Emerging signal processing techniques for power quality applications (editorial)

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Editorial

Emerging Signal Processing Techniques for Power Quality Applications

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The use of signal processing for power quality applications is not a new idea, as several researchers have used signal processing for more than a couple of decades. In the past few years, however, there has been a renewed interest in exploiting signal processing techniques for power quality measurements and analysis. The rationale for such enthusiasm is that signal processing techniques, indeed, provide meaningful and valuable information about voltage and current signals. As a result, a better understanding of time-varying, time-invariant, and transient behavior of power systems can be obtained.

By looking into the development offered by signal processing techniques to the analysis of other well-known signals, such as speech and image, we speculate that we are just at the beginning of a challenge revolution in the power quality field. In fact, the use of signal processing techniques can impact the way that voltage and current signals are measured and analyzed in power system field. In the regards, we point out that power quality analysis is a new research area for the signal processing community as it requires the development of powerful and efficient methods dedicated to emerging power quality problems, for example, pattern classification, multiresolution analysis, statistical estimation, adaptive and nonlinear signal processing, and techniques that can be implemented on power quality (PQ) monitoring equipment.

To this end, two strategies for PQ analysis have been used for tracking long-term, short-term events and variations: (i) a centralized data processing approach, usually demanding large bandwidth for the data transmission and large computational power in the central processing facility, and (ii) a decentralized approach that requires powerful DSP (digital signal processor), FPGA (flexible programmable gate array) or ASIC (application-specific integrated circuit) chipsets for fast implementation of PQ monitoring equipment and low communication bandwidth. In the second strategy, low-complexity algorithms are required so that feasible and low-cost solutions for PQ monitoring equipment implementation may be achieved. The introduction of signal processing techniques for both strategies is indeed challenging issues for the development of new monitoring solutions for PQ applications.

We would like to point out that this is the first special issue on power quality ever made in a signal processing-oriented journal. It is interesting to note that research in these subject areas are most likely to appear in the power system-related journals. The purpose of this special issue is to bring together works done by researchers with different background in signal processing, power systems, and power quality with the common goal of developing a better understanding about the applicability of signal processing in the power quality field and of drawing the attention of the signal processing and power system communities to this challenging field.

We have accepted 11 papers for this special issue. They are divided into four categories: challenges and trends, classification, detection, and diagnosis, transient modeling and analysis, spectral analysis. Most of these papers contain results validated by measurements. Although we believe that theories and experiments should always go hand in hand, we also wish to highlight to the readers with the latest analytical results on signal processing for PQ applications.

(A) Challenges and trends

The first paper is "Challenges and trends in analysis of electric power quality measurement data" by MacGranaghan and Santoso. The paper has reviewed some PQ-related research and identified a list of interesting and important challenging issues in PQ. The discussed issues can dramatically increase the value of power quality monitoring systems and provide the basis for ongoing research into new analysis and characterization methods and signal processing techniques.

(B) Classification, detection, and diagnosis

The classification and diagnosis of power quality disturbance sources is a very timely topic. In fact, nowadays, a great deal of attention is placed on the identification of the source of disturbances and on the classification of multiple types of disturbances as a result of being the problem related to single disturbance classification very well addressed so far. One can note that correct classification of disturbances in electric signals is valuable information in order to correctly identify the sources of power quality disturbances. As a result, we have selected three papers that deal with classical and advanced pattern classification approaches.

Additionally, the detection of disturbances as well as their start and end points (segmentation) in electric signals are important functionalities required by PQ equipment. The correct detection and segmentation of disturbances in electric signals simplifies the use of other signal processing techniques allowing a deeper analysis of the power quality disturbances. Only one paper is presented on the detection topic.

The second paper "Classification of underlying causes of power quality disturbances: deterministic versus statistical methods" by Bollen et al. presents two main categories of classification methods for power quality disturbances based on their underlying causes: deterministic classification, giving an expert system as an example, and statistical classification, illustrated by support vector machines. This important issue provides a way to identify the underlying causes of power quality disturbances measured.

The third paper, "Classification of single and multiple disturbances in electric signals," by Ribeiro and Pereira, introduces a different perspective for classifying single and multiple disturbances in electric signals, such as voltage and current signals. The principle of "divide to conquer" is applied to decompose electric signals into what the authors refer to as "primitive signals or components" which can be independently recognized. As a result, different sets of disturbances can be classified with a good performance.

The fourth paper is "Wavelet transform for processing power quality disturbances," by Chen and Zhu. A large part of this paper contains the review of wavelet theories and existing applications in PQ. Although they are known, the paper gives some useful summaries. In the last part of this paper, a method combining wavelet transform and rank correlation is described for the identification of capacitor-switching transients.

The fifth paper "Detection of disturbances in voltage signals for power quality analysis using HOS" by Ribeiro et al. describes a higher-order statistics (HOS)-based technique for detecting abnormal conditions in voltage signals. The main advantage is the capability to detect voltage disturbances start and end points in a short frame length. The technique can be useful when fast detection of power quality disturbances is required.

(C) Transient modeling and analysis

We can state that the steady-state behavior of electric signals are well-addressed by techniques developed so far. However, understanding transients and associating them with the underlying events in electrical power systems remain an open issue in power quality field. We have accepted three papers about this subject.

The sixth paper is "On the empirical estimation of utility distribution damping parameters using power quality waveform data," by Hur et al. This paper describes an efficient, yet accurate, methodology for estimating system damping. The technique is based on the linear dynamic system theory and on the Hilbert transform for damping analysis. The approach mainly addresses capacitor switching transients. The detected envelope of the intrinsic transient portion of the voltage waveform after capacitor bank energizing and its decay rate along with the damped resonant frequency are used to quantify the effective X/R ratio of a system.

The seventh paper is "Prony analysis for power system transient harmonics," by Qi et al. The paper describes the use of Prony method for estimating the parameters of time-varying power system transient harmonics, being transient signals modeled as sinusoids associated with exponential increase or decay. The method is applied to simulated transients as a result of transformer energizing and induction motor starting. The estimated dominant harmonics are also used as harmonic reference for harmonic selective active bandpass filters.

The eighth paper is "Modeling of electric disturbance signals using damped sinusoids via atomic decompositions and its applications," by Lisandro et al. In this paper the authors present a tutorial reviewing the principles and applications of atomic signal modeling of electric disturbance signals. As well addressed by the authors, the disturbance signal can be modeled using a linear combination of damped sinusoidal components which are closely related to the phenomena typically observed in power systems. The signal model obtained is then employed for disturbance signal denoising, filtering of "DC components," and compression.

(D) Spectral analysis

Spectral analysis in power quality field is not new if one considers the steady-state scenarios and is well-addressed in the literature. However, spectral analysis is an interesting issue when one considers spectral components of electric signals subject to time-varying behavior. These signals result from the increasing use of nonlinear loads in power system. In such challenging situations, improved spectral analysis methods are required since traditional methods may fail under time-varying conditions.

Achim et al. authored the ninth paper "Localized spectral analysis of fluctuating power generation from solar energy systems." The authors propose the treatment of fluctuations in solar irradiance as realizations of a stochastic, locally stationary, wavelet process. Its local spectral density can be estimated from empirical data by means of wavelet periodograms. The wavelet approach allows the analysis of the amplitude of fluctuations per characteristic scale, hence, persistence of the fluctuation. The approach is especially useful for network planning and load management of power distribution systems containing a high density of photovoltaic generation units.

The tenth paper is "Accurate methods for signal processing of distorted waveforms in power systems," by Carpinelli et al. The authors stated one of the primary problem in waveform distortion assessment in power systems which is to examine ways to reduce the effects of spectral leakage. In the framework of DFT approaches, line frequency synchronization techniques or algorithms to compensate for desynchronization are necessary; alternative approaches such as those based on the Prony and ESPRIT methods are not sensitive to desynchronization, but they often require significant computational burden. In this paper, the signal processing aspects of the problem are considered; different proposals by the same authors regarding DFT-, Prony-, and ESPRIT-based advanced methods are reviewed and compared in terms of their accuracy and computational efforts.

The eleventh paper, "Wavelet-based algorithm for signal analysis," is by Tse and Lai. In this contribution, the authors address algorithm for identifying power frequency variations and integer harmonics by using wavelet-based transform. A combination of continuous wavelet transforms is introduced to detect the harmonics presented in a power signal. A frequency detection algorithm is developed from the wavelet scalogram and ridges. A necessary condition is established to discriminate adjacent frequencies. The instantaneous frequency identification approach is applied to determine the frequencies components. An algorithm based on the discrete stationary wavelet transform (DSWT) is adopted to denoise the wavelet ridges.

We wish to thank the numerous anonymous reviewers who have contributed to significantly enhance the quality of this special issue.

It has been a pleasure to put together all these papers in this special issue. We hope this issue will bring joint interests and benefit to both signal processing and the power engineering communities. Further, it will serve asa valuable resource to those starting to work on signal processing for power quality applications. Finally, it will provide researchers with the necessary tools for unveiling the ultimate performance achieved with signal processing in the power quality field, and for inspiring the basic theoretical work that lays the foundation for a new generation of measurement equipment for power quality applications.

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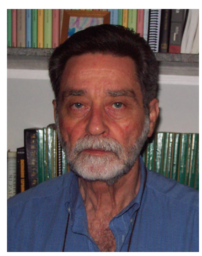

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