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Editorial

New Power Quality Measurement Techniques and Indices in DC and AC Networks

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Currently, we are living through the implementation of the electrical smart grid, a network that can intelligently integrate the actions of all users connected to it in order to efficiently deliver the sustainable, economical and secure supply of electricity. The development of the smart grid is vital for the integration of renewable energy resources and energy saving equipment.

Two main developments are necessary in the implementation of the smart grid; namely, new advanced instruments with the accuracy and processing capacity necessary to fulfil the requirements of future distribution systems, and a high-quality power supply that meets the range of needs of current and future users.

The problems associated with the quality of the energy supply have been growing and have evolved with the evolution of the power network itself. The power quality indices in use today have been used for more than twenty years. New types of disturbances and a greater frequency of occurrence of existing disturbances are increasing with the growth of new types of power generation and with the development of new equipment or existing equipment that relies on new technologies, and this requires additional power quality indices to properly track and study them. The application of the European energy efficiency directives will accelerate this process even more due to the recommendation for the progressive substitution of equipment with more energy efficient devices that decrease greenhouse effects and energy consumption.

Overvoltages, voltage unbalances, power oscillations, voltage fluctuations, rapid voltage changes, high-frequency distortions and new sources of harmonic and interharmonic distortions and flicker emissions are some of the most common power quality issues when connecting distributed energy resources to the power network, such as photovoltaic systems, wind turbines, new lighting equipment, or new equipment with new technologies. This situation requires updating the existing power quality indices and defining new indices in order to provide additional information to better characterize the new power quality aspects in present and future power system networks; it also requires the definition of new emission and new immunity limits, as well as the development of new measurement techniques and new equipment.

In addition, the growing use of low-voltage direct current distribution networks in commercial and residential buildings, data centers, industrial facilities and lighting equipment requires defining and standardizing new indices for the accurate characterization of the energy supplied, as in the case of AC networks. The power quality issues in DC networks are related to differences between the ideally constant voltage in a DC system and the actual voltage provided by power electronic converters. Voltage oscillation, transient and short-circuit overcurrents, and voltage ripple and harmonics are some of the most common power quality concerns identified in DC networks.

This Special Issue on “New Power Quality Measurement Techniques and Indices in DC and AC Networks” includes ten papers covering some of the main issues regarding power quality in existing AC and DC networks, ranging from the current status and future trends in power quality analysis [1,2], to power quality in railway power supply systems [3], the

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measurement of harmonic and interharmonic distortion [4], the simultaneous measurement of low- and high-frequency harmonic distortion [5], the application of new signal processing tools for the detection and classification of power quality disturbances [6,7], the effect of power quality disturbances on new equipment [8], and, finally, the power quality in DC grids [9,10].

Reference [1] presents a systematic literature review on the power quality trends in several fields related to instrumental techniques used to visualize the quality of the energy supply in the smart grid that consider instruments and signal processing methods, both in the time domain and in the frequency domain, for the detection and classification of power quality disturbances, including complex events that result from the sum of several types of simple events. The authors reviewed 153 papers that carried out a power quality analysis and that were published over the last few years.

D. Lumbreras et al. present in [2] a review of the power quality standards applicable to energy suppliers, equipment manufacturers and users, and their different responsibilities in complying with the different regulations. The paper compares the characteristics of different types of harmonic filters, including passive, active and hybrid filters, and presents the results obtained in different real networks with active power filters, which are the most flexible and the most cost-effective solution for low-voltage grids, and which were used to mitigate the distortion within the limits specified in the standards.

Power quality phenomena in electric railway power supply systems are reviewed by H.J. Kaleybar et al. in [3], as they are one of the most critical, high-power loads of utility grids, including AC and DC systems. This paper presents an extensive review of power quality distortion phenomena in different configurations of the electric railway power systems, such us unbalance; harmonics and interharmonics; reactive power; transient events that are impulsive and oscillatory; short- and long-duration rms variations; flicker; waveform distortion; and conducted, induced and radiated electromagnetic interference. A systematic classification of these phenomena was proposed. Some 145 scientific papers were studied and characterized, providing an interesting perspective on the status of power quality indices.

In reference [4], the authors review the different harmonic indices, defined both in the technical literature and in the standards, and analyze which of these distortion indices are most suitable for assessing the harmonic distortion in modern electrical systems that have interharmonics and harmonics in the supra-harmonic range (>2 kHz), distortion produced by renewable energy systems, and equipment with power electronic converters.

The assessment of waveform distortion of very wide spectra, which includes components in the range from 0 Hz to 150 kHz, is very important in modern distribution networks. The problem is complex in terms of time window length and frequency resolution. Low-frequency components are mainly synchronous, whereas high-frequency components are commonly asynchronous and often nonstationary with fast dynamics. L. Alfieri et al. propose in [5] a method for the simultaneous assessment of spectral components in a range from 0 Hz to 150 kHz that provides an accurate estimation of amplitude, phase angle and frequency of the spectral components. The discrete wavelet transform is applied to divide the original signal into low-frequency and high-frequency waveforms, and a sliding-window modified ESPRIT method analyzes the two passbands for a separate estimation of the low-frequency and high-frequency components with different time-frequency resolutions and time behaviors.

An approach based on the use of a modified combination of the Stockwell transform and a decision tree method is proposed in [6] for the detection and classification of power quality disturbances. The Stockwell transform is used to estimate different statistical features of the power quality disturbance, including the distinction between stationary and nonstationary disturbances, and then classifies these features into different disturbances using the decision tree method. The results obtained using simulated and real data show a good performance of the method proposed.

A combined analysis of long-term power quality data using a cluster analysis and newly defined global power quality indices is proposed in [7] for the assessment of power quality in electric power networks with distributed generation. The cluster analysis is used for the identification of power quality data that represent different conditions, and the global power quality indices are used for the comparative assessment of the identified clusters. The method proposed can be considered as an alternative approach to a classical multiparameter analysis of power quality data for the assessment of long-term multipoint measurements.

The sensitivity of modern lighting equipment to different types of rapid voltage changes, a type of power quality disturbance whose number of occurrences is expected to increase with the increasing penetration of distributed energy resources, is measured and analyzed in [8]. The authors report a high dispersion in the response of modern lamps, and mainly, LED lamps, and high values of the instantaneous flicker sensation index were measured with a light flickermeter, although with a lower sensitivity than the standard incandescent lamp. The authors propose a new immunity test to be added to the lamp immunity protocol to ensure that new lamps do not cause irritation to the users of the electrical grid.

Finally, the definition and measurement of power quality disturbances in low-voltage and medium-voltage DC distribution networks is addressed in references [9,10]. In [9], the authors propose some power quality indices for the detection and accurate characterization of voltage supply interruptions, rapid voltage changes and voltage ripples, reporting the results obtained in different laboratory tests using DC voltage shapes delivered by different DC power source types. On the other hand, A. Mariscotti presents in [10] the most comprehensive review of the power quality phenomena and the existing standards in low-voltage and medium-voltage DC networks, including electric transportation, all-electric ships, and craft and electric vehicles. The paper defines metrics for different power quality disturbances, such as harmonics, ripples and transients, analyzing their effect on equipment. The paper includes 156 relevant references on the topic.

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