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Novel power quality indices based on wavelet packet transform for non-stationary sinusoidal and non-sinusoidal disturbances

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ABSTRACT

High power quality (PQ) level represents one of the main objectives towards smart grid. The currently used PQIs that are a measure of the PQ level are defined under the umbrella of the Fourier foundation that produces unrealistic results in case of non-stationary PQ disturbances. In order to accurately measure those indices, wavelet packet transform (WPT) is used in this paper to reformulate the recommended PQIs and hence benefiting from the WPT capabilities in accurately analyzing non-stationary waveforms and providing a uniform time–frequency sub-bands leading to reduced size of the data to be processed which is a necessity to facilitate the implementation of smart grid. Numerical examples' results considering non-stationary waveforms prove the suitability of the WPT for PQIs measurement; also the results indicate that Daubechies 10 could be the best candidate wavelet basis function that could provide acceptable accuracy while requiring less number of wavelet coefficients and hence reducing the data size. Moreover, a new time–frequency overall and node crest factors are introduced in this paper. The new node crest factor is able to determine the node or the sub-band that is responsible for the largest impact which could not be achieved using traditional approaches.

1. Introduction

Recently, power quality becomes an important topic due to the renewed interest in improving the quality of the electricity supply as a requirement for the smart grid. Ref. [1] presented many definitions for the term power quality. Nowadays, evaluating the electric power quality has gained so much attention since delivering power at high quality level represents one of the basic foundations that the smart grid stands on.

The increased use of nonlinear loads such as power electronics-based devices, adjustable speed drives (ASD), personal computers (PCs), uninterruptible power supplies (UPS) and electric arc furnaces (EAFs) in the electric power system over the last decades; create distorted (non-sinusoidal) currents even when supplied with purely sinusoidal voltage. These distorted currents cause voltage and current distortion throughout the system which deteriorates the quality of the electric power that is supplied to consumers owing sensitive devices to voltage and/or current variations.

These PQ disturbances can be classified as stationary and non-stationary based on the statistical characteristics of the voltage and current waveforms. Stationary waveforms have time-invariant statistical characteristics, while non-stationary waveforms have time-variant statistical characteristics and they could be sinusoidal or non-sinusoidal.

Since PQ disturbances can lead to poor power quality which may have negative impact on the economic operation of the electric power system, therefore evaluating the electric power quality becomes very essential for both utilities and consumers especially when moving towards smart grid.

Accurate evaluation of the electric power quality requires accepted and approved indices to quantify the effect of different power quality disturbances. These indices should accommodate present distorted waveforms. Modern accurate power quality indices should reveal and quantify the undetected disturbances (such as sags, swells, and harmonic distortion) that are most often associated with what is called "hidden costs" [2].

Existing power quality indices are based on the Fourier foundation [3–7]. Fourier series and Fourier transform can provide accurate results only for stationary waveforms along with satisfied Nyquist criterion and with sampling frequency being an exact integer multiple of the waveform fundamental period with no time-varying harmonics [8]. If one of those conditions is not met, Fourier transform produces large errors for the measured quantities and

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