Available online at www.sciencedirect.com

SCIENCE DIRECT®

J China Univ Mining & Technol 2007, 17(4): 0590 – 0594

Simulation Research on a SVPWM Control Algorithm for a Four-Leg Active Power Filter

ZHOU Juan, WU Xiao-jie, GENG Yi-wen, DAI Peng

School of Information and Electrical Engineering, China University of Mining & Technology, Xuzhou, Jiangsu 221008, *China*

Abstract: In this paper the topology of a four-leg shunt active-power filter (APF) is given. The APF compensates harmonic and reactive power in a three-phase four-wire system. The scheme adopted for control of the four-leg active power filter, a 3-Dimensional Pulse Width Modulation (PWM) technique, is presented. The theoretical deduction of a space vector PWM (SVPWM) algorithm is given in this paper. The paper also analyzes the distribution of the voltage-space vector of the four-leg converter in $\alpha\beta\gamma$ coordinates and describes methods to determine the location of the voltage-space vector and to calculate duration time. Finally, the algorithm is implemented in simulation; the results show that the total harmonic distortion (THD) of the three phase-current waveforms is reduced. The neutral wire current, after compensation, is about 0 A showing that the topology of the four-leg shunt APF is feasible and the proposed scheme is effective.

Key words: three-phase four-wire system; shunt active power filter; 3-Dimensional space vector PWM

CLC number: TN 713

1 Introduction

Three-phase three-wire shunt active power filters have been widely studied, with many research results already implemented in practical systems[1]. The three-phase four-wire system is now being widely used in different areas including industry, office and civil buildings and power supplies for cities and factories. This configuration results in problems with harmonics in addition to the potential unbalance of the three phases. Active power filters may be used to effectively compensate the harmonic and reactive power on a three-phase four-wire grid.

In the three-phase four-wire system, two devices, namely the four-leg converter and the three-leg converter, have been proposed as active power filters[2–3]. In the former the fourth leg is used to compensate the neutral wire current directly. In the latter, the neutral wire of the three phase power line is connected to the middle point of the DC side, which provides a channel for the neutral wire current. The detection and drive circuits of the switches in the four-leg device are more complicated, whereas an extra capacitor is needed in the three-leg one. Also note that control of the capacitor voltage on the DC side is simpler in the four-leg configuration.

PWM control is the key technology of an active power filter. There are three different schemes of PWM technology, namely triangular wave modulation, hysteresis-band control and space-vector pulse width modulation. SVPWM has the following advantages over other control schemes:

1) The use factor of the DC side voltage is high.

2) Switching losses are low.

3) In applications such as motor drives it can be conveniently used as flux tracking control or current control.

4) It is easy to digitally implement the modulation scheme.

Most literature describing SVPWM in active filters has discussed applications in 2-dimensional space. However, when applied to the three phase four wire system, a 2-dimensional SVPWM cannot solve the neutral wire current problem. Thus there is an emergent need to study the 3-dimensional SVPWM using $\alpha\beta\gamma$ coordinates[5–6].

This paper presents a scheme to control four-leg active power filters using a 3-dimensional pulse width modulation technique. The distribution of voltage-space vectors in $\alpha\beta\gamma$ coordinates, the judg-

Received 10 March 2007; accepted 20 June 2007

Corresponding author. Tel: +86-516-83885667; E-mail address: ariezjjz193@126.com

ment of the sectors and the calculation of duration time are analyzed and then tested using simulation results.

2 SVPWM Control of a Four-Leg APF

2.1 Topology of three-phase four-wire shunt APF

In this paper, a four-leg converter is used as the APF circuit. The reasons for this are:

1) The use factor on the DC side in the four-leg circuit is higher than for the three-leg converter.

2) The control method for a four-leg converter is simpler and may use existing PWM technology that is based on $\alpha\beta$ transformation.

The circuit diagram of the three-phase four-wire active power filter with four-leg converter is presented in Fig. 1. The fourth leg is used to compensate the neutral wire current while legs 1, 2 and 3 generate the compensation currents for phases A, B and C, respectively.

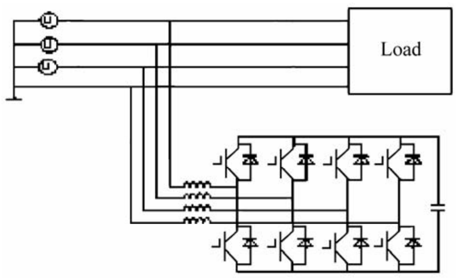

Fig. 1 Configuration of three-phase four-wire APF with four-leg converter

2.2 Space vectors of the four-leg APF

The equivalent circuit of the four-leg APF, shown in Fig. 2, consists of four legs (*a*, *b*, *c* and *f*).

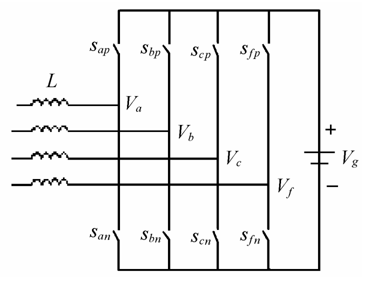

Fig. 2 Equivalent circuit of four-leg active filter

The switch variable is defined as *s*.

If S_{jp} =1 and S_{fn} =1, S_{jf} =1. If S_{jn} =1 and S_{fn} =1 or S_{jp} =1 and S_{fp} =1, S_{jf} =0. If S_{jn} =1 and S_{fp} =1, S_{jf} =−1, where $j=\{a, b, c\}$.

Therefore, the AC voltage (v_{af}, v_{bf}, v_{cf}) vector can be obtained by:

$$\begin{bmatrix} v_{af} & v_{bf} & v_{cf} \end{bmatrix}^{\mathrm{T}} = \begin{bmatrix} s_{af} & s_{bf} & s_{cf} \end{bmatrix}^{\mathrm{T}} V_g \tag{1}$$

where V_g is the DC voltage.

This four-leg APF has 16 switch states including 2 zero vectors. They are transformed into $\alpha\beta\gamma$ coordinates using (2).

$$\begin{bmatrix} V_\alpha & V_\beta & V_\gamma \end{bmatrix}^{\mathrm{T}} = C\begin{bmatrix} V_{af} & V_{bf} & V_{cf} \end{bmatrix}^{\mathrm{T}} \tag{2}$$

where

$$\boldsymbol{C} = \frac{2}{3}\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \\ 1/2 & 1/2 & 1/2 \end{bmatrix}.$$

The location of these 16 switch vectors in terms of the $\alpha\beta\gamma$ coordinates is shown in Fig. 3.

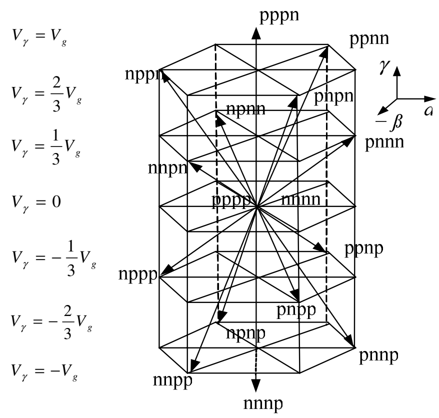

Fig. 3 Four-leg converter switching vectors in $\alpha\beta\gamma$ coordinate space

The diagram of space vectors can be divided into six prisms with every prism further divided into four tetrahedrons. So the 16 switch vectors comprise 24 tetrahedrons. Then the reference voltage vector $\boldsymbol{V}_{\mathrm{ref}}$ must be located in the 24 tetrahedrons.

2.3 Determination of location of $\boldsymbol{V}_{\mathrm{ref}}$

2.3.1 Determination of prism

The reference voltage space vector $\boldsymbol{V}_{\mathrm{ref}}$ is projected onto the $\alpha\beta$ frame, represented in Fig. 4. The projections of $\boldsymbol{V}_{\mathrm{ref}}$ in the $\alpha\beta$ frame are marked as $\boldsymbol{V}_\alpha$ and $\boldsymbol{V}_\beta$ respectively. We can determine which prism the reference voltage vector is located in based on the relationship of $\boldsymbol{V}_\alpha$ to $\boldsymbol{V}_\beta$. The flow chart for doing this is shown in Fig. 5.

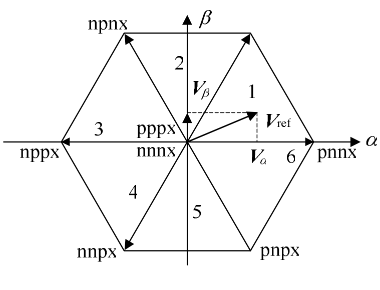

Fig. 4 Projection of $\boldsymbol{V}_{\mathrm{ref}}$ on the $\alpha\beta$ plane