PEA measurement on HVDC full-size joint during long-term test

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ABSTRACT

There were space charge measurements carried out in the HVDC joint over a long period of time using the PEA method. Although it is generally expected that space charge is generated at the heterogeneous interface in the joint, it has never been directly observed where and how much it actually occurs. This paper presents the long-term monitoring of the space charge generated inside the joint using the PEA method.

INTRODUCTION

The joints are known to be one of the most vulnerable parts of an HVDC system. Space charges have been suspected as a source of vulnerability in many cases, but have not yet been verified in the real-world applications. Since it is not possible to directly observe these charges in buried cables and joints, it is more realistic to track their formation and movement during performance testing. There are several methods for measuring space charge, but the most popular currently in use is the Pulsed Electro-Acoustic (PEA) method, which can measure insulator samples as thin as 100um to 1mm, as well as thick cable insulation over 20mm. However, this method can only be used when the sample is flat or cylindrical in shape, limiting its application to products with symmetric structures such as HVDC joints. Additionally, as the joint contains a rubber sleeve with very thick insulation compared to the cables, its sensitivity is reduced, makeing it difficult to measure space charge.

A method to overcome the issue of low sensitivity has recently bee described in [1]. The acoustic coupler, which transmits the acoustic signal generated by the sample to the piezoelectric sensor, has traditionally been made of aluminium metal. However, the acoustic impedance of aluminium is quite different from that of the insulator, causing many reflections at the interface between the insulator and thecoupler. Therefore, replacing the acoustic coupler with a polymer material that has a similar acoustic impedance to the insulating material can dramatically improve sensitivity compared to the conventional method.

With the significant increase in sensitivity, even thick rubber sleeves in the joint can now be measured. The axial asymmetric geometry in the axial direction has been taken into account by making measurements while moving the PEA cell in small increments. Unfortunately, due to the radially propagating nature of acoustic waves, the sensor cannot detect the axial component of the acoustic wave signal. Nevertheless, the radial component of the acoustic wave was sufficient to directly observe the generation and movement of space charges at the interface between the cable insulation and rubber sleeve within the joint.

A new signal processing approach for obtaining the space charge distribution through numerical analysis is proposed at the end of the paper. Although it is not yet perfect, it could also be useful for calculating electric fields and potentials inside the joint as well.

PEA SYSTEM FOR FULL-SIZE JOINT

A PEA system consists of a cell that contains an acoustic coupler and a piezoelectric sensor, a high-voltage pulse generator to excite the charges, and a data acquisition device. In this measurement, a cell with a polymer acoustic coupler and a specially designed mechanical device to move the cell in the axial direction was used.

The thickness of the acoustic coupler is designed to delay the space charge signal sufficiently far away from the ringing wave generated by the pulse. The pulse generator produces 20 pulses per second with a peak voltage of 2kV. The pulse voltage is injected electrically into the outer semiconductive screen of the joint and the ground is connected to the cable screen. As the efficiency of the pulse injection depends on the capacitance between the pulse high-voltage and ground, the pulse injection section must be optimised in size. The detailed configuration is similar to that of the scaled joint in [2].

LONG-TERM TEST CONDITIONS

Three conditions were established to investigate the impact of prolonged voltage application on space charge formation. In the first condition, space charge formation was monitored for one month at the nominal voltage and room temperature. In the second condition, the voltage was raised by a factor of 1.45 and the temperature was raised to 80 degrees Celsius to accelerate degradation. The test lasted 40 days. Finally, in order to evaluate the space charge, the voltage was increased by a factor of 1.75 and the temperature was raised to 70 degrees Celsius. The test duration was 7 days. All tests were conducted using HVDC 150kV cables and pre-molded joint. Discharge and polarity reversal tests were also evaluated.

MEASUREMENT RESULTS

Fig. 1 diplays the configuration of the joint's measurement channels. Each channel is 10mm long and a total of 24 channels were used. Fig. 2 shows the space charge distribution over a long period of time for an test line under the second condition, which is the most interest. The charge distribution was monitored for 40 days under this condition. In the figure, the dashed line represents the initial space charge distribution, while the solid line represnet the distribution after 40 days. To present all of the measurement results on one graph, the measurements are plotted at interval of 2 C/m^3 (= 1 channel) in channel order from the top of the figure, the top graph corresponds to the high-voltage electrode region of the joint, while the bottom graph corresponds to the steering electrode region of the joint. All charge density values depicted in Fig. 2 only reflect the radial component of the electric field, so it is recommended to observe relative changes in magnitude rather than absolute values.