Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Electrical Power and Energy Systems 28 (2006) 537–547
ELECTRICAL POWER & ENERGY SYSTEMS
www.elsevier.com/locate/ijepes

Three-phase active power filter based on current controlled voltage source inverter

E.E. EL-Kholy [a,*], A. EL-Sabbe [a], A. El-Hefnawy [a], Hamdy M. Mharous [b]

[a] Electrical Engineering Department, Faculty of Engineering, Menoufiya University, Shebin El-Kom, Egypt
[b] International Steel Rolling Mill Company (ISRM), Sadat, Egypt

Received 18 December 2003; received in revised form 15 December 2005; accepted 18 January 2006

Abstract

This paper presents a shunt active power filter to compensate reactive power and reduce the unwanted harmonics. A shunt active filter is realized employing three-phase voltage source inverter (VSI) bridge with common DC bus capacitor. The shunt active filter acts as a current source, which is connected in parallel with a nonlinear load and controlled to generate the required compensation currents. Two different proposed control methods for determining the reference compensating currents of the three-phase shunt active power filters based on proportional-integral (PI) controller and artificial neural network (ANN) are presented. Current controller based on modified hysteresis current controller is used to generate the firing pulses. The proposed system is implemented using a high speed Digital Signal Processor (DSP). Experimental and simulation results with different nonlinear loads are presented to confirm the validity of the proposed technique.

Keywords: Active power filter; Current control; Artificial neural network

1. Introduction

The increasing use of power electronic loads in industry and by consumers results in a considerable amount of harmonic injection, and lower power factor [1,2]. Conventionally, passive filters have been used to eliminate current harmonics and to increase the power factor. However, the use of passive filter has many disadvantages [3–5]. Recently, because of the rapid progress in modern power electronic technology, the presented work was oriented mostly on the active filters instead of passive filters [6–8]. The basic difference between passive and active filters is that the active filters have the capability to compensate random varying currents [9–14].

One of the most popular active filters is the shunt active power filter (SAF). The SAF's have been researched and developed, that they have gradually been recognized as a feasible solution to the problems created by nonlinear loads. They are used to eliminate the unwanted harmonics and compensate fundamental reactive power consumed by nonlinear loads through injecting the compensation currents into the AC lines. In addition to eliminating harmonic currents and improving the power factor, SAF can keep the power system balance under the condition of unbalanced and nonlinear loads [9–11]. Generally, the performance of SAF is based on three design criteria [15–22]: (i) design of power inverter; (ii) types of current controllers used; (iii) methods used to obtain the reference current. Many control techniques have been used to obtain the reference current. These techniques such as instantaneous reactive power theory [15], notch filters [18], flux based controller [19], power balance theory [18–22], and sliding mode controller [16,17] have been used to improve performance of the active filters. However, most of these control techniques include a number of transformations and are difficult to implement [9].

* Corresponding author. Tel.: +966500918108; fax: +96646241503.
E-mail address: eelkholy@yahoo.com (E.E. EL-Kholy).

0142-0615/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijepes.2006.01.007

This paper presents two different approaches used to calculate the reference current of the SAF. The first technique used the DC capacitor voltage with PI controller. Although, this method is simple to implement and achieves good results, it had drawbacks at unbalance conditions of the supply voltages. The performance of the SAF is achieved by the second technique, which depends on an ANN. The output of the ANN is used to generate the reference currents of SAF. The basic objective of this control is to provide a very precise solution to get the reference current even under unbalanced conditions of supply voltages. A hysteresis controller based on PWM current control is used, which is widely used due to its fast response. Comparisons of simulation results are presented for the two control strategies. The proposed control system with ANN is implemented using a DSP. Experimental results were presented to prove the effectiveness of the design of the control strategy.

2. System description and operation

2.1. Power circuit description

As shown in Fig. 1, the SAF system consists of a three-phase voltage inverter with current regulation, which is used to inject the compensating current into the power line. The VSI contains a three-phase isolated gate bipolar transistors (IGBT) with anti-paralleling diodes. The VSI is connected in Parallel with the three-phase supply through three inductors L_{f1}, L_{f2} and L_{f3}. The DC side of the VSI is connected to a DC capacitor, C, that carries the input ripple current of the inverter and the main reactive energy storage element. The DC capacitor provides a constant DC voltage and the real power necessary to cover the losses of the system. The inductors L_{f1}, L_{f2} and L_{f3} perform the voltage boost operation in combination with the capacitor, and at the same time act as the low pass filter for the AC source current. Then the SAF must be controlled to produce the compensating currents i_{f1}, i_{f2} and i_{f3} following the reference currents i^*_{f1}, i^*_{f2} and i^*_{f3} through the control circuit.

2.2. System modeling

The representation of a three-phase voltages and currents of the VSI in Fig. 1 are as follows: the voltages V_{f1}, V_{f2} and V_{f3} supplied by the inverter as a function of the capacitor voltage, V_c, and the state of the switches G_1, G_3 and G_5 are:

$$\begin{bmatrix} V_{f1} \\ V_{f2} \\ V_{f3} \end{bmatrix} = \frac{V_c}{6} \begin{bmatrix} -2 & 1 & 1 \\ 1 & -2 & 1 \\ 1 & 1 & -2 \end{bmatrix} \begin{bmatrix} G_1 \\ G_3 \\ G_5 \end{bmatrix} \tag{1}$$

where G_1, G_3 and G_5 represent three logic variables of the three legs of the inverter. The inverter conduction state is represented by these logics. Then the SAF currents can be written as:

$$L_{f1}\frac{di_{f1}}{dt} = V_{s1} - V_{f1} \tag{2}$$

$$L_{f2}\frac{di_{f2}}{dt} = V_{s2} - V_{f2} \tag{3}$$

$$L_{f3}\frac{di_{f3}}{dt} = V_{s3} - V_{f3} \tag{4}$$

where i_{f1}, i_{f2} and i_{f3} are SAF currents and V_{s1}, V_{s2} and V_{s3} are the supply voltages. The voltage in the DC capacitor can be calculated from the SAF currents and switching function as follows:

$$V_c = -\frac{1}{C}\int [G_1 i_{f1} + G_3 i_{f2} + G_5 i_{f3}] \tag{5}$$

The set point of the storing capacitor voltage must be greater than the peak value of the line neutral mains voltage in order to be able to shape properly the mains currents.

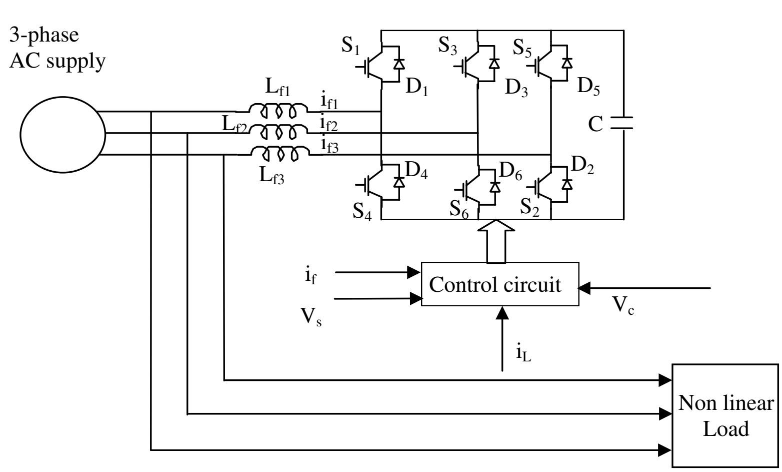

Fig. 1. The proposed shunt active power filter.