecting harmonic currents into the supply network. This constitutes the problems of power system harmonics. One of the problems of power system harmonics is the supply voltage distortion at the Point of Common Coupling (PCC). When a power converter injects a distorted current into the supply network, a harmonic voltage is developed across the source impedance. The voltage at the PCC, being the difference between the source voltage and the voltage across the source impedance, is distorted [2].

Over the last decade, major researches have been carried out on control circuit designs for active filters (AFs) [3–5]. The target is to obtain reliable control algorithms and fast response procedures to get the switch control signals. In this paper, the designs of neural network controls for the series and shunt AFs are presented. These two AFs use an adaptive neural network (NN) extraction algorithm to estimate the harmonics and/or sags present in the system and hence, make the extraction control adaptive to various changes in system operating conditions. The extracted harmonic and/or sag signal is then passed to a neural network controller, which

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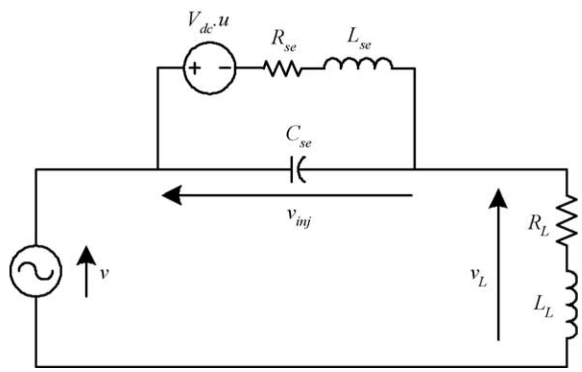

Fig. 1. Equivalent circuit of single-phase series AF.

is used to provide accurate switching signals for controlling the pulse width modulated (PWM) voltage source inverter (VSI) of the AF. The resultant neural network-controlled series AF can compensate for voltage harmonics and sags at the load side, and shunt AF can compensate for current harmonics and power factor at the supply side. Furthermore, both the series and shunt AFs are able to compensate under balanced and unbalanced conditions. The various functional modules of the AF system are discussed in detail. Computer simulations for these two AFs are carried out to verify their operating performances.

2. Series AF with adaptive neural network control

2.1. Operating principles of series AF with adaptive neural network control

The equivalent circuit of the single-phase series AF is shown in Fig. 1. The supply voltage v is used to model the distorted supply voltage at the PCC. v can be represented by

$$v = V_{\text{fund}} \sin \omega t + \sum_{h=3,5,\ldots}^{\infty} V_h \sin(h\omega t - \phi_h) \quad (1)$$

In Fig. 1, the load, which is denoted by R_L and L_L, has a voltage of v_L. The LC low-pass filter across the VSI output is represented by L_{se} and C_{se} with R_{se} as the inverter losses. V_{dc} denotes the voltage of the energy storage unit. The switched voltage across the VSI is represented by $V_{dc}\cdot u$ where u takes a value of either −1 or 1 depending on the switching signal of the PWM, which will be discussed in Section 2.4. The injected voltage of the series AF is represented by v_{inj}. From Fig. 1, it can be shown that

$$v_L + v_{inj} = V_{\text{fund}} \sin \omega t + \sum_{h=3,5,\cdots}^{\infty} V_h \sin(h\omega t - \phi_h) \quad (2)$$

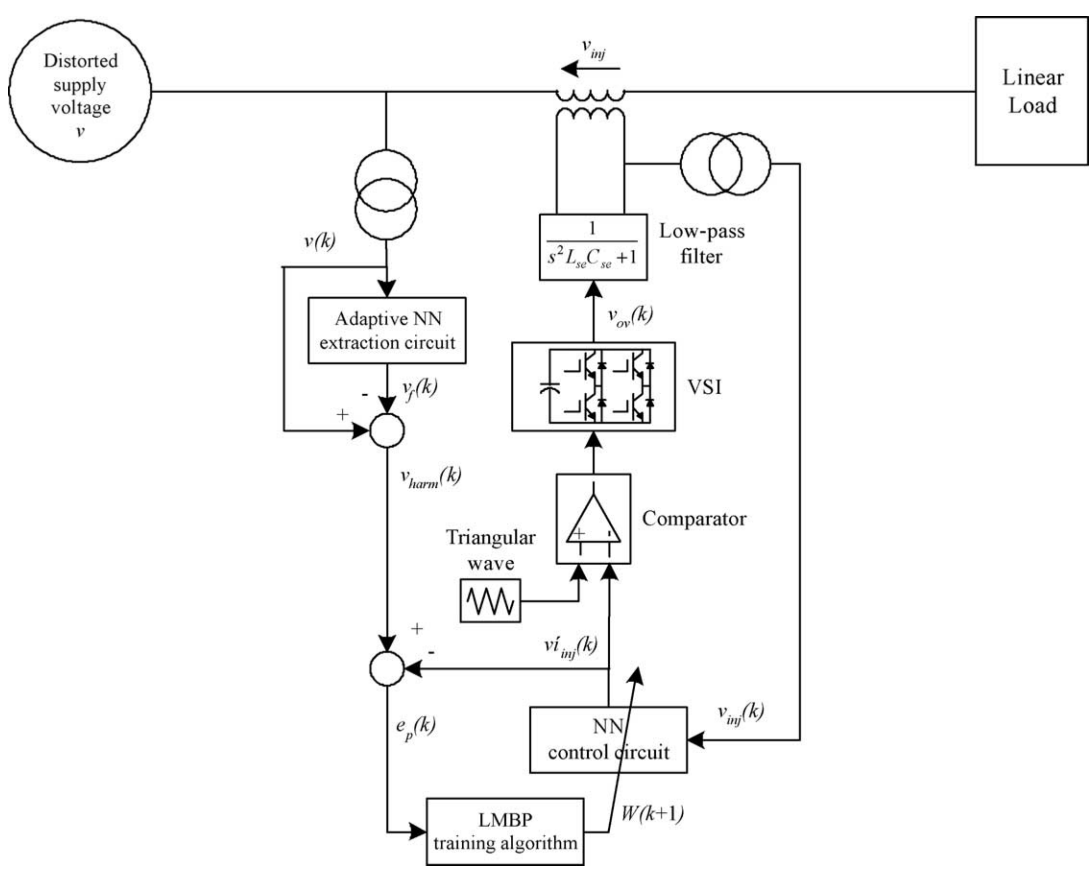

Fig. 2. System block diagram of single-phase series AF with adaptive neural network control.