Analysis and Testing of Internal Arc Phenomena in Gas Insulated Outdoor HVDC Cable Termination up to ± 640 kV

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ABSTRACT

Internal failures in a cable termination can occur due to short-circuit between the cable conductor and ground, leading to an internal electric arc. This paper presents the factors influencing the internal arc event inside a HVDC cable termination. These factors have been analysed to quantify the performance when an internal arc is triggered inside a cable termination. This is supported by high-current arc tests, which have been successfully performed in the High-Power Laboratory of KEMA B.V. The internal arc test was performed with the aim to simulate an internal fault in HVDC cable terminations up to ±640 kV.

KEYWORDS

HVDC cable termination, internal arc, test

INTRODUCTION

A robust cable system must be able to withstand failures without the risk of personal injuries or damage to nearby equipment. Certainly, safety-oriented tests are significant, in addition to electrical and mechanical tests that guarantees the performance of cable systems. An internal failure in a cable termination can occur due to a short-circuit between the cable conductor and ground. This can potentially evolve into an internal electric arc, which is an electrical discharge due to the electrical breakdown of the insulating medium. As high-density current flows in the ionized medium, the available energy heats the surrounding insulating gas inside the termination. Such an event may lead to a sudden and massive increase in gas pressure. A freely burning arc inside a cable termination can lead to external secondary damages and human death. The impact of internal arc should, therefore, be minimized by a hazard mitigation technique, which not only reinforces the termination enclosure but also improves the short-circuit current conduction path to ground together with implementing safety techniques to provide safe and controlled release of exhaust gases by controlling overpressure.

This paper presents the phenomenological factors of an internal arc event inside a HVDC cable termination, among others: arc length, arcing duration, gas pressure and volume. These factors have been analysed to quantify the performance when an internal arc is triggered inside a cable termination. The analysis is further supported by high-current arc tests, which have been successfully performed in the High-Power Laboratory of KEMA B.V. The internal arc test was performed with the aim to simulate an internal fault in HVDC cable terminations up to ±640 kV.

A cable termination must necessarily be treated as an integrated component in HVDC systems. The magnitude and duration of fault current are largely dependent upon HVDC converter architecture, and characteristics of the connected AC grid. The agility of protection mechanisms mainly determines the duration for which the termination experiences a fault. This needs to be considered when determining the internal arc test parameters. Existing HVDC cable termination designs have been retrofitted with internal arc modules that make the termination meet industry requirements of internal arc compliance. Such design aspects, in addition to the analysis of arc phenomena and test performance, will be described in the paper.

DC CABLE ACCESSORIES

DC cable systems differ substantially from AC cable systems in that the electric field distribution is mainly determined by the electrical conductivity of materials, rather than electrical permittivity. This creates new risks such as field inversion, charge build-up at interfaces and space charges [1], but also new opportunities such as novel resistive stress grading concepts [2].

Termination devices are used to terminate the cables when connecting it to an electrical network e.g. converter stations. The disturbance in electric field that is created when breaking the cable outer screen must be controlled in all materials and interfaces for all possible electrical stresses to avoid breakdown.

The HVDC cable terminations consist of an insulator filled with dielectric gas covering the cable end. The electric stress control at the termination of the outer screen is based on a combination of geometrical and non-linear resistive stress grading. This is provided by elastomer adapters and a stress cone, constructed by materials with highly non-linear electric properties and geometric elements. The polymeric composite insulator offers maximum safety without the risk of shrapnel from explosions [3]. To withstand internal arc phenomena, two main improvements have been made to the standard 320 kV and 525/640 kV terminations, shown in Fig. 1. First, the capability to handle fault currents inside the termination has been strengthened by adding copper bars from the grounded bottom plate leading up to an earthing copper ring just below the stress cone. The purpose of the earthing ring is to provide a fixed ground point for the arc, thereby limiting the arc length. Thus, the ring and copper bars are designed to safely carry the short-circuit current throughout the arcing event. Second, the number of bursting discs have been increased to provide quick and rapid relief of the pressure build-up. The bursting discs are non-reclosing safety valves, designed to open when the internal and external pressure difference exceeds a specific threshold relief pressure, p_{relief}. The minimal distance between the arc position and the bursting discs, L_{relief}, is typically 0.5-3 m, depending on voltage level and termination design.