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A predictive current control method for shunt active filter with windowing based wavelet transform in harmonic detection

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ABSTRACT

This paper has been established based on harmonic detection and compensation on power system. The present work deals with two powerful methods in harmonic detection field of digital signal processing. The first one is the windowing technique and the other one is wavelet transform. A traditional synchronous fundamental dq-frame algorithm is modified in filtering process. As an improvement, the Fourier-based low pass filter is replaced with a windowing–wavelet method. The adopted windowing aspect is Hamming window to reduce traditional rectangular window effete in frequency domain. In addition, the applied mother wavelet is selected in terms of its effectiveness on transient response, low overshot and low oscillation at frequency domain. Due to these concepts, the db8 is selected as mother wavelet. In harmonic elimination procedure, the detected harmonic is injected using a shunt active filter based on predictive current control technique. The presented method has been verified with MATLAB–SIMULINK model and wavelet toolbox. The results confirm that this method is superior to traditional FFT based and wavelet based filters because of fast transient response and small negligible sidelobes. As a consequence this technique is able to reduce power system harmonic.

1. Introduction

An unrelenting proliferation of nonlinear loads in industrial, commercial, and residential applications requires the supply of reactive power, harmonics power, and power losses pertaining to the former two [1]. Different solutions to minimize the effects of nonlinear loads in electric power systems (nonsinusoidal voltages, harmonic currents, nonbalanced conditions) have been proposed. As a mater of fact, there is various types of compensators proposed to increase the power system quality [2–4]. One of those compensators is the active power filter (APF). Usually, the voltage source is preferred to implement the parallel active power filter since it has some advantages [2].

The operational process of the active filter can be divided into two stages, one dedicated to the identifying current harmonics and the other one to the compensation of identified current with injection it into power network.

Up to now, different algorithms emerged for the harmonic detection, which consider the detection accuracy, the speed, the filter stability, easy and inexpensive implementation, etc. The classification of these methods can be done regarding to the domain where the mathematical model is developed. Therefore three major directions are based on analysis of time, frequency and time–frequency domain [5].

Traditionally, electrical power quantities are calculated using time and frequency domain approaches. Power quantities in the frequency domain are obtained using Fourier transforms yielding amplitudes and phase angles of voltages and currents involved. The voltage and current signals have become less stationary and the periodicity is often lost completely. This fact

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poses a problem for the correct application of Fourier-based frequency domain power quantities. Practical measurements use the fast Fourier transform (FFT) algorithm, implicitly assuming the infinite periodicity of the signal to be transformed. Therefore, the registered frequency domain quantities are often meaningless and unreliable to be used in power conditioner control [6].

The time domain methods are mainly used to gain more speed or fewer calculations compared to the frequency domain methods [5]. One of the most popular methods based on time domain analysis is synchronous fundamental dq-frame. As shown in Fig. 1, one drawback is the slow time response of the traditional low pass filter versus steady state error.

Among the many methods that have been developed in the field of harmonic detection and generating reference current in frequency domain (such as: fast Fourier transform, discrete Fourier transform, recursive discrete Fourier transform) and time-domain (such as: synchronous fundamental dq-frame, synchronous individual harmonic dq-frame, instantaneous power pq-theory, generalized integrators) some new methods are proposed based on time–frequency domain.

The fundamental restriction in obtaining the time–frequency information, especially for short time records, is that we cannot localize both time and frequency to arbitrary precision. Recent approaches are based on expressing signals in terms of wavelets (much like the Fourier series) [7]. Wavelet transform has the advantage of using a variable window size for different frequency components. This allows the use of long time intervals to obtain more precise low-frequency information and shorter intervals for high-frequency information [8].

Wavelet transform (WT) is a powerful signal processing tool for computing time–frequency representation of power signals [5]. The paper that proceeded to investigate WT on power system harmonic and noise detection are listed in [6,9–16]. Yalazan et al. [11] proposed a discrete wavelet transform based on fundamental positive sequence in order to obtain the reference currents for APF. This paper uses symmetric component of any unbalanced currents and six-level wavelet decomposition. Among these methods, Gupta et al. [12] proposed a WT based controller of APF using synchronous fundamental dq-frame. In this paper, the low pass filter (LPF) shown in Fig. 1 is replaced with a wavelet based filter. In addition to the series and shunt active filters, the wavelet transforms has been used to extract the fundamental component of load current and source voltage in the unified power-quality conditioner (UPQC) [16]. Forghani and Afsharnia used the positive sequence of three phase system voltages and load currents to calculate the voltage and current references of UPQC active power filters. The proposed control strategy extracts the reference currents and voltages of UPQC fast and accurately in the presence of harmonics and/or frequency oscillation.

Due to more advantage of the synchronous fundamental dq-frame an accurate method with fast transient in harmonic detection will be proposed in this paper. As a matter of fact, the response to sudden changes over a few periods is an effect similar to what is visible in other compensation methods where some kind of signal filtering is required: there is a trade-off to be made between accuracy and fast transient response.

In the second stage of the APF control, there are different methods in reference current injection process. Two such methods are distinguished as PI controller based (fixed frequency control) and hysteresis current control (tolerance band control with fix and adaptive band) [17]. With the development of powerful and fast microprocessors, several works have been dedicated to predictive current control. Predictive current controller is the most commonly used as it is suitable for DSP implementation, has more precise current control, has minimum distortion, and provides good static and dynamic performance. Advantages of this method are modeling of nonlinear situation of system on the basis of calculating different treatments of system variants. Heretofore, predictive technique is used in the power electronics domain as a controlling system to decrement switching power loss in high power inverters. In [18–20], there is a method presented on the basis of predictive current control for voltage source inverters that increase dynamic response of inverter control system. In the field of active filters, one of the first concepts of predictive current control had been applied in [21,22]. Massoud et al. [23] extended the suggested predictive current control (PCC) technique into shunt active filter.

Among all methods mentioned above, the proposed WT method will be discussed and accompanied with synchronous fundamental dq-frame in order to make reference current of converter (shunt active filter). The reference current made in the first stage (harmonic term of nonlinear load current) will be injected by using predictive current control of the voltage source inverter. To verify the theoretical analysis, computer simulation in MATLAB–SIMULINK has been used and tested with a rectifier load. The obtained result indicates that the method is accurate and computationally efficient

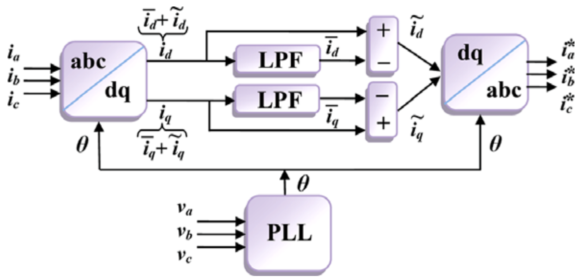

Fig. 1. Principle algorithm of the synchronous fundamental dq-frame.