Space Charge Behavior in Polyethylene under Elevating Stepwise DC Voltage Simulated DC Lamp Voltage

Kotaro Ogura, Hiroaki Miyake, Yasuhiro Tanaka (Tokyo City University)
g1881014@tcu.ac.jp, hmiyake@tcu.ac.jp, ytanaka@tcu.ac.jp

ABSTRACT

In a dc dielectric strength test of a polymeric insulating material it is hard to observe an effect of a space charge accumulation because a breakdown occurs before the space charge accumulates in the material. However, when the space charge accumulates in the insulating material, the breakdown tend to occur under a relatively low applied electric field because the space charge distorted the electric field in the material. It means that using a lamp voltage that raises the voltage in a short time, there is a possibility that the test result shows a higher voltage than the actual application of the DC voltage. Therefore to investigate the dependence of space charge accumulation on the test, the relationship between the space charge accumulation characteristics and the breakdown in LDPE was observed under elevating step wise dc voltage with various voltage increase rate. As a result, it was found that the longer application time for each applied electric field, the longer enhancement of the electric field was observed.

KEYWORDS

LDPE, XLPE, PEA method, space charge distribution, dielectric breakdown test

INTRODUCTION

In recent years, the use of renewable energy has been increasing along with the increase in power demand. However, power plants using renewable energy that use wind power, sunlight, etc. are often located far away from urban areas, and it is necessary to transmit power over a long distance from the power plants to the urban areas. Although AC power transmission is used in urban areas, in the case of long distance transmission, it is necessary to use DC power transmission from the viewpoint of system stability and the efficiency of the transmission. Therefore, particularly in the European region, a transmission network using HVDC (High Voltage Direct Current) is established. In this system, submarine cables are often used to connect countries separated by the sea. Although conventional oil-filled (OF) cables have often been used for such cables, cables with solid insulating materials have begun to be introduced, because it is maintenance-free and it isn't necessary to concern about marine pollution even if an accident occurs. Above all, a "XLPE (cross-linked polyethylene) cable", which shows a high reliability in AC transmission, is considered to be applied to HVDC transmission.

However, when a high DC voltage is applied to a conventional XLPE cable exhibiting excellent insulation performance in AC power transmission, unexpected dielectric breakdown may occur. This is said to be due to a space charge accumulated in the solid insulating material under dc high electric field. Until now, we have investigated the behavior of space charge distribution in polyethylene under dc high electric field using a PEA (Pulsed Electro-Acoustic) method[1] as an evaluation method of cable insulating materials under the dc high electric stress. As a result, large amount of space charge was accumulated inside polyethylene, and a dielectric breakdown followed by the accumulation was often observed in it [2].

On the other hand, a breakdown test by applying a lamp voltage is generally used as a dc withstand voltage test. However, when the lamp voltage is raised in a short time, the space charge doesn't accumulate, and there is a possibility that the dielectric breakdown does not occur up to a higher voltage than that observed in the material under the applied dc electric field for a long time. It means that the insulation breakdown test using a DC lamp voltage cannot properly evaluate the insulation material for HVDC. This is because the space charge measurement is required to evaluate the material. However, the relationship between the space charge accumulation and the raising rate of the lamp voltage has not been clear yet. Therefore, in this report, the voltage simulating the lamp voltage is applied to LDPE (low density polyethylene) by changing the voltage application time, and the influence of an increase rate of the applied voltage on the space charge accumulation is investigated.

SAMPLE AND EXPERIMENTAL PROCEDRE

Samples

As measurement samples, commercially available LDPE and XLPE films with sample thicknesses of about 120 μm and 100 μm were used. In the samples, any additive such as an antioxidant was not included. XLPE was made of LDPE by crosslinking chemically using DCP (dicumyl peroxide). To form the LDPE film, pellet of LDPE was hot-pressed using thin aluminium sheets. In the case of XLPE, LDPE pellet with DCP was also not pressed using aluminium sheets. Since the XLPE film is enclosed between the aluminium sheets after the hot pressing, it is expected that the cross-linking by-products remained in the film[4]. When conducting the experiment, the sample contained some cross-linking by-products in the sample because the aluminium plate was removed just before the experiment[5]. Here, in this report, we describe the sample as "XLPE/F" ("F" means flesh sample.)

Measurement procedure

In an ordinary PEA measurement, a semi-conductive (SC) layer and an aluminium (Al) plate electrodes were used as a high voltage and a grounded electrodes, respectively. All measurements in this report were conducted using the SC and Al electrodes as an anode and a cathode, respectively. The SC layer is used to match an acoustic impedance of the sample with the high voltage electrode. However, an actual power cable, the insulating layer is sandwiched between SC layers. Therefore, in this research, was also measured the space charge distribution in the sample sandwiched between the SC layers.

Figure 1 shows a schematic view of the PEA measurement apparatus in which a sample is sandwiched between SC layers. As shown in Fig. 1, the edge of the