Experimental Study on the Influence of Defect Characteristics of XLPE Cable on the Initial Voltage of Electrical Tree

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Abstract. Experimental Study on the Influence of Defect Characteristics of XLPE Cable on the Initial Voltage of Electrical Tree Cross linked polyethylene (XLPE) has excellent electrical insulation performance. Cross linked polyethylene is widely used as the insulating material of 10 kV power cables. With the acceleration of urbanization, a large number of cable entry projects have started. XLPE cables are widely used in medium and low voltage power grids. However, due to the lax production process and other problems, some defects or impurities will inevitably appear in the cable insulation. These problems accelerate the deterioration of cable insulation and lead to the generation of electrical tree, which further leads to the overall Breakdown Failure of the cable. These problems greatly affect the power supply reliability of the whole transmission system. In view of the above problems, this paper carried out an experimental study on the influence of the defect characteristics of XLPE cable on the starting voltage of electrical tree. First, the test platform of needle electrode short cable is built. Then the growth law of electrical tree under different defects is simulated by using this test platform. This research work is of great significance for constructing the numerical model of XLPE cable defects and analyzing the mechanism of the influence of XLPE cable defect characteristics on the starting voltage of electrical tree.

Keywords: Cross Linked Polyethylene · Cable · Electric Tree Branch · Test Platform

1 Introduction

In recent years, power cables are more and more widely used. As a large number of cables gradually approach the full life cycle, related cable discharge faults cause large-scale power outages one after another [1]. In view of the above problems, domestic and foreign scholars have carried out relevant research work on the development law

H. Yang et al. (Eds.): SmartGIFT 2022, LNICST 483, pp. 397–402, 2023.
https://doi.org/10.1007/978-3-031-31733-0_33

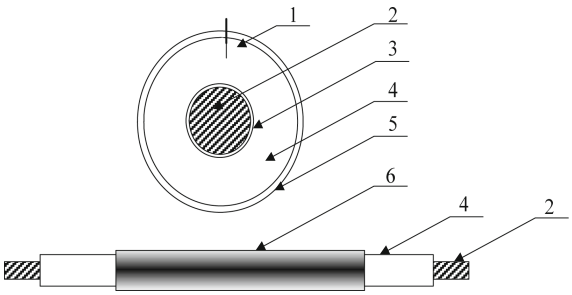
of electrical branches in XLPE cables under different defects. Reference [2] carried out the electrical tree aging test of silicone rubber materials under different curvature radii of needle tips, measured the starting voltage of electrical branch and its morphology under different conditions, and analyzed the influence characteristics of different needle tip curvature on the initiation of electrical tree; Reference [3] used ANSYS software to simulate and theoretically analyze the internal needle tip defects of XLPE cables, and compared with the on-site measured cable compressive strength. At present, most studies focus on the structure, growth features and contributing factor of electric branches and so on [4–6], only a few researchers have studied the effect of internal defects of XLPE cables on the generation and growth of electrical branches. The existing studies select a single object, and do not fully and systematically consider the influence of diverse defect characteristics on the generation of electrical tree.

Therefore, this paper uses the actual project short cable as the object, and first builds a pin electrode short cable test platform. Then the growth law of electrical tree under different defects is simulated by using this test platform. This research work is of great significance for constructing the numerical model of XLPE cable defects and analyzing the mechanism of the influence of defect characteristics of XLPE cable on the starting voltage of electrical branch.

2 Test Samples and Test Platform

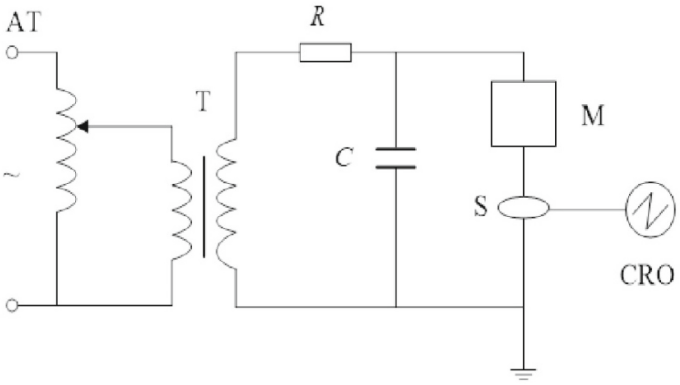
Because the initiation of electrical branch in the real cable is mainly related to the internal air interval and the bulge defects of the internal and external semiconductor layers, both of them induce the generation and development of electrical tree from the aspects of partial discharge damage and local electric field distortion [7–9]. In this paper, in order to simulate the bulge and air interval joint defects on the semiconductor layer, the needle electrode is repeatedly inserted into the insulation layer of the short cable to introduce the tip and air interval defects. The simulation test platform is shown in Fig. 1. Type and medium voltage cables are selected for the test samples to reflect the actual cable characteristics more accurately and avoid the test impact caused by insufficient technology when making samples. The specific steps of making the test sample: first, uncover the outer sheath of the cable and the shielding copper tape; Steel needles with diverse curvature radius are inserted into the insulation of the cable along the radial direction, and the thickness of the remaining insulation is 2.0 mm. During the insertion process, select the method of repeated insertion to promote the production of air interval at the tip of the needle, the combined defect models of bulge and air interval on semiconductor layers with diverse size were established.

Because the generation and development of electrical tree are accompanied by strong partial discharge signals, and show some differences in different stages. Based on the partial discharge signal features of electrical branch, the initiation time and development of electrical tree are determined. When the partial discharge frequency is mainly distributed in the interval, which can be characterized as the initial stage of electrical branch. The partial discharge signal is observed and collected by Luo coil and oscilloscope. The overall experimental schematic diagram is shown in Fig. 2.



1—Needle defect, 2—Cable core, 3—Inner semiconducting layer, 4—Insulating layer, 5—Outer Semiconducting Layer, 6—Copper shielding tape

Fig. 1. Structure of test sample



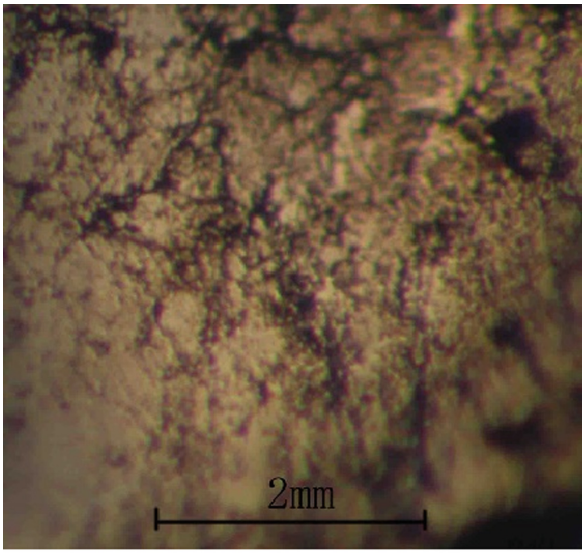
AT—Voltage regulator, T—Test transformer, R—Protective resistance, C—Coupling capacitance, M—Testing system, S—sensor, CRO—Oscilloscope

Fig. 2. Experimental wiring diagram

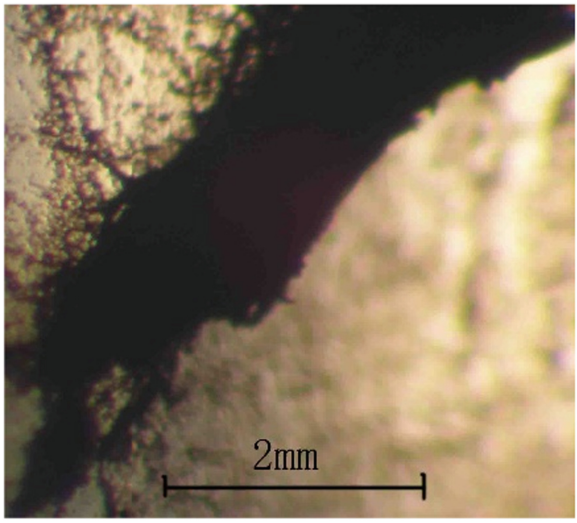
3 Test Result

In this work, the voltage rises at a rate of 5 kV/min and the frequency of the collected stable local discharge is analyzed, and the electric branch is observed by sectioning. Among them, the initial morphology of electrical tree is mainly filiform carbonization (Fig. 3.a) and gradually develops into a centralized carbonization channel shape (Fig. 3.b).

The time node of generation of the electrical tree is confirmed and the voltage rising at the corresponding time is recorded, which is the starting voltage of the electrical branch of the cable. By sorting out the data of several electrical treeing initiation tests, the correlation between the curvature radius of the needle tip and the treeing voltage of XLPE cable is determined. The mean value and error of the initial voltage under different needle tip curvature are shown in the curve in Fig. 4.



a



b

Fig. 3. Initial morphology and channelization growth of electrical tree

According to the experimental results, there is a positive correlation between the radius of curvature of the needle tip and the voltage caused by the electrical tree, that is, with the increase (decrease) of the curvature of the needle tip, the initial voltage of the electrical tree increases (decreases).

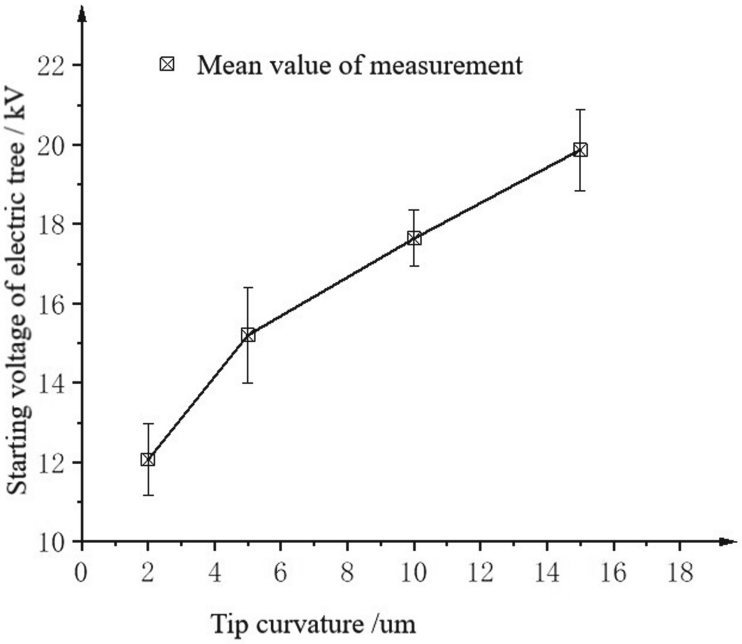


Fig. 4. Correlation between curvature of needle tip and starting voltage of electrical tree.

4 Conclusion

In this paper, a pin electrode short cable test platform is established. Using this test platform, the growth law of electrical tree under different defects is simulated.

(1) The initial morphology of electrical tree is mainly filiform carbonization, and then gradually develops into the shape of centralized carbonization channel.
(2) There is a positive correlation between the radius of curvature of internal defects in cable insulation and the voltage caused by electrical tree, that is, with the increase of the radius of curvature of defects, the initial voltage of electrical tree increases.

Acknowledgement. This work was financially supported by the science and technology project of State Grid Hunan Electric Power Company Limited (5216A520000H).

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