Study on Water Tree Degradation Diagnosis for Dry-cured and Extruded Three-layer 6.6 kV XLPE Cables with Penetrated Water Tree

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ABSTRACT

An accelerated water-treeing test was performed for dry-cured and extruded three-layer (E-E type) 6.6 kV XLPE cables removed after approximately 20 years of operation. As a result, we successfully found a penetrated water tree in one of the XLPE cables. Additionally, for the cable, values for electrical insulation characteristics, such as a DC leakage current, an AC superposition current, and dielectric loss tangent, were investigated. As a result, the cable's DC leakage and AC superposition currents were found to be above threshold values. This result suggests that these methods are useful in finding penetrated water trees in this type of 6.6 kV XLPE cable.

KEYWORDS

High-voltage cross-linked polyethylene cables, E-E type, Water tree, Accelerated water-treeing test, Degradation diagnosis.

INTRODUCTION

Dry-cured and extruded three-layer (E-E type) 6.6 kV cross-linked polyethylene (XLPE) cables were introduced into electric power systems more than 30 years ago [1]. These cables have not experienced failures due to water tree degradation. However, water-tree degradation becomes a serious problem with increasing operating time, making it essential to diagnose water tree degradation.

On-line water-tree degradation diagnostic methods such as the low frequency superposition [2] and AC superposition methods [3] as well as off-line diagnostic methods such as the DC leakage current method [4] and withstand voltage test [5] have been applied to E-T (E: Extrude, T: Tape) type 6.6 kV XLPE cables. Criterion values for degradation with these methods have been established for penetrated water trees that bridge cable insulation [1], since breakdown will not occur until a few years after a water tree has penetrated cable insulation at the operating voltage of 3.8 kV.

If breakdown does not immediately occur following a water-tree penetration of cable insulation in dry-cured and E-E type 6.6 kV XLPE cables, these diagnostic methods can be applied. However, harmful penetrated water trees have not been found in removed, dry-cured, and E-E type 6.6 kV XLPE cables. Therefore, to confirm the applicability of such diagnostic methods to this type of 6.6 kV XLPE cables, growth of water trees should be accelerated for removed XLPE cables.

In this study, an accelerated water-treeing test was performed for dry-cured and E-E type 6.6 kV XLPE cables removed after approximately 20 years of operation. As a result, we successfully found a penetrated water tree in one of the XLPE cables. Additionally, for the cable, values for electrical insulation characteristics, such as a DC leakage current, an AC superposition current, and dielectric loss tangent, were investigated. As a result, its DC leakage and AC superposition currents exceeded criterion values. This result suggested that these methods are useful in finding penetrated water trees in this type of 6.6 kV XLPE cable.

EXPERIMENTAL METHODS

Tested cables

Cable number, year of manufacture, operating period, conductor size, and effective electrode length of the tested cables are listed in TABLE I.

Method for accelerated water-treeing test

Applied AC voltage for accelerating water-tree degradation was 3.8 kV at 1000 Hz. A sequence of the conditions seen in the accelerated water-treeing test is listed in TABLE II. Since there is no existing report on accelerated water-treeing tests for removed 6.6 kV XLPE cables after 20 years of operation, it was assumed that breakdown would occur at once under severe conditions. Therefore, more severe conditions were applied while we checked the electrical insulation characteristics. Details of the temperature and condition of the water supply are outlined as follows.

- Condition I: Water was supplied only for the inner conductor of the tested cables at room temperature during voltage application.
- Conditions II, IV, VI, and Vii-1: Water was supplied for the inner and outer conductors of the tested cables; the cables were immersed in a water tank at room temperature during voltage application.
- Conditions III and V: To supply enough water for XLPE of the tested cables as reported in [6], the temperature of the water tank was kept at 60 °C for 10 days without voltage application.
- Condition VII-2: Water was supplied for the inner and outer conductors of the tested cables; the cables were immersed in a water tank. The temperature of the water tank was controlled between room temperature (20 °C to 25 °C) and 50 °C once per day during voltage application.
- Condition VIII: Water was supplied for the inner and

TABLE I: Cable number, year of manufacture, operating period, conductor size, and effective electrode length of the investigated cables.

Cable number	Year of manufacture	Operating period [years]	Conductor size [mm^2]	Effective electrode length [m]
1	1989	23	60	12.9
2	1990	23	60	7.6
3	1990	22	60	7.6
4	1992	22	60	28.6
5	1992	22	60	10.8
6	1991	24	60	39.8
7	1991	24	60	18.8