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An approach based on rough set theory for identification of single and multiple partial discharge source

Subrata Biswas [a,*], Debangshu Dey [b], Biswendu Chatterjee [b], Sivaji Chakravorti [b]

[a] Department of Electrical Engineering, Netaji Subhash Engineering College, Kolkata 700 152, India
[b] Department of Electrical Engineering, Jadavpur University, Kolkata 700 032, India

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ABSTRACT

This paper describes a methodology to detect the location of single as well as multiple partial discharge sources by sensing the optical radiation from the source. To establish the methodology, an experimental setup has been arranged in the laboratory for generation of partial discharge inside a steel tank provided with five optical sensors placed at the centre of all its five inside walls excepting the top. Analyzing the data by comparing the results from the five sensors give estimation about the position(s) of the partial discharge occurring inside the tank. For successful analysis in the present work, auto-correlation, an extension of correlation based feature extraction technique, is used to extract the features from the recorded signal of the sensors. To classify the extracted features, a rough set theory (RST) based decision support system is used in this work. The novelty of this present work is in locating single as well as multiple sources of partial discharges that emit optical radiation simultaneously. Results show that the auto-correlation based feature extraction technique in conjunction with RST based classifier can localize the sources of partial discharge inside the tank with reasonable degree of accuracy.

1. Introduction

Partial discharge (PD) is a localized dielectric breakdown of a small section of electrical insulation under high voltage stress leading progressive deterioration and ultimate breakdown of the insulation system. Statistics show that more than 60% of incidents related to equipment damage are the result of insulation failure [1]. Failure in insulation often starts with PD activity. As a diagnostic tool, PD measurement is well established and gives satisfactory results. There are various methods available to detect and measure PD in electrical power apparatus, namely electrical, acoustics, UHF, radio-frequency (RF) and optical methods [2–4]. Different algorithms have also been reported for PD pattern classification [5,6].

The aim of the present work is to detect and localize single as well as multiple PD sources within electrical equipment by optical method. The optical spectrum of PD signal extends from the ultraviolet over the visible range to the infrared [7]. In this work PD signals are considered in the wavelength range between 300 nm and 800 nm, i.e. the visible EM wave or optical signal wavelength region. The optical PD pulses are acquired through a real-life laboratory setup. Test voltage, above PD inception level, is applied across the insulator sample under test so that PD takes place inside the voids/defects of the insulator. Various PD patterns are recorded from several such defects (both single and multiple) located at different positions.

Several analysis tools like Artificial Neural Network (ANN), Wavelet Transform, Fuzzy Classifier, Support Vector Machine (SVM) [8–10] are available to analyze the recorded PD data. In the present work auto-correlation an extension of correlation based feature extraction technique, is used to extract a number of features from the recorded PD pulses caused by both single and multiple sources. The auto-correlation technique [11] is a classical and time-tested method for similarity checking of two waveforms. Auto-correlation technique also performs especially well in the presence of random noise. Hence, it is one of the most robust linear techniques of comparing two signals and hence extracting the features of those signals in the time domain with acceptable accuracy. To classify the extracted features, a rough set theory (RST) based decision support system [12] is used in this work. Rough set theory (RST) is suitable where knowledge of acquired data is imprecise or the information system contains superfluous information. The data about a system can be reduced using rough sets keeping all the information or features of the system intact [10–14]. So RST based decision support system is employed here. The novelty of the present research work is that it can localize not only the single source of PD but can also localize multiple sources of PD occurring simultaneously. Results show that the auto-correlation based feature extraction technique in conjunction with RST based classifier can localize different PD signal with reasonable degree of accuracy.

* Corresponding author.
E-mail address: subratab28@gmail.com (S. Biswas).

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2. Experimental setup

In the laboratory, partial discharge (PD) is generated from optically transparent source. This source of PD is placed inside a cubical steel box of side 0.32 m. The top cover of the box is made up of an insulating material to hold the HV conductor. This box will henceforth be termed as Partial Discharge Source Emulator (PDSE) as shown in Fig. 1.

2.1. Source of partial discharge

To facilitate pick up of PD signals by the sensors, optically transparent source of PD is created by making an artificial cylindrical void of known dimension inside transparent acrylic disc of 10 mm diameter and 3 mm height. The discs are placed between two brass electrodes. One electrode (marked as HV) is connected to the high voltage source and the other is kept at earth potential as shown in Fig. 2.

2.2. Fixing arrangement of the PD source

To place the PD source at a particular position inside PDSE, a hole is made inside the insulating lid of PDSE through which the HV electrode is inserted into the box. On reaching the desired height, the HV electrode is fixed with the insulating lid by a collar and lock arrangement. A flexible copper wire is attached to the earth electrode and the arrangement is shown in Fig. 3.

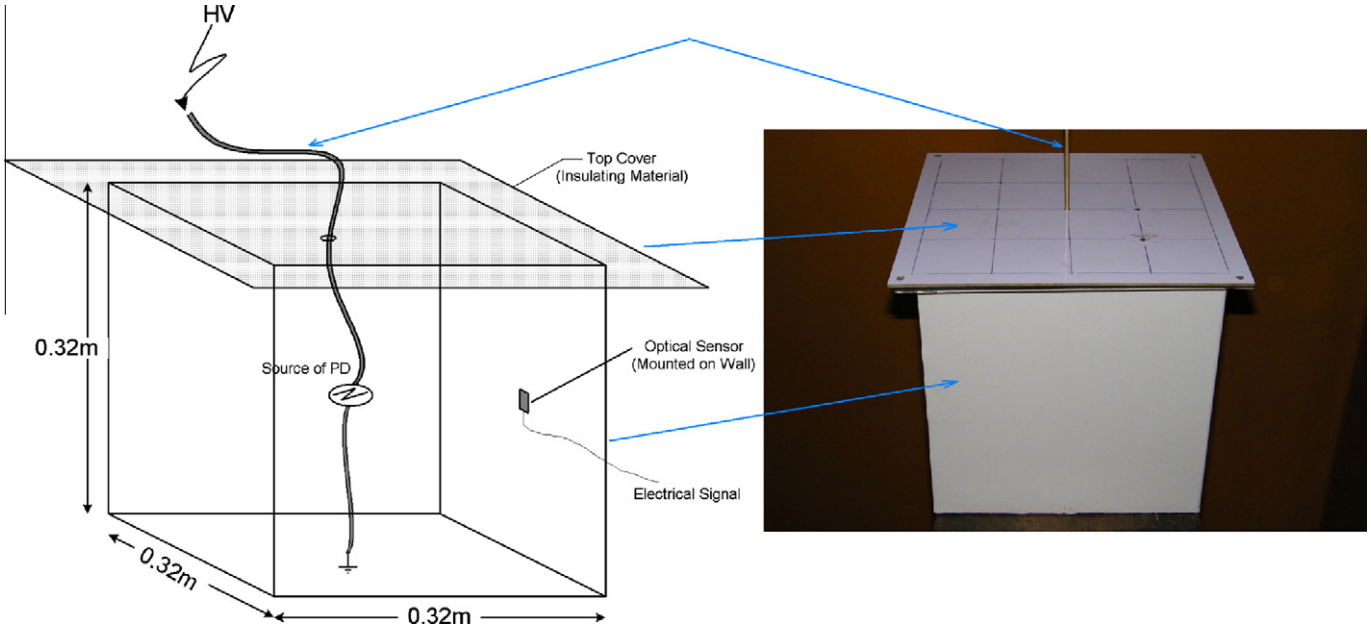

Fig. 1. Partial Discharge Source Emulator (PDSE).

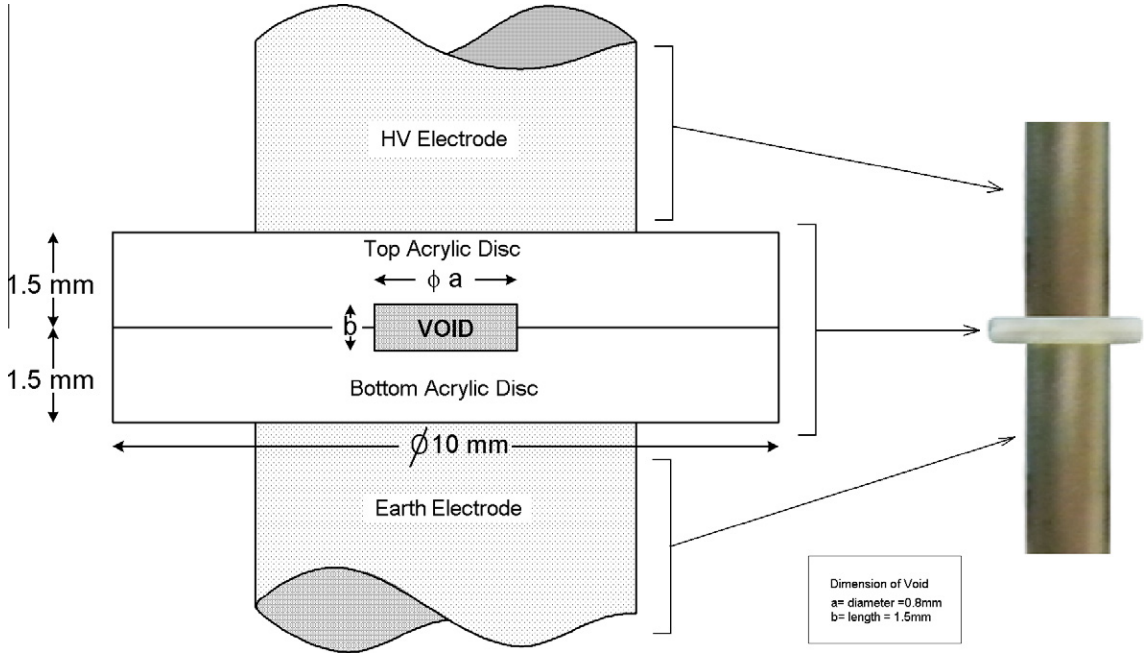

Fig. 2. Source of partial discharge.