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Fuzzy classifiers for power quality events analysis

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ABSTRACT

The present paper proposes the design of a tool to quantify power quality (PQ) parameters using wavelets and fuzzy sets theory. The tool merges the best characteristics of these two theories in establishing a method to analyze PQ events. The proposed method addresses two issues, such as selection of discriminative features and classifies event classes with minimum error. Wavelet features (WF) of PQ events are extracted using wavelet transform (WT) and fuzzy classifiers classify events using these features. Often the captured signals are corrupted by noise. Also the non-linear and non-stationary behavior of PQ events make the detection and classification tasks more cumbersome. WT has been proven an effective tool for detecting and classifying these. We exploited WT for noise removal to make the task of detection and/or localization of events simpler. In the proposed approach of event classification, fuzzy product aggregation reasoning rule based method has been used. Varieties of PQ events including voltage sag, swell, momentary interruption, notch, oscillatory transient and spikes are considered for performance analysis. Comparative simulation studies revealed the superiority of proposed method compared to WF based fuzzy explicit, fuzzy *k*-nearest neighbor and fuzzy maximum likelihood classifiers under noisy environment.

1. Introduction

Today's sophisticated intelligent technology demands power supply free from interruption or disturbance to ensure continuous and smooth equipment operation. Low power quality (PQ) can cause serious problems for the affected loads, such as short lifetime, malfunctions, instabilities, interruption etc. The examples abound in semiconductor industry, chemical industry, automobile industry, paper manufacturing, and e-commerce. A recent study [1] in the USA has shown that industrial and digital business firms are losing $45.7 billion per year due to power interruptions. These issues have raised the awareness of PQ and motivated for efficient detection and classification algorithms.

PQ events are often corrupted with noise due to monitoring devices that makes the detection and classification task difficult. These tasks become more complex with the non-linear and non-stationary behavior of events. Further the scarceness of PQ experts in electric power industry poses a problem in handling huge amount of data manually gathered by various distributed monitoring systems. Existing recognition and classification methods thus need much improvement in terms of their versatility, reliability and accuracy in processing event signals. In this direction, intelligent techniques can be adopted to automate the PQ assessment for improved accuracy and efficiency. Further, PQ event recognition is often troublesome because it involves a broad range of event categories or classes and normally PQ events occur in multiple types at the same time. Therefore, the decision boundaries of event features are likely to overlap and hence hard classifiers may not be useful to classify these classes (because hard classifier assumes the classes as well separable, well defined and possess distinct boundaries). For such problems fuzzy classifiers [2,3] are more applicable as it allows imprecise class definition and recognize patterns belonging to more than one class with varying degree of membership values (MVs). Thus the partitions in fuzzy classes are soft and gradual rather than hard and crisp. In a fuzzy classification task, the class label bearing maximum membership valued is assigned to the input signal pattern.

The power system often taken as a rough estimate of the non-periodic or time-varying voltage variations like voltage dips, swells, and interruptions instead of pure periodic signal. Also for explicit information, such as evaluating duration and localization of disturbance propagation, there is a demand for both time and frequency analysis methods. Discrete Fourier transform (FT) and short time FT (STFT) are popularly used for analysing stationary and periodic signals in the frequency domain. STFT is also applied to non-stationary signals but operated in a varying window size to focus on certain period of time, which can trace the magnitude variations to some extent. Harmonic distortions are typically handled in this manner but for the analysis of inter-harmonics, non-linearity and

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