Robust characterization of the DC-conductivity of HVDC insulation materials at high electric fields

Hossein **GHORBANI** (1), Carl-Olof **OLSSON** (2), Johan **ANDERSSON** (3), Villgot **ENGLUND** (3)
1 - ABB AB, High Voltage Cables, Karlskrona, Sweden, hossein.ghorbani@se.abb.com
2 - ABB AB, Corporate Research, Västerås, Sweden, carl-olof.olsson@se.abb.com
3 - Borealis AB, Stenungsund, Sweden, carljohan.andersson@borealisgroup.com, villgot.englund@borealisgroup.com

ABSTRACT

Testing techniques should be easy to implement, give meaningful and robust results with a high reproducibility that makes it straightforward to analyze and compare results. DC-conductivity, is an important and critical measurement when investigating different insulation materials and need to be measured at high electric fields with controlled thermal conditions. The thickness of the samples might need to be increased when the conductivity is measured on materials containing substances that can diffuse out of the sample. At the same time the electric field should be at the same level as can be foreseen for cable applications. With the equipment used in the present study, reliable measurements can be made up to 50 kV on samples having 1 mm thickness.

The results show that by careful sample preparation and having right test procedures and equipment, it is possible to achieve robust measurement results with a high reproducibility.

KEYWORDS

HVDC; Cable; XLPE; Conductivity; Leakage current; Measurement;

INTRODUCTION

DC conductivity is seen as a key property for insulation materials for HVDC-cable applications. A low conductivity is necessary to minimize the joule heating resulting in unwanted temperature rise in the cable insulation to reach higher voltages in HVDC cables [1]. Measuring the conductivity on samples made of small material quantities, such as compression molded plaques from pellets, has several major advantages compared to full scale testing on cables as for example reduced test time, lower cost, low material consumption during development phase, and quality control.

One of the most common test techniques to measure the electrical conductivity of high resistance materials used in high voltage cable insulation materials is by the use of a guarded three-terminal electrode system together with an electrometer able to measure extremely low currents [2] - [5]. Furthermore, to assess the high field properties of the materials accurately a stable high voltage DC-supply is also needed. The measured conductivity (i.e leakage current) is reported to be a function of material composition, choice of test setup and test conditions such as for example electrode material, pressure, temperature, humidity, electric field strength, sample preparation and sample conditioning, [2][5].

To enable reliable and reproducible measurements a large emphasis needs to be put on the requirements of the test procedure and sample preparation steps. ASTM-D257 and IEC 60093 [2][3], both describe setups and test procedures for measurements, but they also allow for flexibility for the testing procedure and choice of electrodes, which make comparison of data difficult between different setups.

An improved reproducibility can be achieved by introducing a conditioning step prior to testing allowing the sample to reach equilibrium state as described in ASTM 618 and the ASTM D6054 [6][7]. However, this puts constraints when it comes to measuring the influence from volatiles in the samples such as residual peroxide decomposition products (PDP) in XLPE (cross-linked polyethylene). The same concern arises when using conductive paint or vacuum evaporated electrodes that include a drying step or time in vacuum that also permit volatile components to diffuse out from the test sample.

The thickness of the sample is also an important factor. For very thin samples, in range of 100-200 µm, even very short exposure to air, would lead to removal of substantial portion of volatile species from the sample therefore very large fluctuations will be introduced in the content of the samples. This is why in most of the published studies on DC conduction using 100-200 µm thick plaque samples, the specimens are usually degassed to remove the fluctuations caused by varying chemical content of PDP. In case of XLPE, these species are very important to the conduction properties, it is instead better to use thicker specimen, 0,5 to 2 mm thick, to minimize the effect of fluctuations due to evaporation of volatile species.

In this paper we present a rigid measuring system and sample preparation step that gives good reproducibility for conductivity measurements at high electric field strengths while keeping the most of the PDP contained in the sample. A round-robin test on non-degassed XLPE plaques has been completed, with measurements from three different test facilities using identical electrode dimensions and similar test procedures. All measurements were done on non-degassed samples and effort has been made to reduce the leakage of PDP during the testing cycle.

SAMPLE PREPARATION

12 plaque samples, with a thickness of 1 mm and a diameter of 26 cm were produced by compression molding of novel HVDC grade XLPE pellets [8][9]. The large diameter of the samples, helps to reduce the risk of surface flashover during the test. The compression molding is done in two steps, the first at 130°C for 10 min to melt the material and get a homogeneous plaque which is subsequently cross-linked at 180°C for 12 minutes; all samples are manufactured at one location.

Since the DC conduction current is strongly affected by the presence of polar PDP [10], it is important to control the amount of these species in the samples during