Enhancing the Effectiveness of Partial Discharge Measurements on HVDC Cables by Use of Pulsed X-ray

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ABSTRACT

The growing utilization of HVDC systems in the transmission grid leads to an increased demand for reliable DC cable systems where overhead lines cannot or should not be used. For HVAC cables, the PD measurement proved itself to be a valuable addition to AC voltage testing in general and to AC commissioning testing in particular. Prior laboratory investigations on HVDC cables with artificial defects led to the conclusion that the DC-PD activity at a steady state (no load or full load at maximum operating temperature) - even with elaborated DC voltages – is small. This reduces the probability of finding critical assembly defects during DC commissioning test. The creation of additional starting electrons by ionization of trapped air in void-type defects is known to significantly increase the PD activity in defective GIS insulator when tested with AC voltage. The research presented in this paper adapts this approach for a HVDC cable system under laboratory conditions. The cable is prepared with typical assembly defects that may occur during the jointing process. A relatively low X-ray dose is delivered by radiating through the joint body with a portable X-ray device. Vital parameters like the PD inception voltage, PD repetition rate and PD magnitude at various temperatures and voltages are analysed. Furthermore, the applicability of this method during future on-site commissioning tests is being evaluated.

KEYWORDS

partial discharge HVDC X-ray PXIPD

INTRODUCTION

Over the recent years, PD measurement has evolved to a vital asset in HVAC cable testing. For HVDC cables however, it is still unclear to what extend it will benefit the different tests. For HV equipment with gaseous insulations like GIL, GIS, or OHL, HVDC-PD activity in the order of several hundred to several thousand pulses per hour is possible. For polymer insulated HVDC cables, this rate may only be a few pulses per hour, depending on the size and location of the potential defect. When a PD occurs inside a cavity-like defect, a redeposition of inner wall surface charge takes place, which lowers the electric field strength. For the next PD to occur, the walls must be charged again, which can only happen due to the finite resistivity of the insulating material and the resulting conduction current. Since the conductivity of polyethylene is highly dependent on its temperature, the achievable DC-PD repetition rate is far more temperature dependent than its AC counterpart. Raising the temperature during DC-PD measurements on PP films showed a strong increasing effect on the PD repetition rate [1]. While this effect could in theory be used in order to increase the sensitivity of DC-PD measurements, in non-laboratory conditions, especially on-site, the temperature of the cable is often not controllable. Therefore, an additional method for raising DC-PD measurement effectiveness shall be investigated.

PXIPD

The principle of using high energy photons (X-rays) to initiate PD through the generation of charge carriers in enclosed cavities was first mentioned in [2] in the year 1964. While numerous publications regarding this topic were issued since then, none of these investigated the effect off X-rays on PD activity under DC voltage. The research presented in this paper will transfer the approach of pulsed X-ray induced partial discharge measurements (PXIPD as described in [3]) to measurements on polymer insulated cables systems under DC voltage with artificial defects inserted during the jointing process.

In general, two conditions must be met for a partial discharge to occur:

1. Enough unbound electrons must be present in the defective area.
2. An electric field, greater than the PD inception field stress, must be present to accelerate these electrons which then start an avalanche discharge process.

Exceeding the PD inception field stress inside an inner cavity under AC happens more frequent than under DC. There are two reasons for this:

1. In highly resistive materials like polyethylene, the displacement current density $\frac{\partial \vec{D}}{\partial t}$ which can deposit charge on the inner walls of a cavity by electrostatic induction is in the order of magnitudes higher than the DC current density.
2. When the direction of the outer electrical field is reversed, the charge prior deposited on the cavities inner walls by PD increases the effective field stress. The last PD in one halfwave of the testing voltage will therefore increase the chance of PD occurrence in the consecutive halfwave with inverted polarity.

Therefore, after each PD under AC, the critical field stress in a cavity is regained rather quickly.