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Detection and classification of single and combined power quality disturbances using fuzzy systems oriented by particle swarm optimization algorithm

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ABSTRACT

In this paper, a new approach for the detection and classification of single and combined power quality (PQ) disturbances is proposed using fuzzy logic and a particle swarm optimization (PSO) algorithm. In the proposed method, suitable features of the waveform of the PQ disturbance are first extracted. These features are extracted from parameters derived from the Fourier and wavelet transforms of the signal. Then, the proposed fuzzy system classifies the type of PQ disturbances based on these features. The PSO algorithm is used to accurately determine the membership function parameters for the fuzzy systems. To test the proposed approach, the waveforms of the PQ disturbances were assumed to be in the sampled form. The impulse, interruption, swell, sag, notch, transient, harmonic, and flicker are considered as single disturbances for the voltage signal. In addition, eight possible combinations of single disturbances are considered as the PQ combined types. The capability of the proposed approach to identify these PQ disturbances is also investigated, when white Gaussian noise, with various signal to noise ratio (SNR) values, is added to the waveforms. The simulation results show that the average rate of correct identification is about 96% for different single and combined PQ disturbances under noisy conditions.

1. Introduction

The increasing growth in the use of sensitive loads by customers and the demand for high quality electricity have drawn special attention to the causes, effects, and solutions of PQ problems. By providing and installing various types of power quality monitoring equipment in the distribution systems, electric power utilities try to ensure a high quality of service. In most cases, analysis to identify the type of PQ disturbances requires large quantities of data to be collected by this equipment. This requires fast and efficient methods that can be implemented in hardware or software implementation to detect and classify the PQ disturbances [1].

Most single type PQ disturbances can be described as a voltage impulse, interruption, swell, sag, notch, transient, harmonic, or flicker in the distribution systems [2]. The major factors that contribute to the occurrence of these disturbances include the starting of large electric motors, switching capacitor banks, non-linear loads, arc furnace operation, the use of equipment with solid state switching devices, distribution system faults, and so forth [2].

The PQ disturbances include a wide range of events. The discrete Fourier transform is often used for the signal processing of low frequency PQ disturbances such as flicker, but it is more appropriate to employ wavelet transform for the signal processing of high frequency PQ disturbances such as transients [3–8]. Some prior researchers have used these two techniques to extract suitable features of the PQ disturbance waveforms, simplifying the identification and classification of these disturbances [3–7]. In most papers, fuzzy rules are used to make decisions regarding the occurrence and classification of the type of the disturbance [3–6]. In these methods, the large number of inputs to the fuzzy system increases the correct identification rate of the disturbances, but also increases the method complexity and decreases its speed [3,4]. In references [5–7], the fuzzy system complexity for the classification of disturbances is reduced to some extent, and the correct identification rate is not significantly changed compared with references [3,4]. However, no attention has been paid to the detection of combined PQ disturbances. Furthermore, it seems that determining the parameters of the membership functions for the fuzzy systems is only performed based on human reasoning, and the correct identification rate is increased through trial-and-error modification of these parameters. Therefore, there has been no guarantee of optimality for these parameters in the prior research. Of course, other different methods have also been presented for the detection and classification of PQ disturbances [8–15]. Some of these methods have good performance under noisy conditions [14,15]. However, these methods either do not consider [8,11–13] or only consider a few numbers [9,10,14,15] of combined disturbances.

In this paper, a new method is proposed for the detection and classification of single and combined PQ disturbances using two

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