Stability and accuracy of Digital Filters in the presence of Interharmonics

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1. Introduction

One of the main goals of a digital filter is estimating the harmonic spectrum present in an electrical signal being analyzed. Furthermore, the estimating process is critical in the field of digital relaying. This is because the accuracy in the output of the phasor estimator is directly related with a good performance of the protection device.

Nowadays, digital relays have to cope with input signals of an increasing complexity, mainly due to the presence of an increasing amount of nonlinear elements within the electric power systems. Simultaneously with the regular harmonic spectrum, it may appear a complex set of interharmonics. This implies the necessity of developing new digital filters for protection purposes [1]. So, it will be of a great importance to know the influence of interharmonics in the accuracy of algorithms being developed for relaying tasks.

This paper is mainly focused on the influence of interharmonics in the outputs of digital filters. The analysis carried out shows clearly that new digital filters must be designed taking into account the undesirable components present in the signals of an electric power system.

Keywords: Digital filter, phasor estimation, interharmonics, protection relays.

2. Interharmonics in electric power systems

Control and regulation technologies have an increasing importance in electric energy systems. Lately, nonlinear elements based on power electronic have emerged into electric power systems. These elements distort the waveform of electrical signals adding harmonics and interharmonics to the fundamental component.

Harmonics are sinusoidal components which frequency is an integer multiple of the fundamental frequency while interharmonics are sinusoidal components which frequency is not an integer multiple of the fundamental frequency.

Harmonic frequency: $f = k \cdot f$
Interharmonic frequency: $f \neq k \cdot f$

Where f is the fundamental power system frequency and k is an integer.

As the presence and relevance of interharmonics is increasing [2], it is necessary to know its influence on the different parts of the electric power system. Digital filters are heavily affected by such components. These devices receive current and voltage signals and, after an internal calculation process, they must discriminate among normal or abnormal operating system conditions.

The fundamental step of this signal processing is the phasor estimation. The signal is filtered to obtain the phasor corresponding to a specific frequency (normally is the fundamental frequency). This data will be used by the protection functions to evaluate if the relay must operate. Consequently, phasor estimation must be fast and accurate in order to guarantee a correct performance of the protection relay.

Digital filters are commonly based on algorithms of three different types: Type I: algorithms based on matricial methods such as LES (Least Error Squares); Type II: methods based on the MIMIC filter approach and Type III: modified versions of DFT (Digital Fourier Transform). However, all of them have been developed without taking into account the presence of interharmonics in the filtered signal. Consequently, it is necessary to analyze the response of digital relays under the new operation conditions. With this goal, the first step is to know in detail the influence of interharmonics in the behaviour of digital filters used nowadays for protection purposes.

Recently, a lot of research has been carried out and many papers have been published on the field of interharmonics. Nevertheless, those methods are focussed on detecting and estimating interharmonics[3, 4]. They are not meant for protection devices as a great number of cycles is involved in the calculation process.

By all these reasons, the proposed paper shows the influence of interharmonics in modulus and argument estimation in order to quantify the errors in the output data supplied by the digital filter to the protection functions.

3. Influence of interharmonics in digital filter behaviour

Figures 1 and 2 show the results obtained from filtering a signal composed by fundamental component (50 Hz), harmonics (150 and 250 Hz) and interharmonics (112 and 177 Hz). As it can be seen from the figures below, the presence of interharmonics causes a non-decaying oscillation. The consequence of it is an uncertainty in the phasor measured by the protection functions and a possible protective relay misoperation.

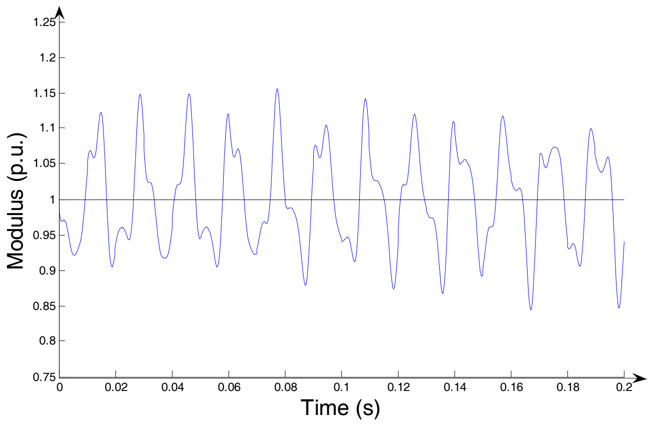

Figure 1. Modulus estimated for the fundamental component.

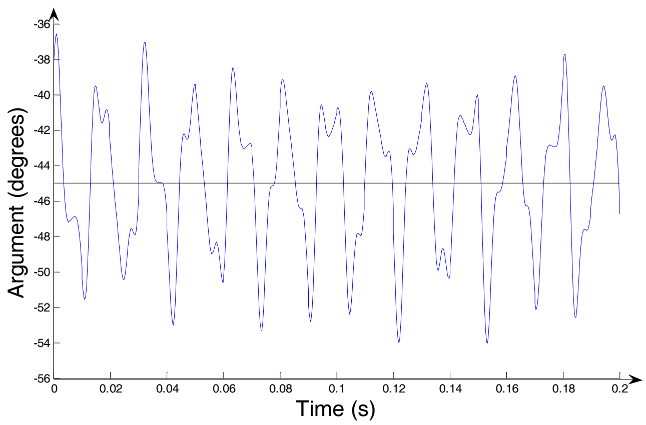

Figure 2. Argument estimated for the fundamental component.

The full paper shows the results corresponding to three different digital filters (Type I, II and III). The results are analyzed in order to establish the relation between the amplitude of non-decaying oscillations and the different characteristics of interharmonics (frequency, modulus and argument).

4. Conclusions

Results show that the output data from a digital filter are heavily influenced by the presence of interharmonics in the analyzed signal. Consequently, these unexpected components must be taken into account through the development of appropriate algorithms in the field of digital relaying.

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