New concept for the design of HVDC cable joints

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ABSTRACT

The basic idea of the new design concept is to use two insulating materials in the joint body, with the two materials having different volume resistivities. FEM simulations show that with such a design concept, the electric fields can be reduced simultaneously at the middle electrode and below the deflectors. This reduction of the electric field at both locations makes the joint more robust overall to changes of the resistivity of the polymeric insulating materials involved, as they can occur with changes in temperature.

KEYWORDS

HVDC, cable joints

INTRODUCTION

In HVDC applications, the electrical field distribution in a cable joint is determined by the ratio of the resistivity of the joint`s insulating material and the resistivity of the cable insulation. This means that the resistivity of the cable insulation material also determines the distribution of the electrical field within the joint. However, the resistivity of the two polymeric insulating materials can vary and change by several orders of magnitude. Such changes can be caused by changes of the temperature during operation, batch-to batch variations in the manufacture of the polymers, or by the processing parameters of the joint or the cable, such as the degassing conditions of XLPE insulated HVDC cables. These changes of the resistivity and hence electrical field distribution within the joint can result in electrical fields so high that breakdown of the joint can occur. This is a fundamental problem in the classical design of joints for HVDC application. The fact that the field distribution in the joint body is affected by the cable insulation also leads to issues in routine testing of joint bodies. In this paper, a new patented design concept is proposed to overcome or at least reduce this fundamental problem.

ELECTRICAL FIELD DISTRIBUTION WITH CLASSICAL JOINT DESIGN

FEM calculations of the electrical field distribution in a 320 kV joint body were carried out to investigate the problems with the classical design. For these calculations, a voltage of 592 kV between cable conductor and earth was used, which corresponds to the applied voltage of a 320 kV HVDC cable system during type tests according to IEC 62895 [1]. For these FEM simulations, it was assumed that the volume resistivity of the cable insulation is higher than the volume resistivity of the joint insulation by a factor of 20. It was also assumed that the temperature coefficient of the resistivity of the cable insulation is higher than that of the joint insulation. Figure 1 shows the calculated total electrical field along the interface between the joint and cable insulation.

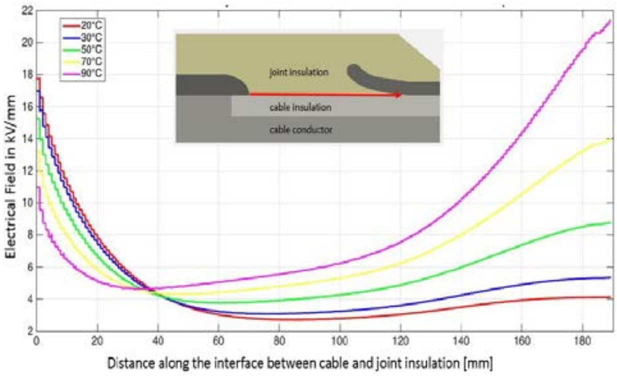

Fig. 1: Electrical field calculated along the interface between the joint and the cable (red arrow) for different conductor temperatures.

The diagrams in figure 1 show that at low temperatures the electrical field at the middle electrode is very high, while the field below the deflector is relatively low. At high temperature, the field distribution reverses. At a conductor temperature of 70°C - and even more pronounced at a conductor temperature of 90°C - the highest electrical fields are below the deflector, while the fields at the middle electrode decrease. These calculations show that HVDC joints with the classical design concept are generally not robust to changes in the resistivity of the polymeric insulating materials involved.

Routine tests with classical joint design according to IEC 62895

According to IEC 62895, cable joints should be tested with a DC voltage of $1.85xU_0$ at ambient temperature during routine tests. Although the voltage during routine tests appears high compared to the operating voltage, the following must be considered when evaluating routine tests of HVDC joints:

- The electrical field distribution in the joint depends on the temperature. Since the temperature in the joint during operation can be much higher than during routine testing, the field distribution in the joint can also be quite different from that during routine testing.
- The field distribution in a joint depends on the electrical resistance of the cable insulation. During routine testing of a joint, it is therefore important to ensure that the cable or adapter on which the joint is tested has the same insulation material and the same electrical resistance as the cable on which the joint is installed for operation.

It follows from the last point that an HVDC joint that is routinely tested on a cable with a particular insulation material may not work on another cable with a different insulation material or with an insulation material with a