Studies on Some Methods for the Analysis of Power Quality Events

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Abstract

Power quality event (PQE) monitoring is essential for the reliable operation of modern electrical power systems due to the increasing use of sensitive electrical and electronic equipment. Since multiple PQEs may occur simultaneously and overlap with one another, this thesis proposes several methodologies for the detection, identification, and classification of both single and multiple PQEs in power system signals. A comprehensive review of PQE analysis techniques and research gaps is presented. Due to the scarcity of real-world PQE datasets, a laboratory setup is developed to generate PQE signals according to international standards. Common PQEs and their standard limits are also discussed. A novel signal-processing-based methodology is proposed for analyzing signals corrupted by single and multiple PQEs. Median filters are employed to eliminate spikes, and quantitative indicators are introduced for event identification. Another approach combining median filtering and discrete Fourier transform is also developed. Experimental results demonstrate detection accuracies of 96.7% and 99.61%, respectively, with low computational complexity. An automatic PQE detection framework based on the Stockwell transform and a customized convolutional neural network (CNN) is developed. Time-frequency grayscale images generated from PQE signals are classified with an accuracy of 99.83%. To further improve classification performance, a deep learning framework utilizing a stacked autoencoder is proposed. Hyperbolic-window Stockwell transform-based time-frequency representations are used for deep feature extraction, and the XGBoost classifier achieves 99.86% accuracy in classifying 18 different single and multiple PQEs, including real-world data. Finally, multisynchrosqueezing transform-based time-frequency images of 9 single and 27 multiple PQEs are analyzed using a pretrained VGGNet16 model. Feature selection through one-way analysis of variance and classification using a support vector machine yield an accuracy of 99.58%, while maintaining robustness under noisy and real-world conditions. Overall, the proposed methodologies provide accurate, efficient, and practical solutions for PQE monitoring in modern electrical power systems.