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Measurement and analysis of partial discharges in SF_6 gas under HVDC

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ABSTRACT

With the rapid development of high voltage direct current (HVDC) technology and the requirements of smart grids, there is a new challenge of monitoring and diagnosing the insulation performance of related power facilities. This paper dealt with the measurements and analysis of partial discharges in SF_6 gas under HVDC in terms of discharge inception voltage (DIV), discharge magnitude and pulse count, as well as the statistical characteristics extracted from discharge distribution and density functions. Five types of electrode systems were fabricated to simulate typical insulation defects in gas-insulated switchgear. All these systems were filled with SF_6 gas in ranges from 0.1 to 0.5 MPa. The measurement system was developed based on the real time operating system by LabVIEW. The results revealed that identification of the defects in gas-insulated equipment operated under HVDC can be realized by analyzing the statistical characteristics extracted from the discharge distribution and density functions.

1. Introduction

The high voltage direct current (HVDC) solution has been widely applied in the electricity industry owing to its advantages of lower investment, asynchronous interconnections, environmental concerns, and long distance transmission [1,2]. Gas-insulated power equipment such as the gas-insulated switchgear (GIS) and the gas-insulated transmission line (GIL), play important roles in HVDC distribution and transmission. However, the failure of such power facilities caused by electrical stress lead to considerable financial loss and personal injury. Therefore, it is essential to diagnose the condition of such power facilities to ensure the reliable operation of power systems, especially in smart grids.

Partial discharge (PD) is defined as a localized electrical discharge that only partially bridges the insulation between conductors, and it can or cannot occur adjacent to a conductor. PD activity can occur at any point in the insulation system, where the electric field strength exceeds the breakdown strength of that portion of the insulating material [3,4]. Although the magnitude of such discharge is usually small at its early stage, it causes progressive deterioration and finally results in the failure of power apparatus such as the power transformer, GIS, and GIL. It is therefore essential to detect PD for condition monitoring and diagnosis of the insulation system [5–7].

Owing to the availability of sensors and computer-aided signal processing techniques, PD has been studied widely under AC for detection, analysis, identification, and localization. However, PD under DC voltage has not been investigated in detail, and the experience from AC PD measurements cannot be applied to DC directly. Therefore, we studied the measurements and analysis of PD in SF_6 under HVDC for condition monitoring and diagnosis of gas-insulated HVDC equipment.

2. Design and measurement

2.1. Analysis method

Owing to the absence of phase information, the widely used phase-resolved partial discharge (PRPD) method cannot be applied to DC voltage. Time-resolved partial discharge (TRPD) was used to investigate the statistical characteristics of PD under DC. TRPD is a time-based discharge analysis method based on the PD sequence and it includes two basic quantities: discharge magnitude q_i and the time of discharge occurrence t_i, $i = 1,2,\ldots,N$, where N is the number of PD pulses. The derived quantity named time interval Δt between two consecutive discharges is important because it is related to the discharge recurrence mechanism [8–10]. Fig. 1 shows the PD sequence. Δt_{pre} and Δt_{suc} are the time intervals of q_i to its preceding and successive discharge, respectively. Based on the basic and derived quantities, the discharge distribution and density function can be established: PD magnitude as a function of time $q(t)$, which is also named as TRPD; a relation between

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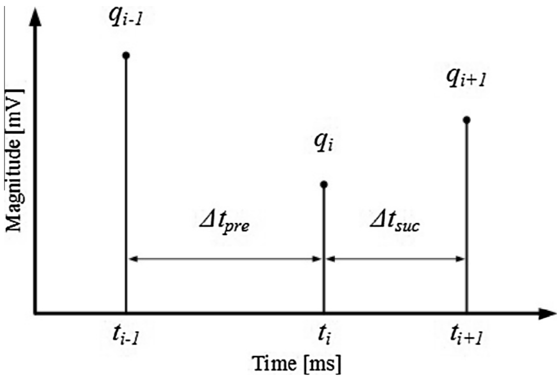

Fig. 1. PD sequence.

discharge magnitude and time interval to its preceding discharge $q(\Delta t_{pre})$; a relation between discharge magnitude and time interval to its successive discharge $q(\Delta t_{suc})$; the density function of the discharge magnitude $H(q)$; and the density function of the time interval $H(\Delta t)$. Three parameters (skewness, kurtosis, and peak) were used to describe the statistical characteristics of the discharge distribution and density functions.

Skewness is a measure of the symmetry of a distribution around the sample and is defined as

$$S = \sum_{i=1}^{n} \frac{(x_i - \mu)^3}{n \cdot \sigma^3} \tag{1}$$

where μ is the mean and σ is the standard deviation. Negative values for the skewness indicate data are skewed left, and positive val-

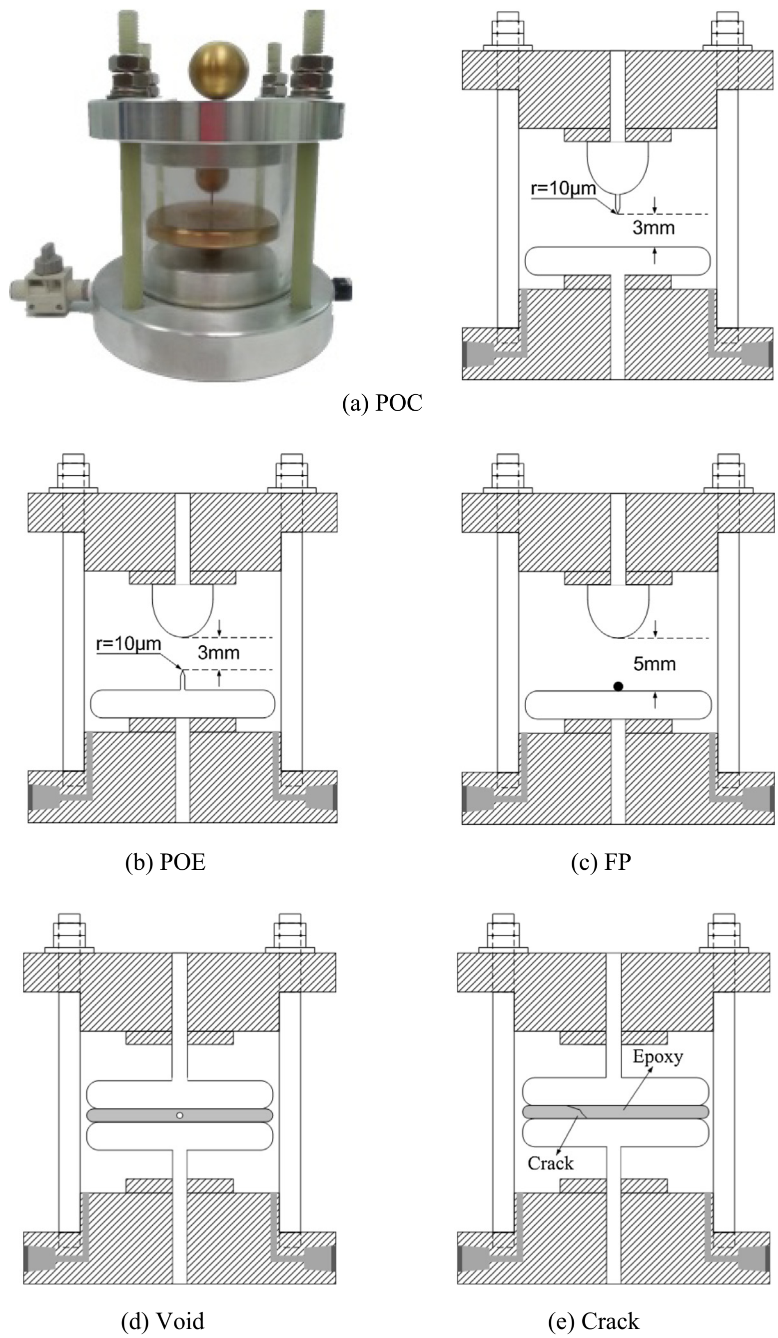

Fig. 2. Electrode systems.