Cause Analysis and Countermeasures of a Breakdown Failure of Flexible 110 kV Cable Terminal

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Abstract. disintegration examination and analysis are employed in flexible terminal breakdown of 110 kV XLPE insulated cables. It is considered that the main reason of breakdown is the separation of the stress cone of the terminal and the fracture of the semi- conductive layer of the cable insulation. Therefore, the finite element method is used to electric field model and simulate the dislocation fault of internal stress cone and outer semiconductor layer of cable insulation. The distribution of the electric field intensity is calculated and compared. The simulation and calculation results verify the validity of the breakdown mechanism analysis, and put forward some practical suggestions.

1 Introduction

It is predicted that the clean energy installation in China will reach 570 million kW in 2020, which exceed 1/3 of the total installed capacity. The emission of CO2 can be reduced 13.8 million tons per year [1]. The rapid increase of power generation and the requirements of friendly environment has a profound impact on power transmission, and brings development opportunities for the application of cable. The demand for power cable is increasing rapidly, and the application scope of cable is also gradually expanding. Because of power cable using closed compact structure, the solid extrusion material insulation or oil paper composite insulation is wrapped in closed enclosure. Once fault occurs, it will lead to power failure directly, and it is difficult to locate and maintain. Therefore, although the failure rate of the cable is much lower than the overhead transmission line in the actual operation, the accidental cable accident still brings great trouble. Compared to cable, cable accessories (terminal and joint) insulation have complex structure and are compose by multilayer material, so the electrical stress concentrates on the insulation shield fracture which is prone to failure. In addition, the cable accessories are generally required to complete the installation on site, it will cause safety problems due to the poor sealing, bad construction technology and inadequate dust prevention measures. So the probability of cable accessory failure is much higher than cable.

The flexible cable terminal is one kind of prefabricated cable terminal, it solves many shortcomings of the traditional high voltage XLPE cable terminal such as complicated structure, inconvenient installation and oil spill. Besides, it has many advantages, such as high consistency of the manufacturing process, the simple installation process, reliable operation and no need to maintain [2-3]. It has become the ideal high voltage XLPE cable accessory and been widely used. In recent years, more and more urban overhead lines have been converted to cable, and the number of flexible cable terminals has increased greatly. With the gradual extension of the running time, the breakdown of prefabricated flexible terminal has appeared all over the country, which brings serious hidden danger to the security and stability of the power grid. As the most concentrated place of the electrical stress, the insulation shield fracture of the high voltage cable is the main part of insulation fault. If the electrical stress isn't evacuated fully, then the part will be the breakdown location on power cable insulation, and the stress cone can't play its due role [4]. The finite element method is a numerical method based on the variational principle [5]. Using this method can effectively calculate the electric field intensity. It is an effective tool for electric field simulation [6].

In this paper, a flexible terminal of 110 kV XLPE cable is disassembled, checked and analysed. The possible cause of the failure is pointed out. Finally, the finite element electric field simulation method is applied to verify the cause of the failure.

2 Failure Information and Cause Analysis

2.1. Failure Profile

In September 2016, a breakdown of outdoor flexible terminal of 110 kV XLPE cable occurred. The basic information of the failure cable is as follows: the cable line was put into operation in October 2006, the cable terminal type is YJZWG4-64/110-1×500mm2, and the cable type is ZR-YJLW02-64/110-1×500mm2. The circulation test of the cable lines has been carried out before the failure, and the three phase circulation values

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are all in accordance with the requirements of the regulations. When the failure occurs, there are no external forces such as construction and excavation on the cable channel. The weather is clear, and there is no overvoltage phenomenon such as lightning.

2.2 Disintegration Examination of Failure Terminal

The cable terminal surface has obvious flexible burn holes after disassembling, and most of the region outside the surface have been blackened, careful inspection shows that the main insulation has complete breakdown, as shown in figure 1. The fault point is located in the insulation shield fracture, and the stress cone has a certain distance of abnormal displacement with the insulation shield fracture.

Fig. 1. Failure Cable Terminal.

Inspection and measurement showed that there was a 2~3 mm gap between the cable aluminium bellows sheath and the longitudinal water blocking buffer layer (the water blocking zone), they were not tightly integrated, as shown in Figure 2.

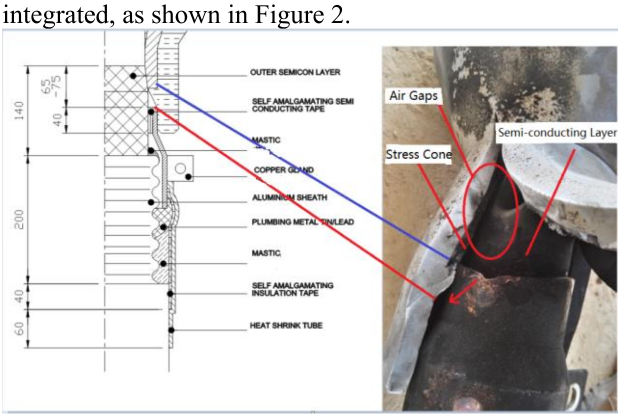

Fig. 2. Internal Gap in the Failure Terminal.

2.3 Analysis of Failure Causes

Because the installation position of the cable terminal is about 15~20 meters from the ground, the cable terminal is manufactured on the ground and then hoisted to the installation position. When the hoisting is fixed, only the aluminium sheath of the cable is fixed. For the cable whose type is ZR-YJLW02-64/110-1×500mm2, its weight is about 10kg per meter. Then the carrying weight of cable terminal can reach more than 150kg. If the cable aluminium corrugated sheath is not closely combined with the longitudinal water blocking buffer layer (the water blocking zone) of the cable, it may cause the phase displacement of the cable body and the aluminium bellows sheath due to the weight of the cable.

As we all know, f is integrated with corrugated aluminium, so it will generate relative displacement between cable body and flexible terminal when the cable body has relative displacement with the aluminium ripple sheath. And it will lead to that the stress cone of flexible terminal can't get in touch with the insulation shield fracture normally because of the abnormal displacement. Then the suspended discharge can be generated because the electric stress can't be evacuated. Finally, the flexible terminal breakdown happened.

3 Simulation Analysis with Finite Element Method

3.1. Simulation Model Establishment

Referring to the structural parameters of the cable terminal, a complete cable terminal model is established according to the actual size (1:1). The finite element method is applied to simulate and calculate the electric field numerical value of the terminal when the applied voltage is 64 kV. The structure of the terminal model is shown in Figure 3, and the dielectric constant of the material is shown in Table 1.

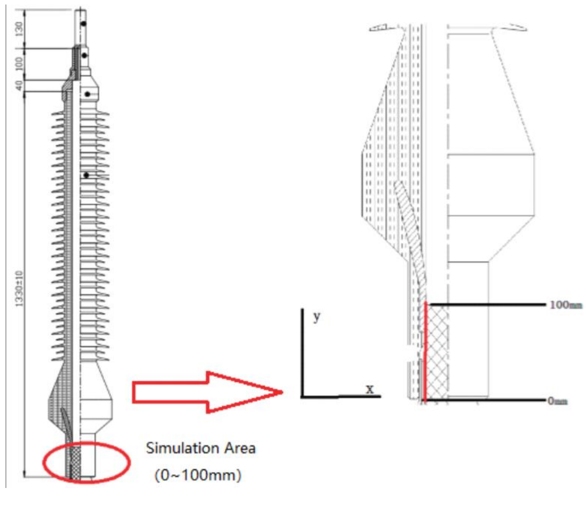

Fig. 3. Model of Flexible Terminal.

Table 1. Dielectric constant of terminal material

Material	Relative Dielectric Constant
XLPE	2.25
Semi Conductive Layer	100
Copper Core	10000
Stress Cone	2.78
Air	1

3.2 Simulation Results

According to the disintegration result and cause analysis of the failure, the simulation of two contact situation of stress cable and semi conductive layer were carried out respectively. The first case is that stress cone gets in touch with semi conductive layer normally, and the second case is that stress cone has 20mm displacement with semi conductive layer. The distribution of electric field was observed, and the electric field value was calculated. The simulation results are shown in Figure 4 to figure 6.

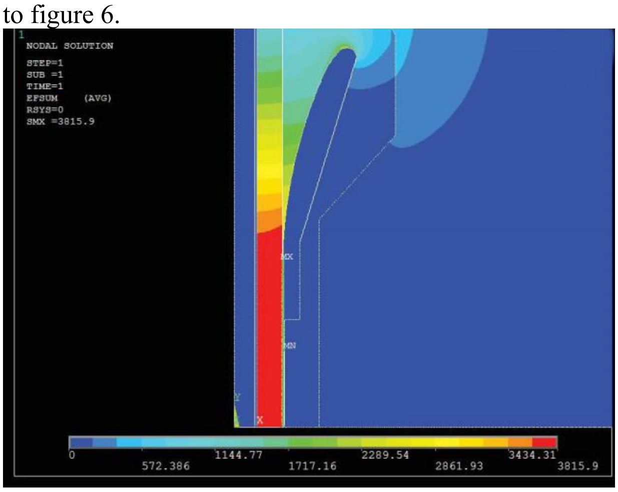

Fig. 4. Electric Field Distribution When the Semi Conducting Layer Overlap the Stress Cone Completely.

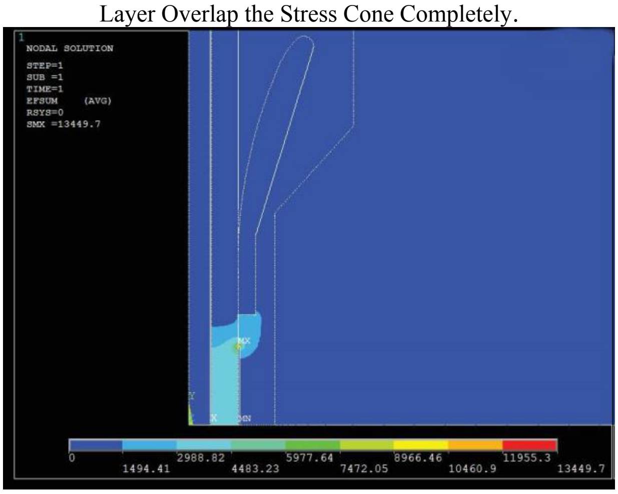

Fig. 5. Electric Field Distribution When Semi Conducting Layer Dislocate the Stress Cone 20mm.

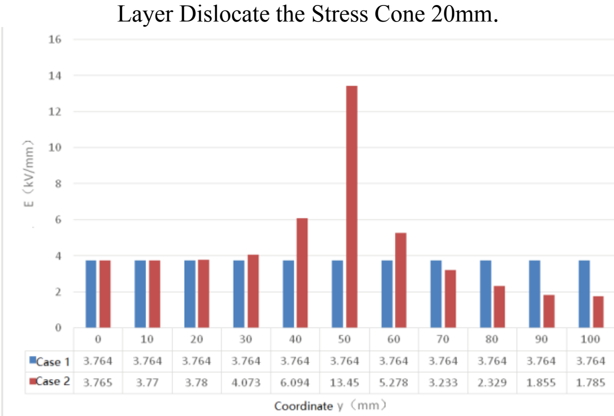

Fig. 6. Diagram of Electric Field Variation Trend.

3.3 Simulation Results Analysis

According to Fig. 6, the electric field is seriously distorted when the semi conductive layer is misaligned with the stress cone. When y=50mm, the maximum electric field value reaches 13.45kV/mm, which is 3.57 times of the normal case. It is far more than the breakdown electric field intensity of air (about 3kV/mm), and it also exceeds the electric field intensity of design interface between the cable insulating layer and the stress cone (about 11kV/mm). It can be seen that the main cause of the cable terminal breakdown is that the inner semi conductive layer of the stress cone and the fracture of the semi conductive layer of the cable insulation can't lap normally.

4 Conclusions and Countermeasures

4.1. Conclusion

According to the analysis of the failure terminal and the simulation results of the electric field, the following conclusions can be drawn:

1) when the cable terminal is installed, only the cable aluminium sheath layer is fixed. The weight of the cable causes the phase displacement of the body and the aluminium bellows sheath, and the stress cone of the flexible terminal can't connect with the insulation shield fracture properly. It resulted in the breakdown of the terminal.

2) The electric field simulation results verify the correctness of the accident mechanism analysis. The electric field distortion is more intense under the condition of the misalignment of the outer semiconducting layer and the stress cone, then partial discharge is generated. When the electric field intensity reaches a certain level, it will cause weakness breakdown.

4.2 Countermeasures

According to the above reasons analysis and practical experience, the following countermeasures are put forward:

1) Cable hoisting is carried out before the installation of the flexible terminal. Before installing cable accessories, cable should be pre hung to install position. Then cable will be put down, so repeated 3 times. Thus the displacement of cable body and the aluminium corrugated sheath will be generated in advance so as to prevent the relative displacement between the two after installation.

2) Improve the space layout of the flexible cable terminal. The flexible cable terminal on the tower should avoid bending as far as possible. Under ideal condition, the cable terminal should be perpendicular to the ground. In cases where the site conditions are not allowed, the proper fixed method should be used to ensure that the bending angle of the terminal is not more than 30 degrees in the long run.

3) The insulation state detection of the flexural flexible terminal should be strengthened. For the flexural flexible terminal, the operation and maintenance personnel can evaluate the running state through infrared thermal imaging, partial discharge test and ultraviolet imaging in order to prevent terminal breakdown.

References

1. Zhou Y, Zhao J, Liu R, et al. Key Technical Analysis and Prospect of High Voltage and Extra-high Voltage Power Cable[J]. High Voltage Engineering, 2014, 40(9): 2593-2612.
2. Yin Q. Technical progress of the accessories for high and extra high voltage XLPE cables[J]. Electric Wire & Cable, 2000(1): 3-11.
3. Wang W. Technical foundation of XLPE insulated power cable[M]. Northwestern Polytechnical University press, 2005.
4. Si C. Power Cable[M]. China Electric Power Publishing House, 2006.
5. Wu X, Zhou L. Application and development of time-domain finite element method on EM analysis[J]. Chinese journal of radio science, 2008, 23(6): 1209-1216.
6. Li H, Zhang L, Zhou Z. Optimizing design of stress controlled corn by FEM[J]. High Voltage Engineering, 2005, 31(11): 55-57.