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A new hybrid pattern recognition scheme for automatic discrimination of power quality disturbances

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ABSTRACT

In this paper an intelligent method for automatic detection of Power Quality Disturbances (PQDs) is presented. The proposed automatic scheme is noticed to retaining informative features or eliminating redundant features simultaneously. This paper presents an effective method, for extracting features, so-called "integrated approach", using integration of Discrete Wavelet Transform and Hyperbolic S Transform. Moreover, a new efficient feature selection method namely Orthogonal Forward Selection by incorporating Gram Schmidt procedure and forward selection is applied for selection of the best subset features. Some different classifiers are empirically compared in order to determine the best classifier. In this automatic scheme, the variable parameters of classifiers are optimized using a powerful method namely Particle Swarm Optimization. The sensitivity of the proposed method under noisy conditions has been investigated. The average rate of correct classification using the proposed hybrid scheme for automatic discrimination of PQDs in various noise conditions 99.55% is obtained.

1. Introduction

The issue of Power Quality (PQ) is now recognized as an essential attribute of a successful electric power system [1]. For electrical power quality, sources of disturbances in the power system must be identified and controlled. This can be done by detection and classification of different types of disturbances. The ability to access a tool that can perform these duties is an essential requirement [2]. This tool should be able to analyze the types of PQ problems simultaneously in the time domain and frequency domain. Yet, the problem of automatic classification of Power Quality Disturbances (PQDs) is difficult, because it includes a wide range of categories of different degrees of disturbance and disorder [3]. A means of improving electric PQ initiates by developing an automatic PQ monitoring system which can systemically identify the PQDs and can maintain an effective PQ monitoring database for maintenance. Existing automatic recognition methods need much improvement in terms of their versatility, reliability, and accuracy.

However, despite all the works that has been done, the detection and classification of PQ events is still a challenging problem. The growing use of tools sensitive to power system disturbances and the related financial aspects, the increasing awareness of PQ problems have created a need for widespread automatic monitoring of the power system operation [1]. Efforts for automatic detection and classification procedure can be found in [4,5]. Extracted features using S Transform (ST) in [6,3,5] and in [7] by Wavelet Transform (WT), have been used to train a SVM classifier for automatic classification of the PQDs. In [8] several methods have been proposed for the selection of useful and elimination of useless features in PQ event classification. Various methodologies based on Multi Support Vector Machines (MSVM), Probabilistic Neural Network (PNN)

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and K Nearest Neighbor (K-NN) and fuzzy have been proposed for the classification of PQDs [9,10,11–13].

The major problems of the traditional analyzing methods are:

1. The Discrete Fourier Transform (DFT) and Chirp-Z Transform (CZT) do not provide adequate information on the time domain [14].
2. Features extracted based on Discrete Wavelet Transform (DWT) are not high severability. (Because of low classification accuracy) [15].
3. Using WT or ST by itself cannot be effective for feature extraction [6]. Most prior researches have focused on combined ST and DFT or WT and DFT, but these hybrid methods also did not have noticeable results [10].
4. Extracted features based on WT are sensitive to noise, specifically those features extracted from high level details [6,16,17].
5. Some papers have investigated a small number of PQDs and most of them have not considered simultaneously events [16,18,19].
6. In many other works in this field, there is not feature selection stage which can improve the detection precision of the algorithm [16,18,20].
7. Neural network classifier needs too many tuning parameters and training process and is very time consuming [21]. Many tuning parameters have been set by trial and error, while a heuristic search algorithm can set these parameters more effectively.
8. For many practical applications, the accuracy and efficiency of the existing methods may not be adequate and improved accuracy is required [17,19,22].

The advantages of the proposed method are:

1. The proposed integrated approach uses both powerful signal processing tools i.e. Hyperbolic S Transform (HST) and DWT, concurrently. This paper is based on the idea that combining the important and effective features of these two methods can provide high- severable feature vectors.
2. Gaussian hyperbolic window is used to provide better time and frequency resolutions at low and high frequencies unlike the ST using the Gaussian window. So, HST compared with S transform has higher computational accuracy.
3. Various and large number of extracted features are remarkably severable. (Due to integration of HST and DWT).
4. In proposed algorithm, a new efficient feature selection method namely Orthogonal Forward Selection (OFS) by incorporating Gram Schmidt (GS) procedure and forward selection is applied for selection of the best subset features.
5. In order to obtain the best detection accuracy, three well- known machine learning are applied as classifier cores. We use three best classifiers in the literature (MSVM, PNN, K-NN) and compare the results of these to search the best.
6. Optimal value of classifier parameters is set by Particle Swarm Optimization (PSO) algorithm that it causes to improve the generalization performance of the classifiers and better accuracy.
7. The high classification accuracy obtained in noisy condition by suggested strategy proves the robustness and effectiveness of the proposed algorithm for real power system application. The classification results of this study have the best accuracy with respect to previous researches.
8. The simultaneous PQDs such as sag with harmonic are considered in this work. PQ data is based on parametric equations and real disturbance signal so that testing and training signals can be changed in a wide range and controlled manner.

The proposed automatic scheme is noticed to retaining informative features or eliminating redundant features simultaneously. This scheme suggests an automatic framework that obtains combination of important and effective features and finds the necessary feature vectors. The proposed algorithm in this paper consists of three sub-systems, feature extraction, feature selection and classification. In general, this paper explains that the automatic process of PQ monitoring can be achieved by following a number of well-defined steps. In this schema, firstly, features are obtained by the proposed integrated approach (i.e. integrated DWT & HST). Secondly, by using the proposed feature selection method (i.e. OFS process [23]), optimum combination of the most useful features is identified for increasing the accuracy of classification. The advantage of using GS orthogonal transforms instead of the renowned feature selection methods such as Principal Component Analysis (PCA) [9] is that features in the GS algorithm can be prepared to connected with the same number of input variables of the measurement space, whereas the features in PCA method are linked with the complete set instead of a subset of the input variables. In third stage, PQDs are classified by machine learning tools, with features vector obtained from previous stages. To validate the proposed scheme is evaluated for both noisy and noiseless PQD signals. In the following we describe the procedures in greater detail.

The rest of this paper is organized as follows. In Section 2, some preliminary definitions, include, descriptions and ideas of the HST, DWT and OFS are introduced. Then, definitions and concepts of classifiers are employed in this paper, are given. In Section 3, feature extraction, selection and classification methods used in this study are presented. In Section 4, simulation and analysis studies are presented and the classification results and performance comparison of proposed expert system are shown. Finally, conclusions are discussed in Section 5.

2. Preliminaries

2.1. Feature extraction tools

2.1.1. Hst

The ST suggested by Stockwell in 1996 [24] is based on the ideas of Short-Time Fourier Transform (STFT) and WT.