Available online at www.sciencedirect.com
SCIENCE DIRECT
Electric Power Systems Research 68 (2004) 75–82
ELECTRIC POWER SYSTEMS RESEARCH
www.elsevier.com/locate/epsr

A novel hysteresis current control for active power filter with constant frequency

Jiang Zeng [a], Chang Yu [b], Qingru Qi [a], Zheng Yan [b], Yixin Ni [b,*], B.L. Zhang [a], Shousun Chen [a], Felix F. Wu [b]

[a] *The Department of Electrical Engineering, Tsinghua University, Beijing, China*
[b] *The Department of Electrical and Electronic Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong, P.R. China*

Received 1 October 2002; received in revised form 17 May 2003; accepted 18 May 2003

Abstract

In this paper a novel hysteresis current control for active power filter (APF) is suggested which is based on optimal voltage vector and in the meantime with constant switching frequency. In the method the location region of the reference voltage vector is detected quickly by a set of hysteresis comparators through one try-and-error process. Two appropriate switches are then selected to control the corresponding two line-to-line currents independently with constant switching frequency. The new method has the advantages of fast allocation of reference voltage space vector, good current tracking accuracy, and constant switching frequency. Therefore, it is efficient and safe in operation. Computer simulation results show that the new current control method can improve APF performance noticeably.

Keywords: Active power filter; Voltage source inverter; Hysteresis current control

1. Introduction

Active power filter (APF) is a very useful tool for eliminating harmonic pollution in power systems. As compared with conventional passive filters APF has significant advantages such as good controllability, fast response and high control accuracy etc. APF can also compensate non-characteristic harmonics, which makes it extremely attractive in certain circumstances. With the development of power electronic technology, APF finds its wide use in the modern industry.

APF eliminates system harmonics through injecting a current to the system that is equal to the load harmonic current, therefore the system-side will almost have no harmonic current remaining. Since the load harmonics to be compensated may be very complex and changing rapidly and randomly, APF has to respond quickly and work with high control accuracy in current tracking. Moreover in order to keep high safety and efficiency in APF operation, the required voltage source inverter (VSI) switching frequency and dc source voltage, which are highly relevant to the current tracking method used, should be as low as possible. It is clear that APF output current control technique is the key issue of its performance and efficiency.

The current tracking controller used in APF mainly falls into two categories: one is the hysteresis current controller (HCC) and the other is the ramp comparison current controller (RCCC) [1]. The former is easier to realize with higher accuracy and fast response. However, its switching frequency might fluctuate greatly. The latter can realize constant switching frequency but with relatively lower accuracy and response speed. In [2–5] efforts are made in ac motor drive to realize constant switching frequency in HCC. In [6] the idea is extended and used in APF. However, the method needs higher dc voltage, which leads to lower efficiency and higher cost. In [7–10] the concept of optimal voltage space vector is used in VSI current control, which can improve VSI current control accuracy and reduce VSI dc voltage noticeably. However, the VSI switching frequency is still

* Corresponding author. Tel.: +852-28-57-8491; fax: +852-25-59-8738.
E-mail address: yxni@eee.hku.hk (Y. Ni).

0378-7796/03/$ - see front matter
doi:10.1016/S0378-7796(03)00158-5

fluctuating. To work out a method that is based on the optimal voltage vector and possesses the advantages of both HCC and RCCC is a challenging topic. It will be addressed in the paper.

In this paper a novel HCC for APF is suggested which is based on optimal voltage space vector and in the meantime it keeps constant switching frequency in operation. In the method, the location region of the reference voltage vector is detected quickly by a set of hysteresis comparators through one try-and-error process. Two appropriate switches are then selected based on the optimal voltage space vector concept and used to control the corresponding two line-to-line currents independently with constant switching frequency. The new method has the advantages of fast reference voltage space vector allocation, good current tracking accuracy, and constant switching frequency. Therefore it is efficient and safe in operation. Computer simulation results show that the new current control method can improve APF performance noticeably.

2. Optimal voltage vector based hysteresis current control

Fig. 1 is a simple system with a VSI-based APF. The three phase load current vector $\mathbf{i}_L$ with its harmonic current to be compensated is measured and its harmonic component is denoted as reference current vector $\mathbf{i}_c^*$. APF output current vector $\mathbf{i}_c$ should be controlled to track the reference current vector. If the error $\Delta\mathbf{i} = \mathbf{i}_c - \mathbf{i}_c^*$ is larger than a certain tolerance, the current control of the APF will be activated. The current controller will determine the VSI switch operation to yield proper terminal voltage for reducing the error $\Delta\mathbf{i}$. The APF drive circuit will then realize the decision. It is clear that the current control block in Fig. 1 is significant to APF performance. It should respond quickly and determine optimal voltage space vector correctly in order to reduce the current error efficiently and in the meantime it is better to keep constant VSI switching frequency for safe operation.

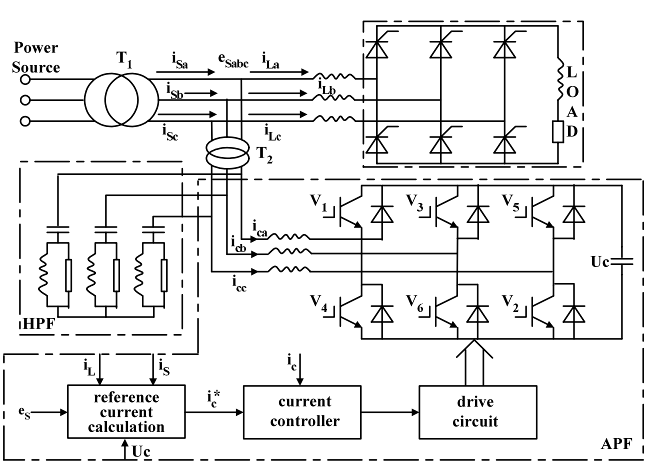

Fig. 1. Schematic diagram of a system with APF.

2.1. Hysteresis current control

Fig. 2 shows a HCC for a single phase VSI. Assume the VSI terminal voltage u connects to a sinusoidal voltage source e through an equivalent inductance L and resistance R. If we want to control APF output current i to track a certain reference current i^*, according to Fig. 2(a), we have instantaneous value equation as:

$$L\frac{\mathrm{d}i}{\mathrm{d}t} + Ri = u - e \qquad (1)$$

When the APF output current is equal to reference current i^*, the corresponding equation will be

$$L\frac{\mathrm{d}i^*}{\mathrm{d}t} + Ri^* = u^* - e \qquad (2)$$

where u^* is the reference VSI terminal voltage corresponding to i^*. If we define APF current tracking error $\Delta i = i - i^*$, it is clear that when $R = 0$, we have:

$$L\frac{\mathrm{d}\Delta i}{\mathrm{d}t} = u - u^* \qquad (3)$$

where VSI terminal voltage u is

$$u = \begin{cases} E/2 & (s = 1) \\ -E/2 & (s = 0) \end{cases}$$

Here E is the VSI dc voltage and s the solid-state switch status. When Δi is greater than 0 and beyond the tolerance, s is controlled to be at lower level $s = 0$ and therefore $(u - u^*) < 0$ (note the dc voltage should be big enough for effective current tracking) which makes Δi to reduce (see Eq. (3)). In the same way if $\Delta i < 0$ and beyond the tolerance, s is controlled to be at higher-level $s = 1$ and therefore $(u - u^*) > 0$ which makes Δi to

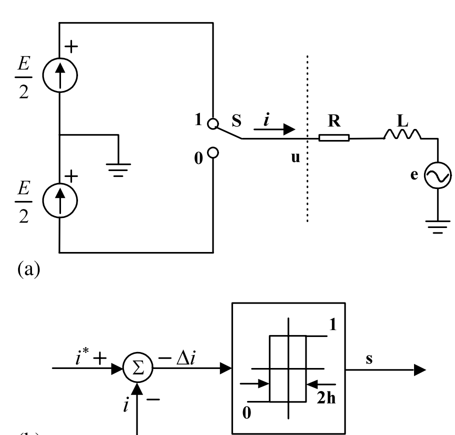

Fig. 2. Single phase VSI and its HCC.