The Electrical Tree of Polyethylene Insulation Study Progress

Wen-Jie MEI[1,a,*], Hong-Liang YANG[1], Chun-Mei LI[1], Ran CHEN[1], Cheng-Cheng SONG[1]

[1]Jiangsu Hengtong High Voltage Power Cable System Co., Ltd, Suzhou 215537, China

[a]892897377@qq.com

*Corresponding author

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Abstract. This article describes some influences factors and growth mechanism of cross-linked polyethylene electrical trees. There are three main factors which are water trees, temperature and voltage levels. Growth mechanism includes growth mechanism of conductive type electrical trees and growth mechanism of non-conductive type electrical trees. This article expound two aspects about improve the anti-electrical trees of insulation. The first, continue to develop the anti-electrical trees materials, to improve the crystallinity of the material, to grain refinement, to uniform the crystallization. Second, improve the technological level, to heat evenly the inner and outer insulation layers.

Introduction

Polyethylene insulation has been widely used in the high voltage cable industry, due to its good dielectric properties and mechanical properties. Polyethylene insulation will appear electrical tree under the electric force, and the electrical tree will finally lead the insulation to breakdown[1]. Especially the demand of high voltage cable market bigger and bigger, the study of the initiation and growth of electrical tree have attracted more and more attention. At present some universities have done lots of experiments about electrical tree, improving our understanding of initiation and growth mechanism. However the understanding of the initiation and growth mechanism have not been formed unified, due to the complexity of itself[2]. This paper introduced the initiation factors, the growth mechanism and the improving electrical tree research. At last, conclude some appropriate measures to reduce the initiation and growth of the electrical tree. We hope to raise readers' understanding of the electrical tree, take some effective measures on the materials, cable construction and processing, to inhibit produce of the electrical tree, improve the reliability and service life of the cable[3].

Influence Factor of Electric Tree

Electric tree can be directly initiation or initiation by space charge and water tree. It has been found that the micro-breakdown of the tree restrict of space charge is the main process of the initiation and growth to be conductive tree[4] Xiaoquan Zheng[5] found that the probability of initiation of electric tree due to dry water tree is higher than wet water tree. The growth of electric tree initiated by dry water tree is faster than the wet water tree. But the initiating speed of sample before degrading is the fastest among them.

Studies have shown that if the defect size of polyethylene insulation does not exceed the allowable value, the probability of occurrence of electrical trees will be much smaller, reduce the normal distribution mean and standard of defect size at the same time, and also further to improve the reliability of anti-electric tree of insulation. Power frequency, aggregation structure, voltage and temperature also have effects on electric tree in the course of actual operation of cable. The temperature is the most important factor among them. Ruijin Liao[7] found that temperature doesn't have a big effect on the shape of electric tree under 90°C. However, as the temperature rises, the lamella will melt and the amorphous area will increase [8], If the time that the operating temperature

of cable exceeds 110°C is not too long, the free volume will increase and accelerate the speed of electric tree initiation. The life span of cable will decrease[9] Xiangrong Chen[10] and Nazer H Malk[11] had found if the applied voltage exceeds the threshold value, the tree areas become more intensive and the destruction areas also extend. The boosting methods have a big effect on the growth of electric tree. The faster the speed of boosting is, the more intensive the tree areas and the larger the fractal dimension is[12].If second voltage is applied, the time of initiation of electric tree is short, the growth speed is fast and the discharge channel is narrow, all of these will accelerate the breakdown of insulation[13].

The Initiation and Growth Mechanism of Electrical Tree

Look from the state of aggregation structure, the electrical tree in uniform crystalline state is conductive type, the electrical tree in the non-uniform crystalline state is non- conductive type. Usually the non- conductive type will develop into hybrid type slowly, each type of electrical tree have their own growth mechanism[14]. Look from the position, electrical tree grow in outer side of insulation is almost conductive type, the growing time is long, electrical tree grow in inner side of insulation is almost non-conductive type, the growing time is long[15].

The Initiation and Growth Mechanism of Non-conductive Type Electrical Tree

Because of difference of the crystal zone density and amorphous zone density, discharge effect during crystallization, when the current flows in the amorphous region, space charge will occur in the traps which are formed by microvoids and impurities. The number of traps increase and reach to a certain extent, the breakdown strength declines and cause partial aging which leads to electric tree[16]. The microvoids are much denser in this area. The growth of electric tree can be initiated by the microvoids on the cusp of the tree[17-18].

Partial discharge will produce ion bombardment, then appear lots of energy and gas expansion phenomenon, resulting in high local temperature and pressure[19]. The high local temperature will decompose and l soften the around material, the high local pressure will swell along the pores direction and the residual stress will make the electrical tree growth along the non-external applied electric field[15]. The difference of crystal zone and amorphous zone will also affect the distribution of field strength inside the material, higher field strength will focus in the amorphous zone, the interfacial free energy will change in the polymer. The interfacial free energy can provide thermodynamics driving force, promoting the electrical tree get more power of growth from the amorphous zone the from the point of thermodynamics[20].

The Initiation and Growth Mechanism of Conductive Type Electrical Tree

The conductive type electrical tree will be formed, while the aggregation of polymer is a small uniform crystal, or the electrical tree deep into a large crystal, the channel of electrical tree has large electric field. The partial discharge almost stopped, A smooth space charge screen is surmised around the electrical tree[14,21], Xiangrong Chen found unordered carbonized products aggregate in the channel of electrical tree from the point of microstructure, the thickness of unordered graphitic carbon layer is about 8nm, the resistance is less than $10\Omega*\mu m^{-1}$, inhibit the development of partial discharge, but there is no unordered graphitic carbon layer in the conductive type electrical tree, resulting in no partial discharge occurred, and then the conductive type of electrical tree grow very slowly.

The Research of Anti-electrical Tree Materials

There is a electrical weak area in almost semi-crystalline materials, the electrical tree is initiated inevitably in electrical weak area, reducing indirect caused by space charge or water tree is more simper to study, It can largely slow down the growth speed of electrical tree, when the electrical tree deep into the uniform crystalline[21]. So we need to rise the crystalline degree and reduce the

spherulite size.

Currently, producing the LDPE-nanoparticles has become a hot research direction, by use the inorganic nanoparticles as a raw material, the nanoparticles can improve the crystalline of composites, working as the electrical tree inhibition, the composite media can also increase the electrical tree starting voltage under the AC voltage, reduce the discharge quantity and repetition rate of electrical tree, and inhibit the electrical tree grow along the electric field direction[23-24].

Summary

Combined with the growth mechanism and initiation factors both of the electrical tree, the electrical tree is initiated due to the presence of electrical material weak zone. The driving force of growth come from the interfacial energy, indicating that the existence of electrical tree is inevitable, what we can do is to reduce the electrical tree growth rate and the probability of initiation, we can also get the following conclusions to reduce the electrical tree during the producing.

In respect of raw materials, improve the degree of crystallinity, refine the spherocrystal and homogenize the crystal, all which can reduce the initiation and growth of non-conducting electric tree. Besides, the preparation of Low density polyethylene nanocomposites will have a good inhibition. However, the increase of impurities and dimension may damage the property of electric tree and water tree retardant. So considering these factors, further researches need to be done before commercialization.

In terms of technology, pre-heating the conductor before crosslinking can reduce the imperfection of crystallinity inside of the insulation. During the crosslinking, the outside of the insulation will cool ahead of the inside layer. So it is easy to form micro voids on the inside layer. The slow cooling speed of the inside layer will also cause the generation of sphaerocrystal and initiate the non-conducting electric tree. To meet the requirements of the uniformity of flaw normal distribution, the flaws in the insulation, especially on the inside layer must be well controlled during the degassing process. In conclusion, further researches must be done on the crosslinking and degassing technology.

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