The investigation of conduction current and dissipation power distributions in XLPE under HVDC at high temperature environment

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ABSTRACT

An improved PEA measurement system was developed to evaluate the space charge, the conduction current and the dissipation power distributions in XLPE used for power cable. The improved system is enable us to measure the space charge distribution and the external circuit current simultaneously under high temperature condition. In the system, by installing a water cooling system for PVDF sensor, it makes possible to measure the space charge distribution without losing the piezoelectricity of a PVDF sensor at high temperature condition. In this report, we introduce some typical measurement results obtained using the system.

KEYWORDS

Space charge, Conduction current, Dissipation power, XLPE, PEA method, High temperature

INTRODUCTION

Nowadays, according to increasing of electric power demand in urban areas, a long-distance power transmission cable from a power far flowing plant of offshore is required. While AC transmission system is dominant in a relatively short distance transmission system, dc system is preferable in the long distance power transmission because of its low power loss and won- necessity of phase stability control. According to such background, HVDC (High Voltage Direct Current) networking projects are in process around EU area. For the cable insulating material for HVDC, the development of adequate soli insulating material is important. While an oil-filled (OF) cable had been usually used as the dc submarine cable, it's a time to use the cable with solid insulating layer like cross-linking polyethylene (XLPE) judging from point of view on maintenance cost and environmental pollution at a time of an accident. However, it is necessary to resolve a problem of space charge accumulation in the solid insulating material under high dc stress. We have investigated that the space charge accumulation strongly affects the breakdown strength of polyethylene using pulsed electro-acoustic (PEA) method [1]. According to the study, a large amount space charge accumulation distorts the electric field locally in low density polyethylene (LDPE) under very high dc stress, and finally it lead an electrical breakdown [2]. On the other hand, in the case of XLPE, we have assumed that the dissipation power induced by large conduction current and high electric field may be dominant factors to lead the breakdown under high dc stress [3]. Such investigation result was derived from the results obtained using a newly developed simultaneous measurement system of the space charge distribution and the external current. However, while the above developed system is used at room temperature, the actual cable insulating materials are exposed to high temperature environment in-service. The simultaneous measurement system which is available at high temperature is required to investigate the actual effect of the space charge accumulation in XLPE under high dc stress. Therefore, we tried to develop a new system. In this report, we introduce the developed system and some typical measurement results obtained using the system.

SAMPLES AND EXPERIMENTAL PROCEDURE

A. Samples

A Polyethylene Terephthalate (PET) film of about 125 μm-thick was used as a sample to confirm the developed simultaneously measurement system. In addition to PET film, a XLPE film about 200 μm-thick was also used as a typical measurement sample for cable insulation. These are commercially available and nominally additive free samples. The XLPE film was made of LDPE with cross-linking agent (DCP : dicumyl peroxide) by hot press methods. In the case of XLPE, to prevent the cross-linking by-products from being volatilized, it was kept in sandwiched between aluminum foils after the hot pressing procedure, and the foils were removed it just before the measurement.

B. Measurement system

Figure 1 shows a schematic diagram of the developed simultaneous measurement system of space charge distribution and external circuit current at high temperature. This measurement system was obtained by improving the previously developed simultaneous PEA measurement system at room temperature [4]. Figure 2 shows a block diagram of the measurement parts in the improved PEA system to measure the space charge distribution and the external current simultaneously [4]. Using this measurement system, we can measure the space charge distribution and the external circuit current in the same sample under high temperature environment. In this measurement system, a lower electrode is switched by using coaxial switch between pico-ammeter and ground electrode to measure the space charge distribution and external circuit current, respectively. When the space charge distribution is measured by applying high voltage pulses, the pico-ammeter is protected by isolating from the applied high voltage pulses. To isolate the lower electrode electrically from surrounding ground electrode, it is held using a polytetrafluoroethylene (PTFE) holder. Moreover, since a glass plate is inserted between the lower electrode and a polyvinylidene fluoride (PVDF) sensor, a current flows into only the pico-ammeter during the current measurement. In this measurement system, the glass(S-LAM3) which has low thermal conductivity is installed not to lose piezoelectricity of the PVDF film associated with the increase of temperature. Moreover, a water cooling system is installed around the sensor as shown in Fig.1. Figure 3 shows a schematic diagram of the water cooling system. This system is enable to keep temperature around the PVDF sensor under 40°C even when