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Design and implementation of predictive filtering system for current reference generation of active power filter

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Abstract

The shunt active power filters are used to attenuate the harmonic currents in power systems by injecting equal but opposite compensating currents. Successful control of the active filters requires an accurate current reference. In this paper the current reference determination based on predictive filtering structure is presented. Current reference was obtained by taking the difference of load current and its fundamental harmonic. For fundamental harmonic determination with no time delay a combination of digital predictive filter and low pass filter is used. The proposed method was implemented on a laboratory prototype of a three-phase active power filter. The algorithm for current reference determination was adapted and implemented on DSP controller. Simulation and experimental results show that the active power filter with implemented predictive filtering structure gives satisfactory performance in power system harmonic attenuation.

Keywords: Active power filter; Harmonics; Predictive filter

1. Introduction

The shunt active power filter is an inverter driven to generate compensating currents that attenuate the harmonic components generated by the nonlinear loads. Therefore, only the fundamental current component would be delivered by the mains supply. The performances of active filters depend on the inverter parameters, control method, and the method for current reference determination. Current reference can be obtained by using the bandpass filters [1] or the instantaneous power theory [2]. Bandpass filters have the disadvantage that they cause delay of filtered signal. The instantaneous power theory, on the other hand, is based on complex voltage and current transforms and their inverse transforms. Further, if the voltage source is distorted by harmonics the instantaneous power theory does not provide an accurate basis for active power filters.

The objective of this paper is to introduce an efficient method to obtain the current reference for the active power filter. The method for current reference determination is based on extracting the fundamental harmonic from a load current waveform without its phase shifting. In such way the current reference can be obtained simply by subtracting the fundamental harmonic from the measured load current. The predictive filtering structure consists of a cascade of digital Chebyshev low pass filter and digital predictive filter. Chebyshev low pass filter extracts the fundamental harmonic from distorted load current waveform and predictive filter cancel out the time delay introduced by low pass filter.

The current reference is calculated for each phase current separately. On the base of current references three independent hysteresis current controllers with a closed loop control system are used to derive the gating signals for the IGBTs in the inverter. Simulation results show that the predictive filtering structure for current reference determination is capable of extracting the fundamental harmonic from a distorted signal without any harmful phase shift.

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The proposed method was implemented on a laboratory prototype of a 16.5 kVA three-phase active power filter. The algorithm for current reference determination was adapted and implemented on DSP controller. The validity of proposed predictive filtering structure for current reference determination of active power filter was confirmed experimentally on laboratory prototype. It was verified that the harmonic current can be efficiently attenuated not only in steady states, but also in transient operating conditions.

2. Principle of active power filtering

The shunt active power filters are inverters driven to attenuate harmonic currents generated by the nonlinear loads. As can be seen from Fig. 1, their operation principle is based on the injection of compensating current in the network so that only the fundamental current would be delivered by the mains supply.

The harmonics of all orders can be compensated by one piece of equipment and better harmonic compensation characteristics can be obtained due to the use of the high controllability and quick response of switch-mode power electronic converters. However, successful control of the shunt active power filter requires an accurate and delayless current reference. The distorted current i_l that nonlinear load draw from power supply can be written as sum of fundamental current harmonic i_{l1} and its current harmonics

$$i_l = i_{l1} + \sum_{v=2}^{N} i_{lv} \tag{1}$$

where v is order of harmonic and i_{lv} current harmonic component.

According to Fig. 1 load current is

$$i_l = i_s + i_f \tag{2}$$

where i_f is current that active power filter injects in the network. Since the sinusoidal current of nominal frequency from power supply is desired the current that active power filter should produce is

$$i_f = i_l - i_{l1} = \sum_{v=2}^{N} i_{lv}. \tag{3}$$

The active power filter uses a current controlled inverter to inject corrective current waveform according to reference current. The inverter should produce a current as close as possible to the reference one and successful control of the active filters requires an accurate current reference. As can be seen from (3) desired or reference current i_{ref} of active filter is equal to sum of load current harmonics and it can be obtained as difference of load current and its fundamental harmonic

$$i_{ref} = i_l - i_{l1}. \tag{4}$$

3. Determination of current reference

Current reference is defined as a difference between the load current and its fundamental harmonic. To obtain the current reference without time delay for fundamental harmonic determination a predictive filtering structure is used. Fig. 2 shows a block diagram for current reference determination. This predictive filtering structure consists of a cascade of digital Chebyshev low pass filter and digital predictive filter. The signal proportional to the load current i_l is converted to digital signal $i_l(n)$ and filtered with low-pass filter. On the output of low-pass filter the fundamental harmonic component $i_{l1}(n-k)$ with time delay is obtained. This harmfully phase shift is compensated by predictive filter and fundamental harmonic component $i_{l1}(n)$ without phase shift is obtained. Therefore, the reference current $i_{ref}(n)$ can be obtained simply by subtracting the fundamental harmonic $i_{l1}(n)$ from the measured load current $i_l(n)$. Since the analogue hysteresis current controllers are used for control of active power filter the reference current $i_{ref}(n)$ is converted to analogue signal i_{ref} [5].

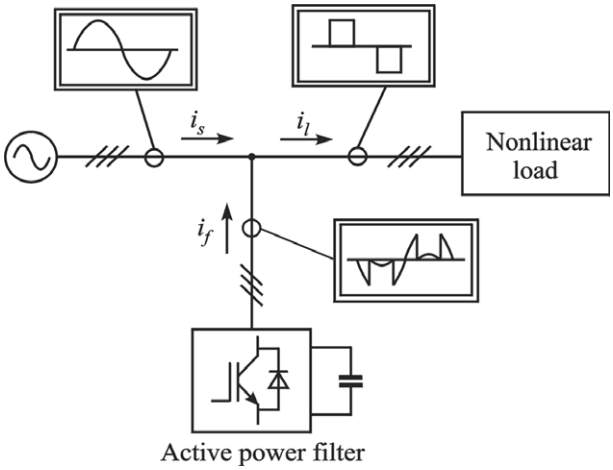

Fig. 1. Block diagram of an active power filter.

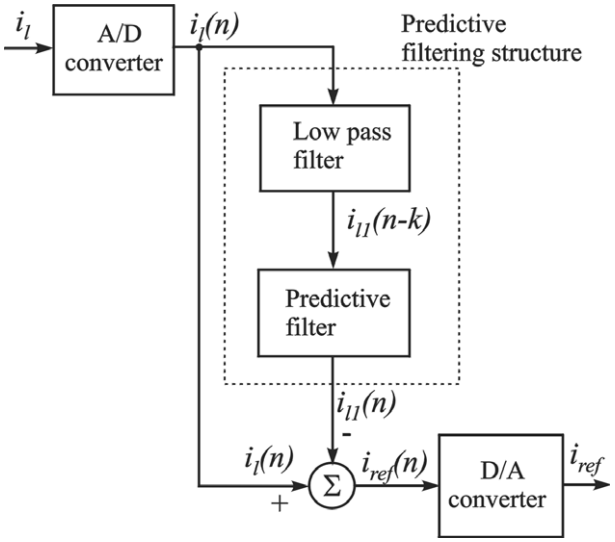

Fig. 2. Block diagram for current reference determination.