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BREAKDOWN CAUSED BY ABRUPT DC-VOLTAGE GROUNDING OF XLPE CABLE INSULATION

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ABSTRACT

This paper shows that although the DC breakdown voltage of XLPE cable insulation with defects is very high, electric breakdown can occur at defects as a result of abrupt grounding after pre-stressing at a DC voltage considerably lower than the breakdown value of cables without the defects. Laboratory experiments were performed using metallic needles inserted 2.6 mm into the 4 mm thick insulation of 1 m long samples of 12 kV XLPE AC distribution cables. The short term DC breakdown strength samples with needle implants was found to be at about 120 kV, a value 3-10 times higher than that obtained from AC 50 Hz endurance testing. During DC pre-stressing the number of abrupt groundings needed to cause initiation of electric breakdown at the needle tips was found to decrease with increasing voltage level. The number of groundings needed was also found to strongly increase with reduced rate of voltage reduction.
At a DC pre-stress level of 95 kV breakdowns occurred after 107 groundings at a rate of voltage reduction of 0.2 kV/ns, while only 4 groundings was needed to cause breakdown if the rate was increased to 2.6 kV/ns.
The short term DC breakdown strength of reference samples, without needle implants, was found to be higher than 400 kV, and no cable failures occurred after 300 rapid groundings at a DC pre-stress level of 150 kV.

KEYWORDS

Test methods, HVDC cables, XLPE insulation, DC breakdown strength, defects, voltage grounding, grounding resistance.

INTRODUCTION

Due to the high and increasing demand for supply of reliable electric power, more high capacity and long distance high voltage DC cable transmissions are required. Until recently most HVDC cables were equipped with insulation of mass impregnated paper, a type of cable that has shown high service reliability. Due to the shift in high-voltage AC cable technology from paper-insulated to extruded polymer cables there is a strong incentive for the cable manufacturer to develop and produce HVDC cables with extruded polymeric insulation offering the same benefits – flexibility and cost-effectiveness – for HVDC transmission. Among these incentives are also: Application of a larger temperature gradient across the insulation and lighter moisture barrier, giving a lighter more compact cable for the same or even higher power rating. In addition joining of extruded cables is considered simpler than in cases of mass impregnated cables.

As for all cables HV there is a also a need for a sound routine test method for HVDC extruded cables. This is partly related to the uncertain effects of defects, which are likely to be present in minute amounts in any high voltage insulation system. In case of a long HVDC subsea transmission cable one critical insulation irregularity may be sufficient to cause a service breakdown. In order to avoid expensive repairs it is essential to be able to reveal such weaknesses before installation. The methods should be applicable for voltage levels up to 600 kV, and for cable test length more than 50 km.

Qualification testing of long HVAC cables is presently done using AC voltage. The most convenient way of producing the required test voltage is to use a series resonance system, either with a variable inductance or with variable frequency. CIGRE has issued a recommendation for test procedures for routine testing of long HVAC cables [1], and are also discussing the use of AC testing of HVDC cables [2]. This is based on the assumption that, with today's knowledge, applying a high AC voltage is the best method of detecting defects in extruded cables.

The critical flaws in an insulation system for DC applications may, however, be very different from that of AC insulation, and the test methods should reflect this difference. It is for example not likely that partial discharges are as detrimental in DC insulation as it is in AC insulation. Other flaws in the insulation, such as e.g. non-conducting particles with a conductivity different from the main insulation is not very hazardous in an AC insulation, but may cause high E-field enhancement and be very dangerous in a DC insulation [3]. Another particular phenomenon for DC cables is polarity reversal or rapid grounding which may stress the insulation in ways not significant for AC insulation systems. Generally the techniques used to generate the high AC test-voltage limits the length of cable that can be tested. As the length increases, the testing equipment becomes more and more expensive, and finally the testing costs will limit the application of HVDC cable transmissions.

One alternative test method is that where a length of a cable is exposed to a DC voltage for a certain time after which one end of the cable is rapidly grounded. With the other cable termination open-ended, a considerable cable length will be exposed to a rapid polarity reversal, which may initiate electrical treeing and breakdown at the tip of energized irregularities [4]. When repeated on