Control Strategies of Selective Harmonic Current Shunt Active Filter

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Abstract— **This paper presents the possible calculation methodologies in order to design a selective shunt active filter. For realizing the selective extraction of harmonic sequences the modulation - filter - demodulation technique is used. The fundamental equations of this method are established in the case of pq theory showing its equivalence with the SRF (Synchronous Reference Frame) method. In order to prove the proposed ways of calculation real non-periodic currents data with a great harmonic distortion of an arc furnace are used; with the good results achieved shows the ability of filtering in a selective and controlled way the undesired current harmonics**

I. Introduction

In the last decades, the evolution of two aspects concerning power systems has created conditions for a more extended use of active filters. The first aspect is related to power semiconductor device development. Converters capable of synthesizing voltages and currents with an adequate bandwidth for harmonic current compensation at MVA - level are now available at competitive prices. The other aspect is the gradual application of regulations limiting the generation of harmonic currents by the customers.

Active filters are ideally suitable for filtering localized harmonic currents in a guided way. This allows to apply the concept "you dirty, you clean". This concept cannot be applied using conventional passive filters. In the same way, active filters allows to eliminate some of the problems of passive filters such as poor tuning due to dispersion of their characteristic parameters and resonances with the impedance of the surrounding electrical network which may appear.

Among the different methods for controlling active filters, the use of pq theory (active and imaginary power) [1], has demonstrated to be specially suitable. In particular, it has been used for separating the residual harmonics and thus eliminating (as theory indicates) or reducing (as it results in practice) the harmonic distortion. For the control of selective active filters several works use the SRF method (Synchronous Reference Frame) [2] [3] [4] [5] [6] which is definitively a particular case of applying the pq method with harmonic voltages as references. In this work, the contribution to this topic done in [7] is generalized.

The question of why canceling the harmonic distortion if the regulations does not require that; is presented and answered in [8]. The results obtained might be accepted by the applicable regulation, except for some harmonics that are difficult to reduce with this strategy. The question if better results could be achieved if each one of the harmonics is reduced in a controlled way in order to adjust exactly to the regulation arises naturally. One answer to this question is the use of selective filters.

II. PQ Theory, Harmonics and Sequence contribution to P and Q spectrum

Pq theory [1] is basically a time domain analysis tool. In a stationary periodic process it is possible to do a frequency domain analysis and current and voltage harmonic and sequences appear explicitly. The equations that are summarized here are explained in detail in [7] [9] [10].

$$\begin{aligned} v_k(t) &= \sum_{n=1}^{\infty} \sqrt{2} V_{kn} \sin(\omega_n t + \phi_{kn}) \\ i_k(t) &= \sum_{n=1}^{\infty} \sqrt{2} I_{kn} \sin(\omega_n t + \delta_{kn}) \end{aligned} \tag{1}$$

$$\begin{bmatrix} I_{on} \\ I_{+n} \\ I_{-n} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} I_{an} \\ I_{bn} \\ I_{cn} \end{bmatrix} \tag{2}$$

$$\begin{bmatrix} I_{an} \\ I_{bn} \\ I_{cn} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_{on} \\ I_{+n} \\ I_{-n} \end{bmatrix} \tag{3}$$

$$\begin{aligned} i_{an} &= \sqrt{2} I_{0n} \sin(\omega_n t + \delta_{0n}) + \\ &\quad \sqrt{2} I_{+n} \sin(\omega_n t + \delta_{+n}) + \\ &\quad \sqrt{2} I_{-n} \sin(\omega_n t + \delta_{-n}) \\ i_{bn} &= \sqrt{2} I_{0n} \sin(\omega_n t + \delta_{0n}) + \\ &\quad \sqrt{2} I_{+n} \sin(\omega_n t + \delta_{+n} - \frac{2\pi}{3}) + \\ &\quad \sqrt{2} I_{-n} \sin(\omega_n t + \delta_{-n} + \frac{2\pi}{3}) \\ i_{cn} &= \sqrt{2} I_{0n} \sin(\omega_n t + \delta_{0n}) + \\ &\quad \sqrt{2} I_{+n} \sin(\omega_n t + \delta_{+n} + \frac{2\pi}{3}) + \\ &\quad \sqrt{2} I_{-n} \sin(\omega_n t + \delta_{-n} - \frac{2\pi}{3}) \end{aligned} \tag{4}$$

Current and voltage of a, b and c phases are given in (1), (2) and (3) are the direct and inverse calculation

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