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XLPE의 절연파괴특성에 미치는 휘발성 불순물의 영향

Effects of Volatile Impurities on Dielectric Breakdown Characteristics of XLPE

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Abstract

Effects of volatile impurities on dielectric deterioration characteristics of XLPE were investigated. Block type plate with needle-plane electrode and artificial void filled with N_2 gas or humidity was subjected under high electric field. The dyed region by oxidation reaction around the artificial void filled with humidity was detected before tree initiation. Electrical tree was started from the tip of void filled with N_2 gas earlier than humidity.

1. Introduction

Cross-linked polyethylene(XLPE) has well combined properties of high dielectric strength, low losses, low dielectric constant, flexibility and good thermal properties[1]. It is used for the insulation of high voltage power distribution and transmission cable. As the polymeric insulation is subjected under high electric field for long period, the system is electrically deteriorated and brokendown finally. The absorbed water molecules, transferred volatile impurities from outside or decomposed by-products play an important role in charge storage and transport, as well as, dielectric breakdown of polymeric insulators[2-4]. So it is very important to observe the dielectric breakdown phenomena in XLPE insulation containing volatile impurities. In this study, the roles of humidity and N_2 gas on treeing deterioration phenomena were investigated by using needle-plane electrode geometry with artificial voids.

2. Experiment

The specimens used in this study were XLPE insulation blocks(4 mm thickness) of power distribution cable(Hanil Power Line Co., 22.9 kV CN/CV cable) with needle-plane electrode geometry(4 mm separation) and artificial void filled with N_2 gas or humidity, respectively. Stainless hard steel needle electrode which has a tip angle of 30° and a radius of curvature of 3 ㎛ was inserted into the specimen with needle inserting equipment at 100 ℃. The specimen was annealed for 12 hrs and then cooled down slowly to the room temperature to minimize the physical defects by the residual thermal and mechanical stress. And the needle electrode was pulled out inside the glove bag filled with N_2 gas or humidity and the specimen was stored at the bag for 48 hrs. A new needle electrode was inserted into the artificial void and the epoxy resin(Araldite of Ciba-Geigy) was mounted on the top of the specimen to protect the leakage of gaseous product. Silver paint was applied on the bottom of the specimen and leading line was attached. The specimen was embedded into the transformer oil(silicon oil) to suppress the occurrence of the surface discharge under high electric field. A constant voltage was supplied to the specimen at room temperature and the treeing phenomena(pit, filamentary channel, void, dyed region, etc.) around the needle electrode were detected by using well advanced image analyzing system(Image Pro Plus). The tree initiation time, the treeing propagation characteristics and the phenomena were observed. The degenerated specimen was microtomed to thin sheets of 30 ㎛ thickness, dyed with methylene blue for 4 hrs at 100℃ and observed through optical microscope.

3. Results and Discussion

Fig. 1 shows the contents of volatile components in XLPE detected by the vacuuming process. The microtomed specimen was degassed for 48 hrs at 100℃ and then stored at room temperature for 48 hrs. About 1.25 w% of the XLPE component was detected as volatile impurities. The impurities were reported by many researchers as the by-products of the recombining reaction of the decomposed residual curing agent(DCP) and transferred things from the environment[5]. These kinds of impurities affect the dielectric breakdown phenomena in polymeric insulator[2].

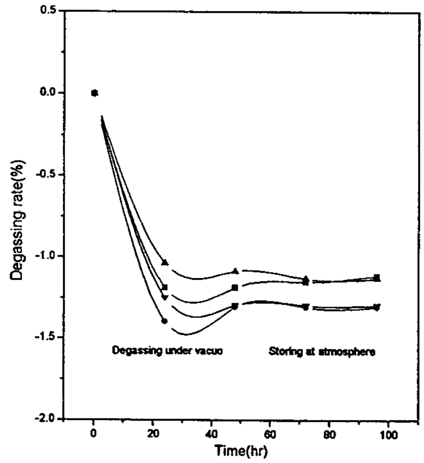

Fig. 1. Contents of volatile impurities in the XLPE

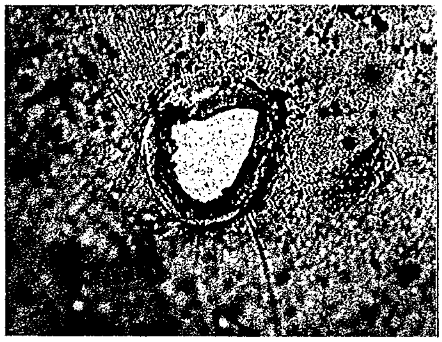

Fig. 2. Optical microscopic photograph at the ambient region around the artificial void filled with humidity before tree initiation.

Fig. 2 shows the cross-section of artificial void filled with humidity and electrically stressed under 10 kV of commercial 60 Hz for 25 mins. Colored region around the void was observed and the dye was brown. It is thought to be the reason of polymeric chain scission by high electrical stress and the oxidation reaction. It was reported that, the discolored or deteriorated region was the pre-breakdown phenomena[1,4]. The injected hot electrons collide with the polymeric main chain and break the bonding of polymer. The radicals produced by the chain scission react with other chains or other radicals and forms the double bonded products or oxidized things. The specimen was sliced with microtome and dyed with methylene blue. The dyed region was observed around needle electrode. The oxidized specimen was well dyed with methylene blue after ac voltage application before tree initiation. After tree was initiated, however, the dyed region was not observed near the tree channel. The degenerated region before tree initiation indicates that the polymeric structure was decomposed and might the micro-void be formed. The dyed region by methylene represents of oxidation reaction. This shows the autoxidation process before the tree initiation under O_2 presence[1,4].

Fig. 3 shows the initiated tree from the artificial void filled with N_2 gas after voltage

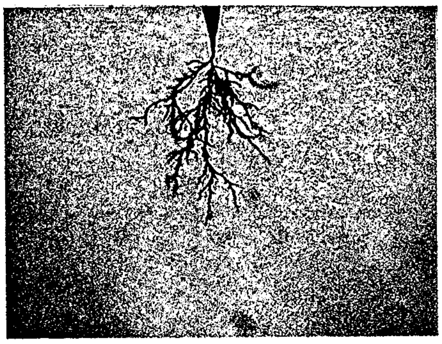

Fig. 3. Treeing phenomena from the tip of needle electrode.

application of 10 kV for 330 secs. Tree initiated after tree inception time of 10 secs. The leading tree extent was 523 ㎛. The width of the tree was 569 ㎛. The treeing phenomena were similar with the sample without voids in which the needle electrode have a direct contact with polymeric insulation. This shows the electrical tree started from the stress concentrated region in polymeric insulation. When the high electric field was applied to the gas inside the void, the dielectric breakdown of gas was occurred first and the tip of void was also stressed under high electric field[5,6]. The condition on the surface of the void affects the propagation of the tree. When the void filled with conducting by-products, the electric field at the tip of the artificial void is magnified and the tree initiates when the electric field at the tip became higher than the limit of physical deformation stress. So the voids act as the stress concentration like the rough electrode surface, conducting impurities inside the insulation, and so forth. When the tree reached the counter-electrode, the dielectric breakdown occurred after treeing deterioration.

Fig. 4 shows the treeing propagation characteristics from the artificial void' filled with N_2 gas and humidity, respectively. The treeing initiation times of N_2 filled samples were 10 and 90 secs. In the humidity-filled-system, however, the time was 600 secs and one of the system showed no tree. It was reported that the formation of C=C and C=O bonds increased the

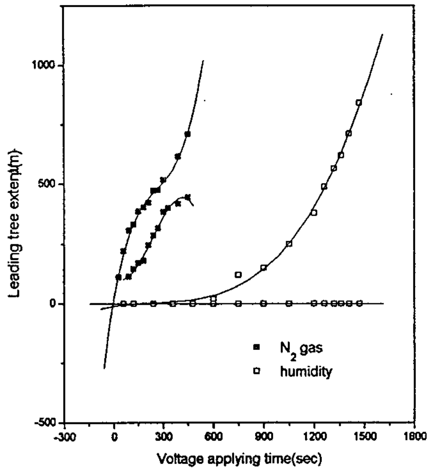

Fig. 4. Treeing propagation characteristics from the artificial void.

permittivity and electric conductivity so that the electric field at the tip of needle electrode could be relaxed in humidity-filled-system[1,4]. But the presence also accelerates the carrier injection and helps to trap the carrier. So the combined phenomena affects the tree initiation and propagation[2,7]. Tree propagated rapidly in N_2-filled-system. In the humidity-filled-system, tree initiated after long hours of tree inception time and propagated slowly but grew rapidly after 1,000 secs.

Conclusions

The effects of volatile impurities on dielectric deterioration characteristics of XLPE was investigated by using block type plate with needle-plane electrode and artificial void filled with gas and the following conclusions were obtained.

1. The dyed region by oxidation reaction around the artificial void filled with humidity was detected.
2. Electrical tree was started from the tip of void filled with N_2 gas faster than humidity after tree initiation time.
3. When the tree was formed, all the trees were propagated rapidly from the tip of void.

Acknowledgement

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