Hybrid demodulation concept and harmonic analysis for single/multiple power quality events detection and classification

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A novel real-time analysis of power quality (PQ) events has been presented using amplitude and frequency demodulation concepts. The earlier techniques were analyzing the few cycles of the power signal based upon wavelets, having the computational complexity of the order \( O(n^2) \). In the proposed method, PQ events can be considered as similar to various modulating signal forms. In this paper, the concept of demodulation has been used to separate various single/multiple event patterns and MUSIC harmonics algorithm has been used to detect the presence of the various harmonics. These techniques have been well tested on transient, sag, swell harmonics and their combinations in real-time. Fuzzy classifiers have been used for the classification of PQ events from the knowledge base, obtained from amplitude demodulation, frequency demodulation and MUSIC harmonic algorithm. It is concluded from the confusion tables that the efficiency of single/multiple PQ events recognition of fuzzy product aggregation reasoning rule (FPARR) classifier is higher.

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1. Introduction

The importance of PQ event detection and classification is ever increasing due to the wide use of delicate electronic devices. Voltage swell and sag occur due to motor starting, nearby circuit faults, or accidents, and can lead to power interruptions. Impulsive-transient and oscillatory-transient PQ events occur due to lighting and capacitor switching respectively. Harmonic currents due to non-linear loads throughout the network also degrade the quality of services to the sensitive high-tech customers, such as India’s IT parks in Bangalore, Hyderabad and many other places. The massive rapid transit system (MRT), Metro Railways in Delhi and few other places in India have facilitated the massive use of semiconductor technologies in the auto-traction systems, resulting in the increased level of harmonic distortion. The solution to the PQ related problems requires continuous monitoring and the acquisition of large amount of data from the distribution system. Emphasize the need of an automated PQ detection and classification system to determine the cause of PQ disturbances is given in Ref. [1].

Several signal processing and statistical analysis tools have been presented for the detection and classification of PQ events. The survey in Ref. [2] cites most of the work in PQ events classification using different signal processing tools like Fourier, wavelet, Gabor transforms etc. Recently, authors have presented PQ event detection and classification using S-transform [3], discrete wavelet transform and artificial neural network with fuzzy logic [4], a support vector machine for the statistical classification of voltage disturbances [5], Hilbert and Clarke transform [6], S-transform based probabilistic neural network model [7], an energy difference of multiresolution analysis [8], slant transform [9], wavelet and neural network [10], S-transform and TT-transform [11], multiwavelet transform based neural network [12], S-transform based on maximum similarity principle [13], S-transform and fuzzy expert system [14], modified S-transform and particle swarm optimization [15], higher order statistics and neural network [16], S-transform and expert system [17], wavelet packet transform [18], Hilbert transform [19]. All above said techniques can detect PQ disturbances but number of samples required is large and hence the complexity of the algorithm is high enough so as not to allow it to work in real-time. The idea behind the proposed method is that PQ events are formed due to modulation of standard power signal as carrier and the event as a modulating signal. Analysis has been performed in four stages; the first stage has been designed to differentiate between the single/multiple PQ event(s) using cross-correlation (between standard sine wave and input power signal) and threshold value. Second and third stage come in picture after taking the decision (depending upon threshold value of cross-correlation coefficient) for single/multiple PQ events. If decision is in the favour of single PQ event then second stage comes into picture else third stage comes into picture except the case of interruption PQ event. In both the stages, hybrid demodulation and