DISCRETE-TIME CONTROLLERS BASED ON THE INTERNAL MODEL PRINCIPLE FOR SHUNT ACTIVE POWER FILTERS

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***Abstract*— This paper presents an analysis and design of discrete-time controllers based on the internal model principle, applied to shunt active power filters. The presented control strategies are aimed to compensate the current harmonics produced by nonlinear loads connected to the point of common coupling in low voltage power grids. The proposed current controllers are based on the internal model principle operating with different sampling frequencies and for even and odd or only odd harmonics. It is demonstrated that the use of a downsampled rate, and fewer poles in the internal model, results in a straightforward digital implementation; improvement of the transient response; increasing of the stability margin of the closed-loop system and it is possible to obtain source currents with reduced total harmonic distortion. To validate the above claims and demonstrate the steady-state and transient performance, simulation results are presented.**

***Keywords*— Shunt active power filter, instantaneous power theory, internal model principle, downsampled controller.**

I. INTRODUCTION

The wide spread use of nonlinear loads such as uncontrolled rectifiers, electric motor drives, induction furnaces, electronic ballasts for discharge lamps and switching power supplies in a variety of power ranges; produces the injection of a high number of current harmonics in the low voltage power grids. This harmonics causes a distortion of the voltage waveforms in the point of common coupling with other loads. That distortion will be greater or smaller depending on the resulting impedance of the line section that being analyzed. In addition to, the current harmonics produce additional losses in the transmission lines and power distribution transformers, resonance effects with power factor corrector capacitors banks and malfunction of electronic equipment.

A classical solution to compensate the current harmonics is the use of shunt RLC notch filters. This results in a simple and highly efficient solution, but the good performance strongly depends on the equivalent impedance of the source. Additionally, the combination of this kind of filters with nonlinear loads and line impedance can cause undesired resonance effects resulting in high level voltage harmonics (Currence *et al.*, 1995). In the last years, by cost reduction and an improved of the power electronics reliability; there is a high preference to perform the compensation of current harmonics using shunt active power filters (SAPF). This results in an effective solution for low and medium power applications, reducing to acceptable limits the current harmonics injected by nonlinear loads (Bhattacharya *et al*., 1995; Akagi, 1996; El-Habrouk *et al*., 2000). Additionally, the SAPF in comparison to its passive counterpart allows a significant improvement of the transient response with load dynamic changes. Also, the control of SAPF can be done efficiently using digital control techniques programmed in DSCs (digital signal controllers) with reduced RAM. These devices allow a simple realization of control strategies which can only be done in the discrete-time domain; with the easily update of the different control techniques.

Concerning to the SAPF current control, exist an important contribution in the literature. The main used current control techniques are: hysteresis controllers, deadbeat controllers in stationary reference $\alpha\beta$ frame and synchronous reference *dq* frame, *plug-in* repetitive controllers in stationary and synchronous reference frames; and resonant controllers, also in both reference frames (Buso *et al*., 1998; Lindgren and Svensson, 1998; de Camargo and Pinheiro, 2005; Bojoi *et al*., 2005). The two last mentioned techniques, based on the internal model principle (Francis *et al.*, 1974) are implemented with considering that the sampling and switching frequency are the same. In the particular case of microcontrollers or DSCs with reduced RAM memory and low computational speed, the *plug-in* repetitive controller needs an important memory space with high sampling frequencies and require a high computational effort. Another drawback is that the system dynamic response is poor to load changes. This is due to the high number of delays of the periodic signal generator. Therefore, aiming to reduce the memory space, as well as the computational effort and even improve the overall performance of the system, in this paper it is demonstrated that an internal model based controller with a downsample rate allows achieving such improvements. This control strategy is named here *DSIM* or *downsampled internal model based controller*”. Furthermore, the proposed internal model based controller strategies, depending on the structure of the periodic signal generator, makes it possible to compensate the even and odd current harmonics; or only odd harmonics. These proposals are validated with simulation results and a performance comparative analysis is carried out to highlights the improvements.