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Control Method of the Three-Phase Four-Leg Shunt Active Power Filter

Li Bin*, Tong Minyong

Tianjin university of technology and education, Hexiqu,Tianjin 300222,China

Abstract

This paper presents a novel all-digital approach applied to three-phase four-wire active power filter (APF), which is made up of three-phase four-leg voltage source converters. The controller just detects the main current and DC side capacitor voltage. Calculation method of the switch duty cycle is deducted on the base of mathematics model formed. This controller has fewer measurement, higher robustness and simpler calculation as comparing to traditional controllers. Simulation verify that the APF with proposed controller can compensate the harmonics effectively.

Keywords: active power filter, harmonic, three-phase four-leg;

1. Introduction

The application of new power electronic equipments in power grid makes the power transformation and application more flexible. But it brings serious power quality problems such as harmonic pollution, reactive power shortage, voltage fluctuations, imbalances, etc. As a traditional method for harmonic control, passive filter (PF) will be gradually replaced by new devices, due to the disadvantage that it can only filter some specific orders of harmonics and may lead to series-parallel resonance with power grid [1-4]. Active power filter (APF) has been recognized as one of the most effective means for harmonic control, reactive pollution control and power quality improvement [5-8]. Thus, it has become a new research focus in the application of power electronics technology. In this paper, by using four-bridge converter circuit structure, a new digital control method was put forward. This method just detects the

* Corresponding author. Tel.: +86-22-28221083; fax: +86-22-28111083.
E-mail address: libinfly@163.com.

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system current and the dc-side voltage of the converter. Through the simple calculation of voltages, the duty cycles of each switch for the arm are obtained.

2. Theoretical Analysis

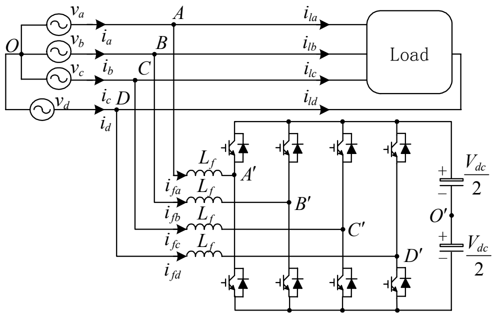

Fig. 1. Diagram of the main circuit

Fig.1 presents the circuit diagram of the three-phase four-wire active power filter. In Fig.1, i_a , i_b and i_c respectively represents the system input currents of phase A, B and C; i_d is the zero line current of system side; i_{la} , i_{lb} and i_{lc} respectively represents the load currents of phase A, B and C; i_{ld} is the zero line current of load side. The four-bridge-arm voltage source inverter is connected to the system with four series inductances and a three phase parallel load. Capacitance is used as energy storage devices to maintain a constant voltage V_{dc} of DC side. To simplify the analysis, the capacitance is divided into two equivalent capacitances. O' is set to the dc side voltage reference point. In order to express the quantities of D phase in unified way, the D phase voltage is supposed as $v_d = V_{DO}$. From the symmetry of circuit, $V_{OO'} = 0$ exists when the system runs in the steady-state. Thus, the voltage balance equation can be expressed as

$$\begin{cases} V_{AA'} = v_a - V_{A'O'} \\ V_{BB'} = v_b - V_{B'O'} \\ V_{CC'} = v_c - V_{C'O'} \\ V_{DD'} = v_d - V_{D'O'} \end{cases} \tag{1}$$

Where $V_{A'O'}$, $V_{B'O'}$, $V_{C'O'}$ and $V_{D'O'}$ respectively represent the APF's output voltages of phase A, B, C and D. Their values can be set to $\pm V_{dc}/2$ according to the switch states. When the upper leg conduction and the lower leg off, the output voltage is set to $V_{dc}/2$. In the contrast, $-V_{dc}/2$ is used. $V_{AA'}$, $V_{BB'}$, $V_{CC'}$ and $V_{DD'}$ represent the voltages of each inductance L_f .

Under the steady-state condition, by using the voltage-second balance characteristics of the inductance, there exists in one switch cycle. The aim of APF control is to make the phase currents of power grid have linear relationship with the corresponding system voltages. When this goal is achieved, the system becomes stable. Thus, in system side, the load and the active power filter can be equivalent to a resistance as