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Deep Learning and Long-Duration PRPD Analysis to Uncover Weak Partial Discharge Signals for Defect Identification

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Abstract: This study focuses on improving the defect recognition accuracy under weak partial discharges (PDs) in epoxy resin through phase-resolved partial discharge (PRPD) analysis. The method is to refine the data rather than enhance the algorithm. Two measurement conditions are compared until PRPD pattern saturation is achieved: one-minute and one-hour durations. The PD data specifically target three void types located at different positions within the epoxy material. The aim is to evaluate how the presence of weak PDs at the PD extinction voltage (PDEV) influences defect recognition accuracy. This research sheds light on the potential implications of neglecting the significance of weak PD signals in defect detection. A convolutional neural network (CNN) model is trained using PRPD data recorded at the repetitive PD inception voltage (RPDIV) and tested using the new PRPD data from both conditions recorded from a lower PDIV to a PDEV. The trained CNN model achieves a defect recognition accuracy of 100% for a one-hour duration, highlighting the importance of not neglecting weak PD signals. This emphasizes the significance of extended measurement duration and pattern saturation in capturing and analyzing weak PD signals for an improved defect recognition. This study contributes to the advancement of practical applications by understanding the behavior of the epoxy material and enhancing defect detection techniques.

Keywords: convolutional neural networks; defect recognition; partial discharge measurement durations; epoxy resin; PRPD

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1. Introduction

Partial discharges (PDs) occur in electrical insulation systems and indicate the presence of defects or degradation within the insulation material [1–3]. According to IEC 60270, a PD is referred to as an electrical pulse-type discharge that partially bridges the insulation [4]. It is a critical parameter to monitor because excessive PD activity can lead to insulation breakdown and failure [5,6]. In recent years, the development of advanced measurement techniques and defect recognition methods has been instrumental in improving the accuracy and reliability of PD detection [7,8]. One method that has gained significant attention is phase-resolved partial discharge (PRPD) analysis. PRPD analysis involves capturing and analyzing the patterns of PD pulses in a time domain, allowing for a more comprehensive understanding of PD behavior and improved defect recognition capabilities [9]. Valuable insights can be gained regarding the condition of the insulation material by examining the characteristics of PD pulses from a partial discharge inception voltage (PDIV) to a partial discharge extinction voltage (PDEV).

The accurate detection and characterization of defects are of the utmost importance in the field of epoxy resins that are widely used as insulation materials in various electrical applications [10–12]. Artificially fabricated voids are commonly used as representative defects to simulate the imperfections that occur in epoxy resins. The positions of these voids within the resin can significantly influence the PD characteristics and, consequently, the accuracy of defect recognition. In this study, the positions of the voids in the epoxy were placed at the top, center, and bottom.