Characteristics of Electrical Treeing Initiation and Propagation in Silicone Rubber

Yun-xiao **ZHANG,** Yuan-xiang **ZHOU** (1), Xu **ZHANG** (2), Rui **LIU** (3)

1 State Key Lab of Control and Simulation of Power Systems and Generation Equipments, Department of Electrical Engineering, Tsinghua University, Beijing 100084, China, zhangyxthu@gmail.com, zhou-yx@tsinghua.edu.cn.

2 North China Electric Power Research Institute Co, Ltd, Beijing 100045, China, zhangxu2013ncepri@163.com.

3 State Grid Hubei Electric Power Research Institute, Wuhan 430077, China, liurui0728@gmail.com.

ABSTRACT

Electrical tree is an important reason of insulation failure in silicone rubber (SIR) which affects the SIR insulated electrical equipment reliability seriously. In order to prevent this kind of failure, we should look into the characteristics of the electrical treeing initiation and propagation. In this article, two-dimensional (2D) and three-dimensional (3D) images of electrical tree were observed. It is found that the electrical treeing branches are hollow insulating channels. Partial discharge (PD) was recorded with the electrical treeing growth. It is believed that PD magnitude and pulse sequences are well corresponding to the treeing growth which illustrates that PD drives the trees to propagate after they initiate. This mechanism explains most of the phenomenon observed in electrical treeing experiments of SIR, and provides a theoretical basis to proper application of SIR in cable accessories.

KEYWORDS

Silicone rubber, electrical tree, treeing image, channel characteristics; partial discharge;

INTRODUCTION

Silicone rubber (SIR) is widely used as main insulation material of prefabricated cable accessories due to its excellent electrical, thermal and mechanical performance. Electrical tree is an important reason of insulation failure in polymeric dielectrics. In fact, electrical tree is a kind of insulation defect which looks like tree. Occasional breakdown failures caused by electrical tree in SIR have threatened the reliability of extra-high-voltage XLPE (cross-linked polyethylene) power cable lines which have been strongly developed. Figure 1(a) shows the failure cable accessory used in the power cable line where the breakdown phenomenon caused by electrical tree was found (as shown in Figure 1(b)).

Recent researches of SIR mainly focus on the short-term characteristics, such as the influence of frequency [1], cracks [2], curvature radius [2] and temperature [3, 4] on electrical tree and electrical property of SIR. Electrical treeing growth is closely related to its partial discharge (PD) characteristics [5 - 7]. Meanwhile, the growth can also be characterized by microcosmic physical parameter and chemical structure [8, 9]. In SIR, however, the process of electrical treeing initiation and propagation is unclear. To reveal the role of PD in electrical treeing growth, not only PD characteristics need to be studied, but also physical and chemical characteristics of discharge channels should be combined.

(a) Failure cable accessory

(b) Electrical treeing channels found in Fig. 1(a)

Fig .1: Failure cable accessories and its electrical treeing channels

In this paper, electrical trees were observed and the corresponding PD characteristics of electrical treeing growth were obtained by experiments. The characteristics of electrical treeing channels were studied by two-dimensional (2D) image and SEM. Then, the confocal laser scanning microscope (CLSM) was used to obtain three-dimensional (3D) fluorescence electrical treeing images [8]. Based on the observed results and PD theory, characteristics of treeing growth under the PD are explained. In addition, it is proved that electrical treeing channels in SIR are hollow channels generated by PD, which corresponds to the observed results.

EXPERIMENTAL DETAILS

Test samples

The SIR used in samples is two-component high temperature vulcanization (HTV) liquid SIR. Figure 2 shows the sample configuration with needle-plate electrode system simulating defects and protrusions in cables, which cause electric field distortion under certain voltage. The cone angle of needle tip is 30° and electrode curvature radius is 3 μm. The diameter of needle electrode is about 250 μm and vertical distance between