Novel leakage current sensor for non-intrusive dielectric state assessment of HVDC cables

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ABSTRACT

This paper proposes a monitoring principle based on leakage current measurements to monitor the state and health of HVDC cable dielectric. First, the leakage current measured during different phases of electrothermal stresses applied to a reduced scale cable are compared. Then, a novel magneto-optical current sensor tailored to monitor leakage current of HVDC cables is presented along with its preliminary validation results.

KEYWORDS

HVDC cable, leakage current, optical sensor, monitoring

INTRODUCTION

The use of High Voltage Direct Current (HVDC) links is rapidly growing and is forecasted to grow even faster over the next decades to accommodate the increasing need of long-distance power transmissions for the integration of renewable energies into the electrical network. As the HVDC links constitute the backbone of such transmission system, it is becoming increasingly important to monitor their integrity and their health.

Today, underground HVDC cable links are often monitored using Distributed Temperature Sensing (DTS) and Distributed Acoustic Sensing (DAS). DTS detects hotspots and real time power flow adjustment, and DAS detects vibrations caused by nearby civil work. DAS provides rapid localization of mechanical perturbations to the cable system, which allows the operators to rapidly intervene and to possibly prevent further critical damages.

For High Voltage Alternative Current (HVAC) cable systems, the electrical integrity of the interface between cable and accessories is typically tested at commissioning and is in some cases monitored online. Works has been undertaken to develop partial discharge (PD) measurement techniques for HVDC links. The interpretation of the PD signals is, however, highly complex due to absence of the voltage frequency reference.

Higher power transmission is possible thanks to voltage and temperature increase in the cable systems. However, this is done at the expense of a growing electrothermal stress. The current challenge is now to prevent thermal runaway and increased electrical stress due to abnormal space charge evolutions by monitoring the state and health of the cable dielectric.

This paper proposes a monitoring principle based on the measurement of the current passing through the cable dielectric commonly called leakage current. The aim of the present paper is twofold. First, it evaluates the use of leakage current monitoring as a tool to assess the operating state of HVDC cables. For this, the leakage current of a reduced scale cable is monitored during the application of selected electrothermal stresses. The evolution of the measured leakage current is compared across the different phases of stress application.

Second, a novel current sensor tailored to monitor leakage current of HVDC cable systems is presented. This sensor, based on a magneto-optical technique, is designed for high sensitivity and non-intrusive online current measurements. The results of proof of concept in a laboratory environment is presented in this paper.

DIELECTRIC TESTS

The dielectric tests presented in this section have been extensively described in [1].

Load cycle (LC) sequences, similar to the ones performed during Type Test as per Cigré TB852, were applied on a reduced scale cable extruded with HVDC grade insulating and semiconducting materials. The average electric field during the stress application was 38 kV/mm, e.g. 1.85 times 20 kV/mm, and the maximum conductor temperature was 70 °C. Leakage current was monitored during the load cycles. The conductivity was characterized between the 3 LC sequences, using the protocol described in [2].

The monitored leakage current during the first LC sequence is shown in Figure 1. The leakage current (I_{Leak}) magnitude varies with the conductor temperature (T_{cond}) and the LC numbers. Within the LC, the leakage current also shows different behaviours.

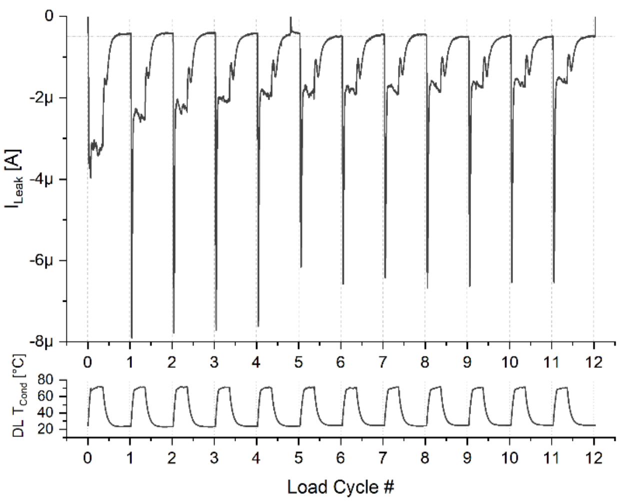

Figure 1: Model cable leakage current monitored during the first load cycle (LC) sequence

A closer view of the leakage current dynamics within LC 1 and 12 is shown in Figure 2. For clarity purposes, the LC are presented in 3 phases, based on the T_{cond} dynamics: