

Observation of Space Charge Accumulation in Cable Insulating Materials at Voltage Polarity Reversal

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ABSTRACT

Investigation of space charge accumulation process in cross-linked polyethylene (XLPE) and improved XLPE (SXL-A) at voltage polarity reversal was carried out using pulsed electro-acoustic (PEA) measurement system. We found that a huge amount of so called a packet like charge generated in XLPE at the polarity reversal of DC stress. It enhanced the electric stress locally in the sample by almost twice of the applied average stress. On the other hand, we also found that the packet-like charge was not observed in SXL-A under the same experimental condition.

KEYWORDS

HVDC cable, XLPE, Polarity reversal, Space charge, PEA method, Crosslinking by-products, Nano-composite

INTRODUCTION

Space charge accumulation property in cable insulating materials at voltage polarity reversal is one of important research objects in HVDC (High Voltage Direct Current) system because the polarity reversal is necessary to change a direction of current flow using a LCC (line commutated converter) system. It is said that the space charge accumulation sometimes strongly affects the breakdown characteristics of the materials. Especially, many engineers have pointed out that the polarity reversal test on a conventional XLPE (cross-linked polyethylene) cable showed somehow dangerous results including the breakdown, and the space charge accumulation has been thought as the reason of the results. However, there are few attempts for the measurement of the space charge accumulation in cable shape sample at the polarity reversal of very high dc voltage.

In the ordinary space charge measurements, thin films like several hundred μm -thick is preferably used to apply a high dc electric field to it. Authors are thought that the existence of the crosslinking by-products in the sample is important factor for the space charge accumulation, which must strongly affect the breakdown strength under high dc stress. However, since the crosslinking by-products easily volatile from such thin films, the measurement results on such sample does not reflect the actual condition of the cable insulating materials. Therefore, at first, we prepared some samples including them, then we tried to investigate the space charge accumulation behavior at the polarity reversal of very high dc stress in the fresh XLPE thin film including the cross-linking by-products. Furthermore, also measured the space charge in a degassed sample to confirm the effect of the cross-linking by-products. The space charge distributions in the fresh and the degassed samples were measured using pulsed electro-acoustic (PEA) method [1].

SAMPLES AND EXPERIMENTAL PROCEDURE

Sample

Chemically cross-linked polyethylene (XLPE) films were made from commercially available low density polyethylene (LDPE) using cross-linking agent of dicumylperoxide (DCP) by hot-press procedure. Thickness of them were about 150 μm . Any anti-oxidation agent was not intentionally added to it in the procedure. Since some crosslinking by-products are volatile from such thin films in atmosphere, the films were kept by packing them in aluminium foils to prevent it. The foils were removed from the films just before the experiments. Figure 1 shows a time dependence of amounts of acetophenone and cumyl alcohol in XLPE film (ca. 100 μm -thick) in air atmosphere after the aluminium foils were removed. The amounts of them were measured using a gas chromatography mass spectrometry system. As shown in the figure, it was found that the amounts of both cross-linking by-products gradually decreased in air atmosphere. However, it was also confirmed that these crosslinking by-products were still remained in the films for several hours after the removal of the foils. In this report, we describe the fresh samples used just after the removal of the foils as "XLPE/F".

We also prepared degassed XLPE films, which were assumed to be including tiny amounts of cross-linking by-products. To make the degassed one, XLPE/F films were kept in a vacuum chamber under pressure of few hundreds Pa for 24 hours. Judging from the result shown in Fig. 1, there must be only tiny amounts of them included in the degassed XLPE films. The degassed sample is described as "XLPE/D" in this report.

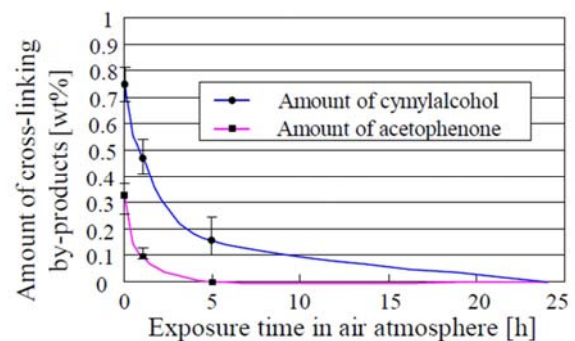


Figure 1. Time dependence of amounts of acetophenone and cumyl alcohol in the film of XLPE (ca. 100 μm thick) in air atmosphere after the aluminum foil was removed.