Thermal and Electrical Breakdown Phenomena in Electrical Insulator of Power Cable

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Abstract

Thermal and electrical breakdown phenomena in XLPE insulator of power cable were investigated. At high temperature the polymeric insulator was thermally deteriorated. Under the magnified high electric field, electrical tree was initiated at the sharp tip of needle electrode which was inserted to simulate the defects and impurities such as void, crack, metallic particles, dusts, and so on.

1. Introduction

As the consumption of clean energy of electricity increased, it became one of the most important things for the supply of electric power with stability and reliability. The electrical insulating part in power cable takes the largest volume and the dielectric breakdown in it is the main cause of electric failure[1]. Developing new materials and designing technique are the topics in the electric power field. The long-term dielectric deterioration phenomena in the polymeric insulator under electrical and thermal stresses have been investigated world wide. Polyethylene is the most widely used polymer in the electric power cable industry. Expecially, cross-linked version has been used for electrical insulating parts of high voltage electric power distribution and transmission cable because of its excellent dielectric properties, such as high dielectric strength, low losses and low dielectric constant at wide frequency[2]. Power cable insulated with XLPE is generally operated at higher temperature than 75℃ and thermally deteriorated in the long run. So that, investigating the thermal stability and treeing resistance is very important to characterize the polymeric insulator for the power cable[3]. In this study the thermal degradation characteristics and electrical treeing phenomena in XLPE insulation of power distribution cable were observed.

2. Experiment

The polymeric material used in this study was XLPE of power distribution 22.9 kV CN/CV cable and its gel content was 85-90%. The microtomed thin film(20 ㎛) sample was heated by TGA(Cahn TG-121) under N_2, O_2 and air flowing at the rate of 50 ml/min, respectively. The block sample with needle-plane electrode(3 ㎛ tip radius) geometry was electrically stressed until dielectric breakdown at room temperature and the dielectric pre-breakdown phenomena of electrical tree were observed. The detailed procedure of sample preparation and test procedure appear in the previous literature[4].

3. Results and Discussion

The TG curves of XLPE at 5 different heating

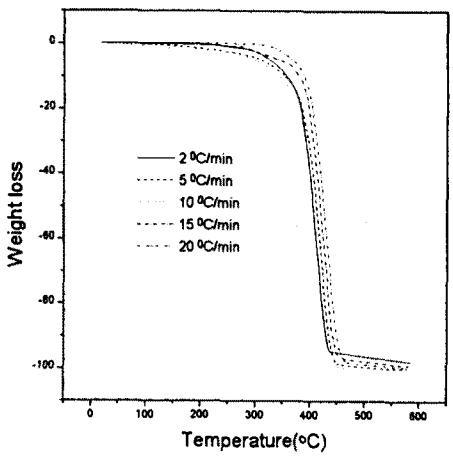

Fig. 1 Thermogravimetric thermograms of XLPE at 5 different heating rates under dry N_2 gas flow rate of 50 ml/min.

rates are shown in Fig. 1. One step weight loss was observed. As the heating rate increased the thermograms moved toward right. At the presence of oxygen, the TG thermograms get complicated.

Fig. 2 shows the TG thermograms of XLPE at 3 different ambient gases, respectively. One stage weight loss was observed at N_2 ambient gas condition and the decomposing temperature was 290℃. However, two step weight loss was observed at O_2 and air ambient gas condition

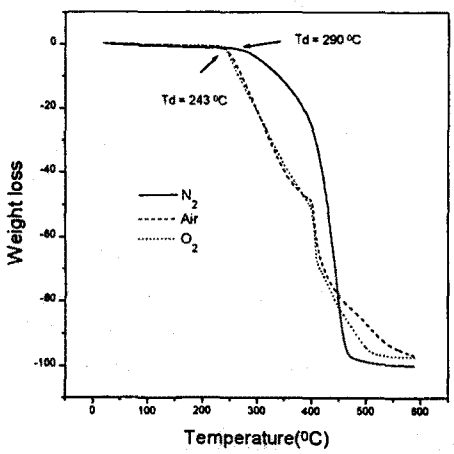

Fig. 2 TG thermograms of XLPE under 3 different ambient gases.

and the initial decomposing temperature was decreased to 243℃. Under the high temperature and oxygen presence condition, the polymeric insulator degraded by oxidation reaction after oxidative induction time[5]. When the polymeric main chains were cut and the weight of decomposed products become volatile enough, the transition of base line on TG curve is observed and the initial decomposition temperature(IDT or T_d) is detected. It was reported that, the carbonyl(C=O) groups are formed by oxidation reaction under the O_2 ambient gas. At high temperature, the chain can be attacked by the oxygen and form free radicals. The free radicals are stabilized and produce C=O and C=C bonds[3]. So that the chain scission is accelerated and the weight is decreased rapidly. At O_2 condition, in this way, the decomposition reaction occurs continuously by autoxidation process, especially, at the presence of metallic impurities and so on. The dielectric breakdown phenomena of electrical treeing deterioration may be affected by the thermal-oxidation reaction.

Fig. 3 shows the electrical tree from the tip of high voltage needle electrode inserted into XLPE at 100℃ to simulate the defects or impurities such as voids, cracks, metallic particles, dusts, and do on. The electrode separation was 2 mm and the supplied electrical stress was 7.5 kV at room temperature. It is generally agreed that the long-term performance of XLPE insulated cables depends on the number and size of voids, contaminants, defects and impurities on which electrical stress is concentrated and magnified. Electrical tree is initiated when the magnified electric field gets high enough to the limitation field of mechanical breakdown by the Maxwell stress. When these conditions are associated with water, then can sometimes give rise to water-treeing deterioration. The initial tree was started from the needle electrode and propagated toward the counter plane electrode,

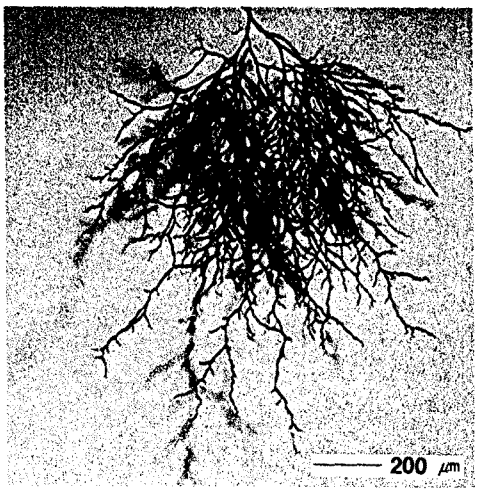

Fig. 3 Electrical tree from the tip of HV needle electrode inserted into XLPE to simulate the defects or impurities.

step by step. At the initial stage, low density tree was observed but as the voltage applying time increased the branching density of tree increased. Treeing phenomena is one of the main cause of dielectric failure in the electric power cable. The initiation and growth mechanism of electrical tree have been investigated worldwide to minimize the initiation and growth of electrical tree and to suppress the propagation toward the outer electrode. The electrical treeing phenomena are too complex and various according to the test conditions[6]. So it is not easy to characterize the shape and to correlate the phenomenological information to the insulating capability. The investigation of the fractal characteristics and optical intensity of the treeing phenomena are on the process and the test results will be shown at the presentation.

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