# NON DESTRUCTIVE WATER-TREE DETECTION IN XLPE CABLE INSULATION

John **DENSLEY**, ArborLec Solutions, (Canada), j.densley@ieee.org
Sverre **HVIDSTEN**, SINTEF, (Norway), Sverre.Hvidsten@sintef.no
Willem **BOONE**, KEMA, (Netherlands), Wim.Boone@kema.com

## *ABSTRACT*

*Water treeing is one of the major causes of premature failures in medium-voltage cross-linked polyethylene (XLPE) cables operating in a wet environment and widespread replacement of failed cables has been very costly to many utilities. There are several techniques presently available to detect water treeing in cables that could help prioritize their cable replacement programme. This paper is a summary of work undertaken by CIGRE JWG D1/B1.20 and will be published as a Technical Report. It provides information on how to select the best water tree detection method and how to improve the interpretation of the test results to get an accurate assessment of the condition of cable systems.*

## *KEYWORDS*

Water trees, cross-linked polyethylene (XLPE), off-line, on-line, tangent delta.

## INTRODUCTION

Water treeing is one of the main forms of degradation of XLPE insulation used in medium-voltage cables and occasionally in high-voltage cables when the insulation is exposed to water [1]-[3]. Water trees gradually reduce the electrical breakdown strength of cables and are one of the main causes of failures of early designs of extruded medium-voltage cables after only five to fifteen years in service. As partial discharges are not involved in water tree growth, such degradation is difficult to detect in cables in situ using non-destructive techniques. However, tests have shown that insulation containing water trees has lower insulation resistance and higher dielectric losses and the measurement of these properties is being used to assess the condition of the insulation. The insulation resistance and dielectric loss are sensitive to the measurement technique and also to parameters such as temperature, voltage, frequency and the severity of the water treeing. There are presently several techniques available commercially. Utilities presently have a choice of measurement techniques but generally lack the expertise to make informed decisions regarding which technique to use and, more importantly, how to interpret the data from such tests to assess the condition of their cable system.

CIGRE SC D1 identified the need for a guide to inform cable system owners and users about water treeing and to inform them what tests were available to detect treeing in cables. A joint WG was set up in liaison with SC B1 to prepare such a guide. This paper summarizes the work of the JWG and provides a review of the measurement techniques available to detect and measure the extent of water treeing in XLPE cable insulation and discusses the interpretation of data, including a discussion of the limitations. This independent review will help Utilities, or other users of XLPE insulation subjected to wet conditions, to evaluate non-destructive water tree detection techniques and gives guidance on how to interpret the data obtained from such tests, however excluding considerations of costs The paper also describes what water trees are and what factors affect their initiation and growth.

Testing up to 2Uo is assumed to be non-destructive for the majority of XLPE cables when no indication of ageing is determined for test voltages up to Uo. The risk of failure during testing increases with (a) increasing voltage, the higher the test voltage the greater the risk, and (b) increasing severity of the aging of the insulation, e.g. water treeing. Thus, testing above Uo (up to e.g. 2Uo) can increase the risk of cable failure during or shortly after the test and should preferably be done in agreement with the cable owner taking into consideration the design and age of the cable and its previous service history.

## Water trees

Water trees generally initiate and grow in the direction of the electric field from contaminants, voids or protrusions at interfaces in most polymeric insulations exposed to an AC voltage and water. They are tree-like structures, see Fig. 1, that consist of rows of voids or 'string of pearls' [4]. The diameter of these voids may vary from approximately 0.1 μm up to 5 μm with hydrophilic tracks interconnecting the voids along which water can move to fill up the voids [5]. Water trees are generally non-conducting although they are more conducting than the healthy insulation. The conductivity of treed regions tends to increase with time.

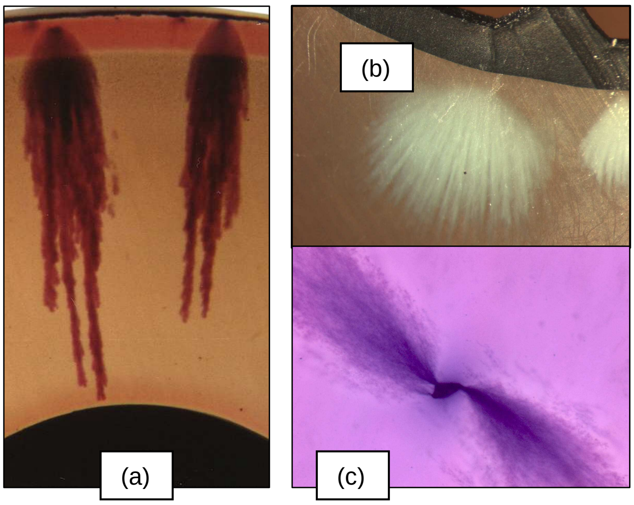


**Fig. 1: Typical water trees growing from a) the insulation screen, b) conductor screen and c) from a contaminant within the XLPE insulation.**

As shown in Fig. 1, there are two types of water trees; vented (Fig. 1a and b) and bow-tie (Fig. 1c) water trees. Bow-tie trees grow from impurities and voids within the