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Digital Signal Processing Techniques for Improving the Automatic Classification of Power Quality Events

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Abstract

Electric power quality problems have become an important issue due to their technical and financial consequences on industry. Several solutions have been provided for addressing these problems such as the use of custom power solutions. These solutions, however, could themselves be a source of power quality distortions. On the other hand, existing power quality monitors provide sufficient information on power quality distortions, which require individual inspection of the events. However, with the growing number of monitors installed in power systems, the amount of data collected continues to grow, which makes individual inspection of events impossible. Therefore, it is desirable to have automatic analysis tools integrated with the monitoring systems, that can be applied to large existing databases for automating the classification process. This makes the clustering of similar events more visible which is necessary for analysing and identifying the source of the distortion in a particular power system.

The work presented in this thesis investigates the application of digital signal processing techniques in the power quality automatic classification field, and thus, proposes an optimized automatic monitoring system with an improved accuracy. The proposed monitoring system involves three main sections: detection of the power quality events, extraction of the distinctive features that characterise each event, and automatic classification of the similar events under pre-defined categories. The thesis proposes new power quality processing techniques for detection and feature extraction sections, including the Hilbert and Clarke transforms. The former proposed technique was used for analysing single phase signals, while the later technique was proposed for the simultaneous analysis of three phase signals.

In the classification section of the monitoring system, the k-Nearest Neighbour pattern recognition technique was used as a decision-making technique. The main advantage of the k-Nearest Neighbour technique is that it is nonparametric technique which is simple, yet, effective in many cases, as no prior statistical knowledge about the data is required. Although the k-Nearest Neighbour technique requires a large capacity of memory to store the training data, the ever development the memory size technology makes it a good candidate in the automatic recognition of power quality events.

The k-Nearest Neighbour technique was used in this thesis with two feature extraction techniques (the Hilbert and the Clarke transforms) to construct two new classifiers for single-phase systems and three-phase systems. As the number of neighbors affects the accuracy of the decision-making in the technique, this research also determines the optimum number of neighbors in each classifier.

On the basis of the classification tests performed on nine power quality classes, (including specified classes such as, sags due to starting motors and sags with harmonics), it was demonstrated that the proposed classifiers are very effective. The performance of the proposed classifiers was compared with the k-Nearest Neighbour classifier based on the up-to-date feature extraction techniques; S Transform and Wavelet Packet transform. By considering identical test data set, the over all accuracy of the k-Nearest Neighbour classifier with Clarke transform was around 88.5% and the k-Nearest Neighbour with Hilbert transform was about 89.2%, whereas the accuracies of the k-Nearest Neighbour with the S Transform and Wavelet Packet transform were 82.2% and 74.4% respectively. It should be noted that the above accuracy figures are calculated based on all nine studied power quality classes, which can be increased significantly if the classes with similar characteristics, (such as sags due to starting motors and sags with harmonics), were excluded from the calculations. A number of real time measured events based on laboratory experiments and on-site measurements was also provided in this study for testing the proposed feature extraction techniques and classifiers.

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