# A VERSATILE SYSTEM FOR ELECTRICAL TREEING TESTS UNDER AC AND DC STRESS USING WIRE ELECTRODES

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## ABSTRACT

*An alternative method to evaluate electrical treeing in solid dielectric materials is presented. Here the test sample utilises a wire electrode for creating the necessary high divergent electric field. This introduces a different preparation method and several of the disadvantages with the traditional needle sample can be avoided. Together with the test object a versatile test setup for both AC and DC measurements is illustrated. This alternative method has proven successful and an evaluation thereof as well as a comparative study between the two electrode systems is included.*

## KEYWORDS

Electrical treeing, XLPE, Cable insulation, Test method.

## INTRODUCTION

Cross-linked polyethylene (XLPE) is nowadays commonly used as insulation material in high voltage cables and with its introduction, as an alternative to paper-oil based insulation, new types of ageing and degradation mechanisms need to be studied and understood. Among them one important phenomenon is electrical treeing [1], a degradation process in the insulation that ultimately leads to a complete breakdown and cable failure. Although considerable research has been made on electrical treeing, both considering the methods of detection [2-4] as well as the physical phenomenon as such [5], further advancement is still necessary.

Electrical treeing tests are commonly used to evaluate newly developed polymeric materials, often containing different additives, with respect to the resistance to electrical treeing [6]. ASTM standard [7] specifies test objects with double needle electrodes for electrical treeing test. One of the needles is sharpened with a tip of 3 µm in radius and acts as the high voltage electrode. The second needle has a hemispherical tip with a diameter of 1 mm and is grounded. The sharp needle produces a point of highly divergent stress in the material to be tested and it mimics the influence of an impurity within the cable insulation. A number of concerns have however been raised concerning the use of this method, especially considering the way the needle insertion is made, as it is a known problem that the sharp needle tips easily become damaged [7]. This way the actual needle tip radius and the resulting field enhancement may vary strongly, yielding non-repeatable results. Another critical aspect is formation of gas filled voids at the tip [8], which provide inception points for initiation of micro-electrical discharges. Furthermore, the needle insertion may introduce changes into the morphology of the material due to the forced mechanical stress as this is made after cross-linking of the sample [9]. The complications of bent tips and voids also necessitate microscopic inspection of the samples and a considerable part of them has to be discarded. These concerns make it essential to continue the search for testing methods providing accurate and reproducible results.

In an attempt to overcome the concerns listed above, it is suggested that using a wire electrode instead of the sharp needle may be advantageous. Additional advantage of the proposed solution is that a larger volume of the material tested is exposed to the high electric stress; especially for material containing additives this is an advantage as these are difficult to disperse perfectly. As several trees often grow more or less simultaneously at different positions along the wire, it is easier to see if the inception voltage of the first tree differs significantly. This could then be an indication that the insulation differs somehow at this point. Also the amount of material necessary for producing the test object is reduced. The alternative test object is presented in this paper together with the high voltage test setup capable for performing tests under AC and DC voltages. For comparing the results of the wire-electrode object with the needle-electrode type, comparisons of electrical tree inception voltage, with emphasis on scatter in the data, are presented.

## EXPERIMENTAL METHOD

### Test object

The specimens comprise a thin tungsten wire electrode (10 µm in diameter) moulded into the insulation material to be tested, as shown in Fig. 1. Tungsten has been chosen as the electrode material for its good electron emission ability, its high elastic modulus and hardness, as well as its low thermal expansion [10]. The wire provides the necessary divergent electric field to stress the insulation and thereby initiate the degradation by electrical treeing. A semiconducting tab serves as connecting element between the wire and the external high voltage supply. The design and dimensions of the sample are provided in the figure.

The test samples used for initiation of electrical treeing are smaller than the conventional needle samples. According to the ASTM standard, the samples have the dimensions: 25 × 25 × 6 mm. In the method proposed in this paper the samples are of a size 19 × 30 × 2.5 mm, meaning that the material used for their manufacturing is