Available online at www.sciencedirect.com
SCIENCE DIRECT
Electric Power Systems Research 76 (2006) 857–864
ELECTRIC POWER SYSTEMS RESEARCH
www.elsevier.com/locate/epsr

A novel lowpass to bandpass transformed PI control strategy for series hybrid active power filter

N. Raghavan [a,b,*], T. Taleb [c], T. Ellinger [a], U. Grossmann [a], J. Petzoldt [a], K. Vasudevan [b], K.S. Swarup [b]

[a] *The Department of Power Electronics and Control, Ilmenau Technical University, D-98684 Ilmenau, Germany*
[b] *The Department of Electrical Engineering, Indian Institute of Technology Madras, Chennai, India*
[c] *The Department of Electrical Engineering, University of Jijel, Jijel, Algeria*

Accepted 3 July 2005
Available online 19 December 2005

Abstract

In this paper, simulation and experimental based evaluation of novel lowpass to bandpass transformed PI control strategy for series hybrid active power filter is presented. In the series hybrid topology, the active filter is in series with a capacitor and this whole arrangement comes in parallel with an inductor. This hybrid setup is introduced in series between the source and load. The control structure is derived in the stationary reference frame through lowpass to bandpass transformation of ordinary PI controller transfer function. The effect of controller on system performance as well as its selective harmonic elimination is illustrated. The modelling, simulation and experimental results are presented.

Keywords: Series hybrid active power filter; Lowpass–bandpass transformation; Stationary reference frame

1. Introduction

Nowadays, power electronics devices are utilized more and more widely in domestic and industrial applications. Power electronics offer economical and reliable solutions to better manage and control the use of electrical energy. However given the characteristic of most power electronics circuit they tend to introduce harmonics in voltage and current waveforms at the point of common coupling. An active filter provides a good solution to mitigate the problem of harmonics produced by non-linear loads. There are different topologies which are used for such filters namely shunt, series, hybrid shunt, hybrid series and shunt and series together as illustrated in numerous literatures [1–6]. However each one is used depending on the type of power quality problems namely whether the load is current harmonic or voltage harmonic generating load.

Amongst the various topologies shunt and series hybrid topology using voltage source inverter are most researched and developed ones. Also many control strategies have been developed in past decade in the area of active filter, but among these PQ-theory [1–6] is widely used. But in PQ-theory based harmonic control strategy, selective harmonic compensation is not possible. Recently control strategies based on stationary references frame are reported and have relative advantages in terms of reduced computational efforts. In [7], the authors transform the natural reference frame I-controller into the stationary reference frame where it appears as a complex oscillator. Feeding back the output signal of the complex oscillator [8] to its input yields a complex bandpass transfer function which has a gain of unity and zero phase delay at its resonance frequency. In [8], the author uses a dead beat inner current control loop along with the transformed I-controllers to have fast load current transient response. In [9] a novel PI based control strategy in the stationary reference frame is formulated and applied to the shunt active power filter. In [10] the authors reported a simulation study of a novel series hybrid filter. The use of PI controller and a transformed first order controller for this topology have been studied and compared.

This paper presents the lowpass to bandpass transformed PI based controller and the hardware verification study is done on a

* Corresponding author. Tel.: +49 3677 691536; fax: +49 3677 691469.
E-mail address: raghavan_snr@yahoo.com (N. Raghavan).

0378-7796/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.epsr.2005.07.007

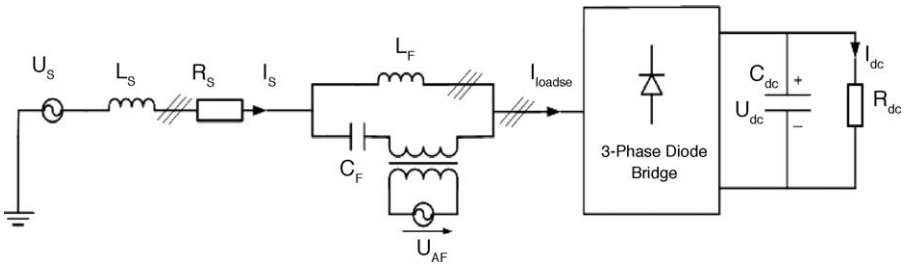

Fig. 1. Series hybrid filter configuration.

series hybrid active power filter. The non-linear load considered is a diode bridge with a filter capacitor and a resistor load. As against the implementations of I-controller in [8], an inner loop to control the inverter is not used since the injected quantity is a voltage. The transformed PI controller is modelled using the state space approach.

The proposed system for simulation is a 16 kW system as shown in Fig. 1. The basic idea for having hybrid structure is two-fold, one it forms a parallel resonance around fifth harmonic thereby effectively blocking it. Secondly, the hybrid structure provides two paths for the source current, working as a current divider. This current divider is designed such that the fundamental current flows through the inductor and most of the harmonic current flows through the capacitor and active filter. The fundamental current through the active part is therefore small, leading to the reduction in the KVA rating of the active filter. An experimental prototype of 16 kW rating is developed using the proposed control strategy. Simulation studies are done in MATLAB and experimental results are presented. The merits and demerits of this control strategy are brought out.

2. System configuration and modelling

The proposed simulation is carried out on a three-phase system consisting of balanced three-phase sinusoidal source voltage U_s of 400 V, 50 Hz with source inductance L_s of 500 μH. The source supplies a non-linear load which is a diode bridge converter of rating 16 kW. The values of the components and system parameters are listed in Table 1.

The series hybrid topology is shown in Fig. 1. It consists of inductor L_F and a capacitor C_F which forms a parallel resonant

Table 1
Component values and system parameters for simulation and experimental prototype

U_s	400 V
L_s	500 μH
L_{VSI}	240 μH
C_{VSI}	30 μF
L_F	1.34 mH
C_F	330 μF
C_{DC}	250 μF
R_{dcse}	15.0 Ω

circuit tuned at 4.8 times the fundamental frequency. The voltage source inverter (VSI) is connected through a transformer in series with capacitor C_F. In the simulation study, the transformer is taken to be ideal with transformation ratio 1:1.

The current through C_F is given by Eq. (1) where I_S is the source current and γ_{res} is the ratio of the harmonic to fundamental frequency called the harmonic number.

$$|I_C| = \frac{1}{\gamma_{res}^2 - 1}|I_S| \tag{1}$$

where

$$\gamma_{res} = \frac{\omega_{res}}{\omega_1} \tag{2}$$

From Eq. (1) we can calculate the fundamental current through the filter capacitor and active filter. For example, when ω_{res} is tuned at 230 Hz, γ_{res} equals 4.8. Then from Eq. (1) we get,

$$|I_C| = \frac{1}{(4.8)^2 - 1}|I_S| \tag{3}$$

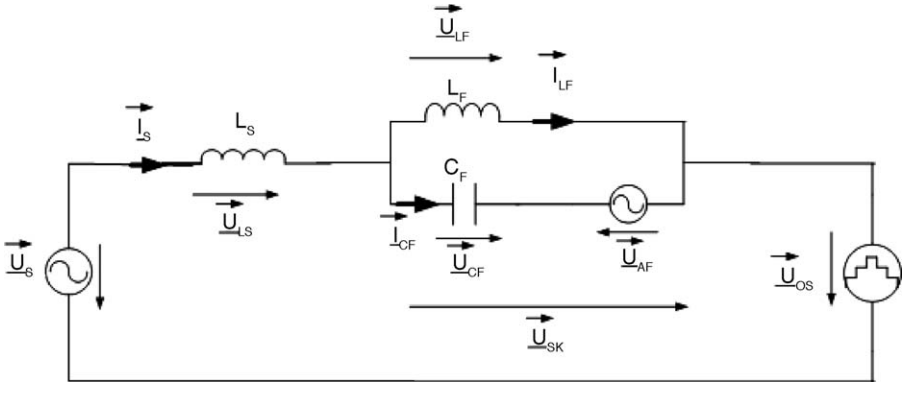

Fig. 2. Space vector equivalent circuit of the series hybrid active filter topology.