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Abstract

It is known that the quality of power has been the subject of several researches aiming to provide relevant information to users of electrical systems that are becoming increasingly smart. This study presents an approach for single and multiple power quality disturbance detection and classification using multidimensional analysis, higher-order statistics and a neuro-tree based classifier. The system was implemented in an FPGA (Field Programmable Gate Array), a real-time processor and a remote computer, with LabVIEW interface. This implementation enables real-time execution and its application to monitor smart grids. It is able to detect deviations in the measured voltage waveform from the nominal one and classify 20 classes of single and multiple disturbances with a global efficiency upper to 97%.

Keywords: Higher-order statistics, Neuro-tree, Real-Time, LabVIEW

1. Introduction

The development of the electrical system and the insertion of several types of nonlinear loads in the power system have caused growing interest in the area of Power Quality (PQ). The first mention of the term occurred, according to [1], in 1968, in a U.S. Navy study. Since then, technologies have emerged and many of these have been introduced into the power distribution system, leading to the development of Smart Grids [2], [3]. This scenario reaffirms the relevance position of the PQ area.

The consequences of a poor PQ involve the malfunction of electronic devices and may even lead to their loss. This certainly creates costs, which can be divided into direct costs, indirect costs and non-material inconveniences [4]. According to [5], PQ costs in industry and commerce, in the European Union, are estimated in 10,000 million EUR per year.

The term "Power Quality" is related to the characteristics of both current and voltage waveforms. According to [1], PQ is the combination of voltage quality and current quality, not the deviation of the product of voltage and current (the power) from an ideal shape. According to [6], PQ is the branch of science that studies all variations that can appear on the ideal waveform of the current and voltage in a generic electric power network.

Deviations in voltage waveforms are referred as disturbances and grouped according to their characteristics on both time and frequency. Definitions of PQ disturbances can be found in [7].

To determine the causes and sources of disturbances, one must have the ability to detect and classify these disturbances [8]. These activities are recommended before appropriate mitigating action can be taken. Thus, works in the area of detection and classification of PQ disturbances, data compression and real-time systems are widely disseminated. A brief review of the scenario is made as follows.

Signal analysis by means of time-frequency representations is the most used technique in the feature extraction stage of a PQ disturbance detection and classification system. The concept of the S-transform was directly applied in [9, 10, 11, 12, 13]. Other aspects of this transform can be found in some works such as: Discrete Orthogonal S-Transform [14] and Fast S-Transform [15]. Similar to S-transform, the Wavelet transform is also quite widespread and presents its differentiations. In [16, 17, 18, 19, 20], the Wavelet transform was applied to PQ analysis without major modifications. In [21], the Fourier transform was applied and in [22], the short-time correlation transform (STCT) was also implemented. In [23], it was used the Wavelet Packet Transform and in [24], the Maximum Overlapping Discrete Wavelet transform and the Second Generation Wavelet transform were implemented. Another time-frequency representation is the Gabor-Wigner transform, applied in [25]. In [26], an improved Curve Fitting Algorithm (CFA), which is based on a least squares formulation, was presented and power quality parameters

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