Influence of the dielectric losses in EHV cables on the cable temperature during laboratory testing and resulting requirement for alignment of standards

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ABSTRACT

It is well known that Edition 1 of IEC 62067 was based on extending IEC 60840 to cover cables above 150 kV (Um = 170 kV). The rated voltages of IEC 60840 for "unfilled" XLPE do not fall under the category of having "important dielectric losses" and are ignored. However, this is not the case of the rated voltages of IEC 62067 (of extra high voltage cables: EHV cables). As per IEC 60287, the dielectric loss is voltage dependent, and becomes important when Uo ≥ 127 kV for unfilled XLPE cables. Based on this fact, all the specified rated voltages of IEC 62067 fall under the category where dielectric losses are important and cannot be ignored. This paper verifies the same on 220/380 (420) kV cable and validates this fact by actual temperature measurements.

KEYWORDS

Cable core; heating cycles voltage test; dielectric loss; heat capacitance; EHV; informative reference; main cable; maximum conductor temperature; normal operation; normative reference; reference cable; steady temperature; thermal resistance.

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INTRODUCTION

EHV AC cables are currently the backbone of transmission systems in most countries. These cables connect the "Bulk Power Supply" substations, which are the major substations in the grid. Laboratory tests are followed precautions to ensure the quality of cables. The tests focus on the entire cable parts, and mainly on the core as it is the heart of the cable. Among these tests is the dielectric loss factor, where the same shall not exceed the specified standard value under the specified test conditions.

DIELECTRIC LOSS

Tangent delta or loss angle represents the amount of dielectric loss in a cable. It is the angle difference from 90° of the ideal capacitive charging current of the cable. It is computed as per equation 1 which is based on IEC 60287-1-1:

$$W_d = \omega . C . Uo^2 . tan\delta \quad (\mathrm{W/m}) \qquad [1]$$

Where:

ω : angular frequency = 2 π f
C : capacitance (F/m)
Uo : voltage to earth (V).

Hence, di-electric loss is voltage dependent, and it is proportional to the square of the voltage.

IEC 60287-1-1 specifies that the dielectric loss should be considered for values of the phase to earth voltage Uo equal to or greater than the values of Table 1:

Table 1: Values of voltages where dielectric losses are to be considered (when equal or exceeded) for XLPE cables

Type of cable	Uo [kV]
XLPE (unfilled)	127
XLPE (filled)	63.5

As di-electric loss is of our prime interest, heating effects of the same was computed in line with IEC 60287 method as well as checked by actual measurements during actual type testing heating cycles.

HEATING CYCLE VOLTAGE TEST

As per Clause 12.4.6 of IEC 62067 "The assembly shall be heated by conductor current only, until the cable conductor reaches a steady temperature 5 K to 10 K above the maximum conductor temperature in normal operation". This is the basic requirement in the standard. There is no specified current rating value for the conductor's current, but the requirement is to reach the specified temperature range of the cable conductor under test.

Cable conductor temperature

Reference cable method

As per Annex A (informative: i.e. additional information that is included in a normative document but has no effect on its substance) the following applies:

- "a reference cable identical to the cable used for the main test loop is heated with the same current value as the main test loop".
- "The difference between the heating currents should be kept within ±1 %".

Based on this informative annex, the same current is considered in practice! Which is not a standard (normative) requirement! The requirement is simply to reach the temperature range value of the main cable i.e. a steady temperature 5 K to 10 K above the maximum conductor temperature in normal operation, which is 95°C to 100°C for XLPE cables.