Electric Power Systems Research 80 (2010) 1191–1196

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Performance of three algorithms for frequency measurement under transient conditions

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ARTICLE INFO

Article history:
Received 30 November 2009
Received in revised form 10 March 2010
Accepted 15 March 2010
Available online 26 May 2010

Keyword:
Frequency measurement

ABSTRACT

This article compares the transient performance of three algorithms for electric frequency measurement. The algorithms are based on different techniques: (a) measurement of intervals between zero-crossings; (b) adjustment of points to a sinusoidal waveform; and (c) measurement of phase shift between fundamental components of Discrete Fourier Transform. The comparison was performed by application of the three algorithms to signals obtained by numerical simulation and to voltage waveforms sampled in experimental cases. For the case of numerically simulated signals, a theoretical frequency was defined as a reference value for the comparison with the measured values. In the experimental sampled waveforms, the effect of abrupt signal changes and the effect of filters are shown. The characteristics of the filters were selected to obtain a similar time delay in the measurement of a step in the frequency. With such filters, the three algorithms showed a similar transient behavior in all the analyzed cases. The analysis of the effect of harmonic distortion in the voltage signal is out of the scope of this article.

1. Introduction

It is usually necessary to compute the value of the electrical frequency of power systems, in order to perform protection or control actions, to start an information storage activity, or to analyze the waveforms of voltage records. Recently, the electrical frequency value has acquired another special relevance due to its application for power quality evaluation.

Different methods for the digital measurement of the frequency have been developed in the last decades, for example: (a) use of signal zero-crossings and digital counters, without computer algorithms [1,2]; (b) use of the fundamental components of the Discrete Fourier Transform (DFT) [3]; and (c) other methods [4–12]. The literature on this subject is very extense, and the references show only a small sample of the published articles. The signals are not periodic under transient conditions, therefore a mathematical definition of the frequency does not exist in such cases. By this reason, it is not obvious which is the reference value of the frequency for the cases presented in some articles [8–10], even when other articles show a clear description of the transient behavior of the frequency [11,12]. Recently, an article highlighted the necessity of a standard for the measurement of the frequency under transient conditions [13].

The effect of harmonic distortion on the frequency measurements is seldom a concern in electrical transmission systems. For example, frequency relays based on signal zero-crossings are commonly used in such systems [14,15]. The analysis of the effect of harmonic distortion on the frequency measurements is out of the scope of this article.

The purpose of this article is to compare the transient behavior of three different algorithms for digital measurement of the frequency. The comparison was performed by application of the three algorithms to signals obtained by numerical simulation and to voltage waveforms sampled in experimental cases. The characteristics of the filters were selected to obtain a similar time delay in the measurement of a step in the frequency and, with such filters, the three algorithms showed a similar transient behavior in all the analyzed cases. The transient behavior of the three algorithms is similar but it is not identical; this result reinforces the idea about the necessity of a standard for the measurement of the frequency under transient conditions.

2. Description of the algorithms

2.1. Algorithm based on signal zero-crossings

This algorithm is based on the measurement of the time interval between two zero-crossings of the sampled signal. The exact time of the zero-crossing is obtained by linear interpolation between two consecutive samples of different sign. During the time interval between two zero-crossings, it is possible to assume that the

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doi:10.1016/j.epsr.2010.03.008