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LDPE에서 발생된 전기트리에 수반된 내부 부분방전 펄스 해석

Electrical Pulses of Internal Partial Discharges Accompanying with Electrical Tree in LDPE

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ABSTRACT

The correlation between propagation of electrical tree and internal partial discharges is discussed. We use specimens with needle-plane electrode system made of LDPE(Low Density Polyethylene), observed inception and propagation of electrical tree by optical microscope and investigated the characteristics of the partial discharge (PD) pulses accompanying with propagation of electrical tree.

In the specimens with needle-shaped void, the tree propagates branch type. The length of the tree has good linear relation with average discharge power of PD pulses.

In the specimens without needle-shaped void, the tree grows bush type tree. The correlation between the area of the tree and the average discharge power of PD pulses has linear relation.

국 문 요 약

전력용 케이블은 전선로의 지중화 추세에 따라 사용이 증가하고 있다. 케이블 절연체의 경우 장기간의 전압인가에 의해 열화 및 절연파괴 된다. 전력용 케이블의 절연파괴시 발생하는 사회/경제적 문제는 매우 심각한 것으로 알려져 있다.

절연체의 열화에 영향을 주는 요인은 매우 복잡하지만 그중에서도 전기트리 열화에 의한 파괴는 비

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교적 두꺼운 고체 유전체인 경우에 절연파괴 사고의 주된 원인이 되고 있다. 전기트리의 개시나 진전시 부분방전이 발생하므로 부분방전의 검출에 의해 전기트리의 발생 및 진전 양상을 관측할 수 있고 부분방전의 해석에 의해 절연재료의 잔여 수명을 예측할 수 있다.

본 논문에서는 고전압 전력용 케이블 절연재로써 광범위하게 사용되고 있는 저밀도 폴리에틸렌 시편에서의 전기트리 진전 양상을 비파괴 진단 기법에 의하여 검출하고자 내부 부분방전을 관측/해석하였다.

1. Introduction

As electrical tree generates and propagates in insulation materials, insulating thickness is decreased and local parts of degradation are generated. Finally, insulation materials become breakdown. Electrical tree is closely related with insulation life, because the generation and propagation of electrical tree severely decreases insulation life[1].

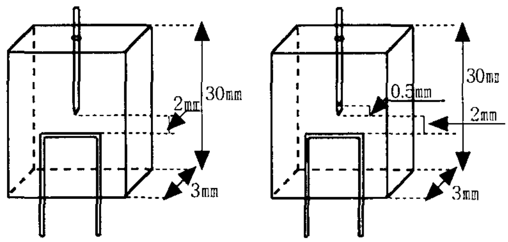
Thus, it is important to detect inception and propagation of electrical tree to prevent electrical failure. Since the inception and propagation of electrical tree cause partial discharge[2,3], we can observe generation and propagation aspects of electrical tree[4,5], so predict remaining life of insulation materials[6] by analysis of PD.

But, it is difficult to find direct relationship between propagation of electrical tree and internal partial discharges as a results of study until now[7]. More profound studies are needed, so we investigate and analyze internal PD pulses accompanying with electrical tree in LDPE.

2. Experiment

2.1 Specimen

Specimens are made of pure LDPE pellets with density 0.92g/cm^3. Pellets are hot-pressed at 120℃ for 5min. The samples have plane-needle electrode system and the thickness is 3mm in order to perform optical observation of tree under high resolution. Fig. 1 illustrates structure of specimen.



(a) without void (b) with void

Fig. 1 Shape of specimens

We make specimens with needle-shaped void and without needle-shaped void. Steel needles are used for point electrode and their tip radius are about 20㎛. Copper plane electrodes with diameter 0.55mm are used.

The gap of electrode is 2mm. The needle-shaped void is formed by pulling out needle electrode and the length of void is 0.5mm. And, to prevent diffusion of gaseous decomposition products formed by PD, we seal interface of electrodes and surface of specimens with epoxy resin.

2.2 Measuring system

In order to suppress surface discharge, we put the specimens in silicon oil. The PD measurement system is shown in Fig. 2.

Since PD is affected by aspects of applied voltage, we increase voltage at 0.5 kV/s and apply constant voltage with 13 kV.

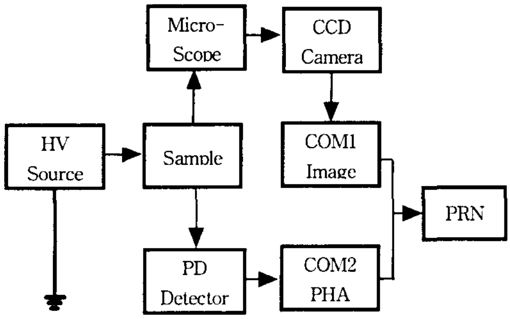


Fig. 2 PD measurement system

We observe electrical tree using the optical microscope with CCD camera. The output of camera is transported to computer1, processed data using DT3851 image processing board and de liberated the propagation of tree as a function of voltage application time. PD detecter acquires PD pulses and transports data to computer2, then computes the data with peak discharge pC, average discharge power and repetition rate n/s.

3. Results and Discussion

3.1 Specimens with needle-shaped void

Fig. 3 is an example of electrical tree acquired by computer 1 and processed by GL Image. The shape of electrical tree is branch type. Fig. 4 is an example of ϕ-q-n distribution of internal partial discharges. Several processing of internal partial discharges originate from ϕ-q-n distribution as Fig. 4.

Tree in specimens with needle-shaped void propagates branch type tree. In Fig. 5 the characteristics of growth of branch type tree with application time are shown.

In Fig. 6 peak charge and repetition rate of PD pulses as a function of the length of branch type tree are shown. The PD magnitude at the inception stage of branch type tree appears small and uniform, but at the initial stage of propagation, the PD pulses are became more active and classified big group and small group.

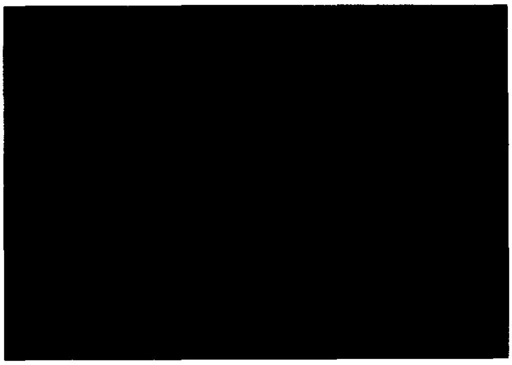


Fig. 3 An example of electrical tree

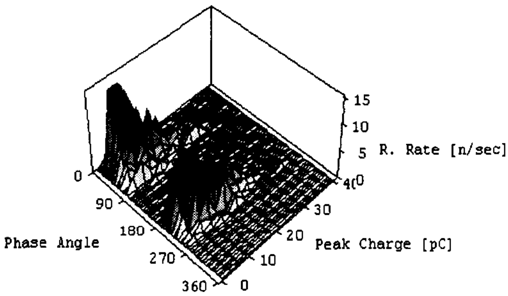


Fig. 4 An example of ϕ-q-n distribution of internal partial discharges

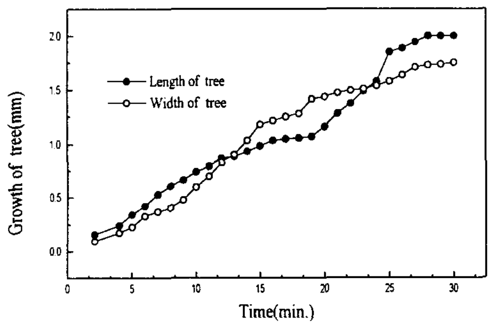


Fig. 5 The characteristics of the growth of branch type tree vs. voltage application time

Average discharge power is given by

$P = 1/T(q_1 v_1 + q_2 v_2 \cdots q_n v_n)$ (W) where T is period, v_1, v_2, $\cdots$ v_n are voltage over specimen when discharges occur with q_1, q_2, $\cdots$ q_n. In Fig. 7 the correlation between the length of branch type tree and the average discharge power of PD pulses is shown. It's clear that the length of tree has linear relation with the average discharge power of PD pulses.

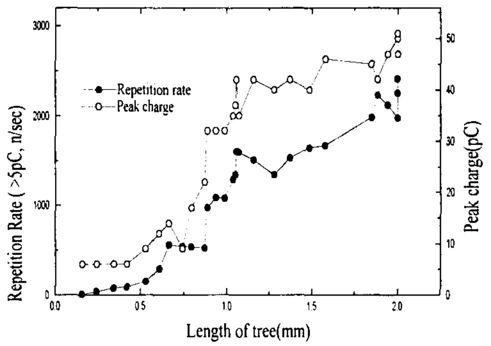


Fig. 6 Peak charge and repetition rate of PD pulses vs. the length of branch type tree.

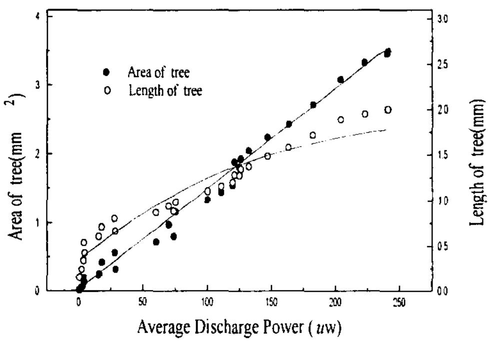


Fig. 7 The length and area of branch type tree vs. the average discharge power

3.2 Specimens without needle-shaped void

Tree in specimens without needle-shaped void propagates bush type tree. Fig. 8 shows the characteristics of growth of bush type tree as a function of voltage application time. Fig. 9 shows peak charge and repetition rate of PD pulses of bush type tree as a function of the area of bush type tree. The peak discharges of the PD pulses with the growth of bush type tree increases regularly and the repetition rate of PD pulses increases linearly comparing with those of branch.type tree. Because the characteristics of PD pulses of bush type tree are different from that of the branch type tree, we can discriminate tree type by measurement of PD pulses accompanying with the propagation of tree.

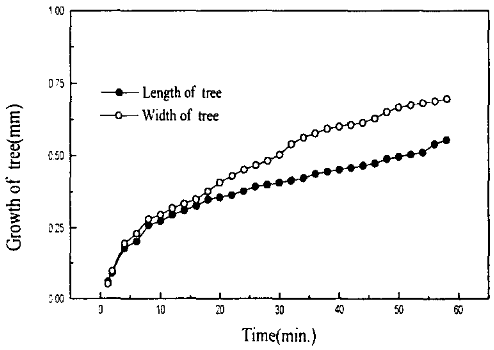


Fig. 8 The growth of bush type tree vs. voltage application time

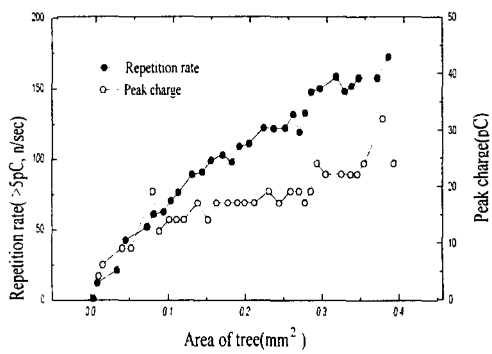


Fig. 9 Peak charge and repetition rate of PD pulses vs. the area of bush type tree

Fig. 10 shows the correlation between the area of bush type tree and the average discharge power of PD pulses. It's clear that the area of bush type tree has linear relation with the average discharge power of PD pulses. Since the correlation of between the area of bush type tree and the average discharge power of PD pulses is linear, we can diagnose inception and propagation of the tree by measuring the average discharge power of the PD pulses generated in electrical machine and comparing that of initial value. By successful diagnosis, we can predict remained life of insulation and prevent disastrous electrical failure.

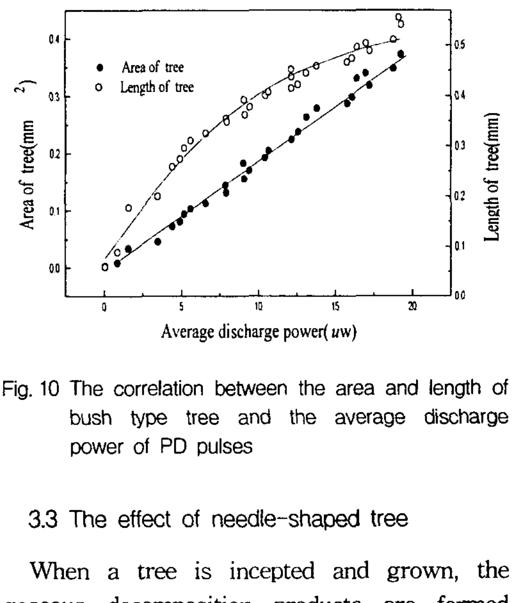


Fig. 10 The correlation between the area and length of bush type tree and the average discharge power of PD pulses

3.3 The effect of needle-shaped tree

When a tree is incepted and grown, the gaseous decomposition products are formed and accumulated in tree channel. Then the gas pressure of tree channel increases and space charge is formed. Thus PD at the wall of tree channel is predominant rather than that toward tip of tree because the discharge length is more short, so the tree propagates bush type tree.

These gases increase in pressure until PD extinction condition reached. Then PD doesn't appear and the growth of tree is restrained. These gases diffuse through the LDPE until the pressure is low enough for PD ignition to occur.

The gaseous decomposition products with growth of tree in the specimens with needle-shaped void are diffused in needle-shaped void and not trapped. Since the increase of pressure in the tree channel doesn't appear, the activity of PD become more vigorous. This can result in fast growing tree and the tree becomes branch type tree.

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