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INITIATION SITE ANALYSIS OF VENTED WATER TREES GROWING FROM THE CONDUCTOR SCREEN OF SERVICE AND LABORATORY AGED XLPE CABLE INSULATION

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ABSTRACT

The main purpose of this paper is to present results from examinations of initiation sites of vented water trees growing from the conductor screen of laboratory and service aged XLPE insulation systems. This has been discussed in terms of cable operation conditions during service, cable design and semi-conductive material properties.

The results show that stress-induced electrochemical degradation (SIED) causing growth of vented trees from the conductor screen, occur in service aged medium voltage XLPE cables. A prerequisite for the formation of such structures is liquid water in the conductor (causing corrosion of the Al conductor). During normal service operation this was found to be less probable. Corrosion of the Al conductor can also occur during laboratory standardized long-term wet ageing tests (e.g. CENELEC HD605) by condensation of water at the conductor diffused through the insulation. The data from the lab-scale model systems using the accelerated SIED test, indicate that optimization of the material characteristics by e.g. type and content of carbon black as well as peroxide content can have a significant impact on SIED formation.

Keywords
Water treeing, XLPE insulation, stress induced electrochemical degradation (SIED), conductor screen.

INTRODUCTION

Water tree degradation occurs in all known polymeric materials and the water trees grow by the combined action of an electrical field, ions and water [1]. It is generally observed that the old Nordic cable designs from the seventies are particular vulnerable to degradation, with the majority of the vented trees growing from the insulation screen consisting of graphite painting and semi-conductive tapes. However, in a study of XLPE cables produced from about 1975 to 1985, i.e. with extruded semi-conductive insulation screens, vented trees growing from the conductor screen are more frequently observed [2].

A mechanism that can initiate vented water trees from the conductor screen is the so-called stress-induced electrochemical degradation (SIED) [3]. This is essentially a mechanism causing porous structures in the conductor screen. The porous structures can then act as pathways for impurities from the metallic conductor to the XLPE insulation surface.

It has been proposed that the porous channels are generated by an electrochemical reaction between the aluminium conductor and the semiconductive layer under the influence of mechanical stress. When an electrolyte is present in the conductor area of an insulation system a galvanic cell is formed between the conductor as the anode and the carbon black of the semiconductive layer as the cathode [3].

The main cause for the formation of these zones is proposed to be the formation of hydrogen gas during corrosion by water of the Al conductor [4]. Although it is well known that also other initiation sites are involved (e.g. protrusions and water soluble impurities), it is the SIED mechanism that will mainly be paid attention to in this paper.

This paper presents results from examinations of initiation sites in service and laboratory aged XLPE cable systems. This includes SEM and light microscopy examinations and measurements of electrical conductivity and carbon black content of the conductor screen. In case of the service aged cables, the water causing the water trees had either diffused through the insulation to the conductor screen from outside (wet environment) or diffused from the interstices between the conductor strands (water in the conductor). The laboratory ageing was performed with liquid water subjected to the conductor strands for the cable model system (equivalent to water in the conductor) and to the insulation screen of the medium voltage cables.

EXPERIMENTAL

Test Samples and Ageing Conditions

Service and Laboratory Aged MV XLPE Cables

Table 1: Description of the examined medium voltage XLPE cables.

No.	Rated Voltage [kV] Uo)	Aged in: Service (S) Laboratory (L)	Ageing time (years)	AC breakdown voltage (Uo)
1	12 (6)	S	13	5-7
2	24 (12)	S	22	4
3	12 (6)	L	2[1]	13-24

[1] Cable ageing according to the CENELEC procedure [5]

A description of the examined MV cables with stranded Al conductors is presented in Table 1. All of the cables had stranded Al-conductors. Cable 1 was equipped with a