Analysis of gas generation characteristics in XLPE cables induced by partial discharge

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ABSTRACT

Partial discharge (PD) causes the decomposition of materials in cross-linked polyethylene (XLPE) cables and generates gaseous products. Concentrations of the key gaseous products change with the duration and magnitude of PD, which can be employed to evaluate the condition of the cables. In this paper, the gas generation of XLPE induced by PD was characterized by simulated experiments. The influences of duration and magnitude of PD on the gas generation characteristics were investigated. The results showed that the decomposition of XLPE induced by PD mainly generated CO and CO_2. Besides, the ratio of CO_2 to CO increased with PD duration but was almost independent with PD magnitude. When the electrical discharge completely bridged the gap, (i.e., flashover), CH_4, C_2H_6, C_2H_4, C_2H_2, H_2, and a considerable amount of CO and CO_2 were generated. The generation of the key gases as well as their ratio could be employed for PD detection and condition assessment in XLPE cables.

KEYWORDS

Cross-linked polyethylene cables; Partial discharge; Flashover; Gas generation characteristics; Influence factors

INTRODUCTION

Power cable is one of the most important components in a power grid. With great mechanical, electrical properties and high melting point, cross-linked polyethylene (XLPE) has become the globally preferred insulation material for power cables [1]. Normally, XLPE cables can perform reliably for more than 20 years. However, defects introduced during manufacture, shipment, or installation and material deterioration due to excessive electrical or thermal stress during operation are likely to shorten the lifetime and result in cable failure [2, 3]. Cable failure may lead to unplanned outage and cause large economic losses. Condition assessment techniques can be employed to identify weak spots within cable insulation [4, 5] so that actions can be taken to improve reliability while minimizing the overall cost. Partial discharge (PD) testing is one of the most adopted condition assessment methods for XLPE cables [6]. Defects like voids, sharp points and electrical treeing induce distortion of electric field within the air gap of the insulation. When local electric field intensity exceeds the dielectric strength of the air within the air gap, it leads to PD. Detection and analysis of the PD signal can be used to recognize the type and localize the position of the insulation defects. However, PD is a stochastic process. It may not necessary occur even when there are severe cable defects [7]. Besides, PD signal attenuates and distort during the propagation from source to sensor. And the testing results are adversely affected by electromagnetic interferences. These factors significantly decrease the reliability and sensitivity of the PD testing method.

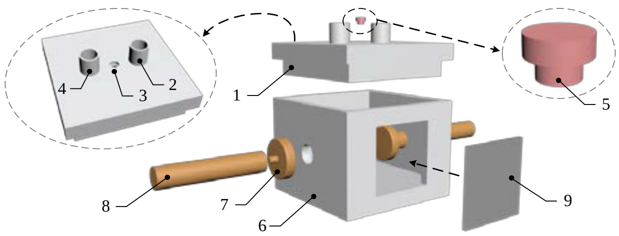
In the field of power transformers, condition assessment techniques based on gas analysis have gained worldwide acceptance, i.e., dissolved gas analysis method [8, 9]. When subjected to excessive thermal and electrical stresses, the insulation materials decompose and generate gaseous products. The concentration of the gases can be used to identify faults and estimate the severity. Recently, researchers started applying the gas analysis method to the condition assessment of XLPE cables. Mo et al. analysed thermal decomposition behaviour and kinetics of pyrolysis process of XLPE material [10]. Wan et al. investigated the characteristic gases for the internal thermal faults of XLPE cables [11]. Liu et al. studied the sensing performance of commercial sensors for detecting outer sheath overheating gaseous products [12]. These works mainly focus on the detection of thermal faults in XLPE cables by the gas analysis method.

In this paper, we investigate the gas generation characteristics when PD occurs within the XLPE insulation by simulated experiments. It provides a new idea for PD detection and condition assessment in XLPE power cables.

METHODS

Experimental systems

An experimental apparatus was designed to study the gas generation characteristics of XLPE due to partial discharge, as shown in Fig. 1. The main structure (the lid and chamber) of the apparatus was manufactured using 3D printing technology with a print accuracy of 0.1 mm. There were three gas channels at the top of the lid, i.e., the gas inlet/outlet and the gas sampling outlet. The gas inlet/outlet were connected to valves through gas pipes. The gas sampling point was sealed with a rubber plug. Two copper electrodes, with diameters of 24 mm, heights of 4 mm, and edges rounded to give a radius of 2 mm, were arranged coaxially in the chamber. The electrodes were connected to the external circuit by two copper rods through the holes in the wall of chamber. Both of the rods and the holes were 10 mm in diameter. An observation window made from organic glass was designed on one side of the chamber.



(a) Schematic diagram