Cost-effective and practical solutions for testing HVDC cable systems

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ABSTRACT

This paper focuses on two main aspects of testing HVDC cable systems. The first part emphasises an active, cost-effective control of the temperature difference across the cable insulation while the second part draws attention to the method of superimposed impulse voltage testing of HVDC cable systems.

A set of program-controlled heating belts realises the temperature control, and a spark gap method is applied to superimpose impulses. This paper is aiming to discuss and share the experience gained from KEMA laboratories' practice, and eventually to improve the quality of testing HVDC cable systems.

KEYWORDS

Testing, HVDC, High Voltage.

INTRODUCTION

Nowadays, HVDC cable systems play an essential role in power transmission due to their capabilities for long distance bulk power transmission. Therefore, the demand for HVDC cable and testing of HVDC cable are increasing. Since the publication of CIGRE TB 496 and IEC 62895, they introduce two unique test requirements for HVDC extruded cable systems: to maintain the temperature difference across the cable insulation in designed value within a specified heating period and to subject a series of superimposed impulse voltage tests after heating cycle voltage tests.

As mentioned already above in the abstract, this paper organises in two sections: the first part introduces an actively-controlled, cost-effective method to control a specified temperature drop (ΔT) across the cable insulation while the second part discusses the spark gap method to realise the superimposed impulse tests. Each section includes the description, analysis, results, discussion and conclusion of each method.

PART 1: THE METHOD OF CONTROLLING THE TEMPERATURE DIFFERENCE ACROSS THE CABLE INSULATION

1.1 Scope of this method

An essential requirement for testing HVDC cable systems is to maintain a specified ΔT across the cable insulation in the radial direction during the thermal steady-state period at maximum conductor temperature of a heating cycle period including the test at high load. During this steady-state period, with the conductor at maximum specified temperature, it is crucial to maintain a constant surface temperature of the cable to guarantee a required ΔT. The reason is that in DC cables, stress distribution is not constant as in AC cables. The stress shifts from adjacent to the conductor to the outside of the cable due to the resistivity of cable insulation. The resistivity of the cable insulation is highly dependent on the temperature. That is why it is essential to control a desired temperature gradient across the cable insulation (ΔT). It is evident that ambient temperature variations influence the cable surface temperature; hence also the ΔT is affected. Traditional methods passively compensate for the influence of the ambient temperature, like by the application of external thermal insulation around the cable or by a controlled ambient temperature in an enclosure (tent) covering the cable. This paper introduces an alternative, cost-effective, practical and active method which is developed to achieve a proper cable surface temperature to eliminate the impact of the ambient temperature. The kernel of this engineering solution is to wrap the surface (outer sheath) of a cable with heating belts in a helical pattern for external thermal control. In doing so, the desired cable surface temperature is achieved by actively controlling the heating belts with dedicated control software. The foundation of this control system and its design are presented and studied. This economical and practical method is applicable for various designs of HVDC cable for short- and long-term tests in a wide range of ambient temperatures.

The proposed solution can be applied in a wide range of ambient temperatures (5 °C to 40 °C), and it is easier to handle and cost-effective for test laboratories. Laboratory experiments have demonstrated the suitability of the control system for specified ΔT values from 10 K to 17 K in this way (note: the highest steady cable conductor temperature was 75 °C for this experiment).

1.2 Description of the method

The purpose of this method is to compensate for the impact of ambient. Based on the required ΔT, two designed programs, one for controlling conductor temperature, another one for controlling insulation screen temperature were developed. These two programs communicate with each other. They control the current through the conductor to reach the required conductor temperature, and at the same time, control the power in the heating belts to control the outer sheath temperature of the cable, to keep ΔT during the heating cycle or period at a constant pre-set value. Eventually, the desired ΔT can be guaranteed.

The critical elements of the test setup are the conductor heating circuit and the heating belts circuit. The conductor heating circuit consists of a heating transformer to induce a current into the conductor, to heat the conductor to reach the specified operating temperature during the heating period. The applied resistive heating belts to control the temperature of the outer sheath are helically wound around the cable, having a rating of 1200 W / 230 V. The dimension of each heating belt is 6 m x 50 mm (L x W). The heating belt has glass fibre wraps around the resistance wires inside, which makes it flexible and easy to handle.

Fig. 1 gives a diagram of the test setup. The first step is to cover the cable with at least two thin layers of aluminium foil. The aluminium foil helps to distribute the heat from the