3-D Partial Discharge Patterns Recognition of Power Transformers Using Neural Networks

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Abstract. Partial discharge (PD) pattern recognition is an important tool in HV insulation diagnosis. A PD pattern recognition approach of HV power transformers based on a neural network is proposed in this paper. A commercial PD detector is firstly used to measure the 3-D PD patterns of epoxy resin power transformers. Then, two fractal features (fractal dimension and lacunarity) extracted from the raw 3-D PD patterns are presented for the neural-network-based (NN-based) recognition system. The system can quickly and stably learn to categorize input patterns and permit adaptive processes to access significant new information. To demonstrate the effectiveness of the proposed method, the recognition ability is investigated on 150 sets of field tested PD patterns of epoxy resin power transformers. Different types of PD within power transformers are identified with rather encouraged results.

1 Introduction

Power transformers play a crucial role in operation of transmission and distribution systems. A dielectric failure in a power transformer could result in unplanned outages of power systems, which affects a large number of customers [1]. Therefore, it is of great importance to detect incipient failures in power transformers as early as possible, so that they can be switched safely and improve the reliability of the power systems. Partial discharges phenomenon usually originates from insulation defects and is an important symptom to detect incipient failures in power transformers. Classification of different types of PDs is of importance for the diagnosis of the quality of HV power transformers. PD behavior can be represented in various ways. Because of the randomization of PD activity, one of the most popular representations is the statistics-based $\phi$-$Q$-$N$ distribution, i.e., the PD pattern is described using a pulse count $N$ versus pulse height $Q$ and phase angle $\phi$ diagram. Previous experimental results have adequately demonstrated that $\phi$-$Q$-$N$ distributions are strongly dependent upon PD
sources, therefore the 3-D patterns can be used to characterize insulation defects [2]. This provides the basis for pattern recognition techniques that can identify the different types of defects.

The automated recognition of PD patterns has been widely studied recently. Various pattern recognition techniques have been proposed, including expert systems [3], fuzzy clustering [4], and neural networks (NNs) [5], [6]. The expert system and fuzzy approaches require human expertise, and have been successfully applied to this field. However, there are some difficulties in acquiring knowledge and in maintaining the database. NNs can directly acquire experience from the training data, and overcome some of the shortcomings of the expert system. However, the raw values of 3-D patterns were used with the NN for PD recognition in previous studies [7], the main drawbacks are that the structure of the NN has a great number of neurons with connections, and time-consuming in training. To improve the performance, two fractal features that extract relevant characteristics from the raw 3-D PD patterns are presented for the proposed NN-based classifier. It can quickly and stably learn to categorize input patterns and permit adaptive processes to access significant new information. To demonstrate the effectiveness of the proposed method, 150 sets of field-test PD patterns from HV epoxy resin power transformers are tested. Results of the studied cases show that different types of PD within power transformers are identified with rather encouraged results.

2 Fractal Features of 3-D PD Patterns for Recognition Purposes

2.1 Fractal Theory

Fractals have been very successfully used to address the problem of modeling and to provide a description of naturally occurring phenomena and shapes, wherein conventional and existing mathematical methods were found to be inadequate. In recent years, this technique has attracted increased attention for classification of textures and objects present in images and natural scenes, and for modeling complex physical processes. In this theory, fractal dimensions are allowed to depict surface asperity of complicated geometric things. Therefore, it’s possible to study complex objects with simplified formulas and fewer parameters [8]. PD also is a natural phenomenon occurring in electrical insulation systems, which invariably contain tiny defects and non-uniformities, and gives rise to a variety of complex shapes and surfaces, both in a physical sense as well as in the shape of 3-D PD patterns acquired using digital PD detector. This complex nature of the PD pattern shapes and the ability of fractal geometry to model complex shapes, is the main reason which encouraged the authors to make an attempt to study its feasibility for PD pattern interpretation.

2.2 Calculation of Fractal Dimension

While the definition of fractal dimension by self-similarity is straightforward, it is often difficult to estimate/compute for a given image data. However, a related measure of