A calorimetric measuring system for measurement of loss in high voltage cable conductors

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ABSTRACT

A calorimetric measuring system for measuring the ratio between AC and DC resistance, R_{AC}/R_{DC}, of high voltage power cable conductors has been designed and constructed. An uncertainty analysis predicts that the ratio R_{AC}/R_{DC} at 90°C of a 2500 mm^2 cable of low loss design can be measured with an uncertainty of 1,0%. But the uncertainty of an actual measurement was larger due to unresolved sources of uncertainty.

KEYWORDS

High voltage AC cable, Power loss measurement, AC resistance, skin effect, calorimeter, measuring system, uncertainty analysis.

INTRODUCTION

The CIGRE Working Group B1.03 recommends that the AC resistance of large cable conductors should be measured when the cables designs are being type tested [1]. Electrical measuring systems measuring both AC and DC resistance accurately has been developed e.g. [2][3]. For cable conductors of low loss design where lacquered wires are used it is not obvious that electrical measuring systems will give correct results. Hence, a calorimetric measuring system for loss measurement has been developed. The measuring system measures the ratio of the AC resistance relative the DC resistance.

CALORIMETRIC MEASURING SYSTEM

Principle

The calorimetric measuring system is inspired by AC-DC transfer measurement. Two equal samples of a power cable are arranged in one AC and one DC current circuit, Fig 1. The AC and DC currents are adjusted until the self-heating increase the temperature of the conductor of both samples to 90°C. The ratio of the AC resistance and the DC resistance of the conductor, R_{AC}/R_{DC}, can then be determined as:

$$\frac{R_{AC}}{R_{DC}} = \frac{I_{DC}^2}{I_{AC}^2} \qquad [1]$$

when $\Delta T_2=0$ and $T_{DC}=90°C$. To assure that the temperature rise at the center of the two samples is due to self-heating only both ends of the two samples are cooled and kept at equal temperature, Fig. 1.

The cable ends are cooled to approx. 20°C and so that $\Delta T_1 = \Delta T_3 = 0$, Fig 2.

By having two samples the heat loss does not need to be measured, just made equal for both samples. So the cable samples need to be equally supported and have an equal environment so that losses due to convection and radiation are equal for both samples.

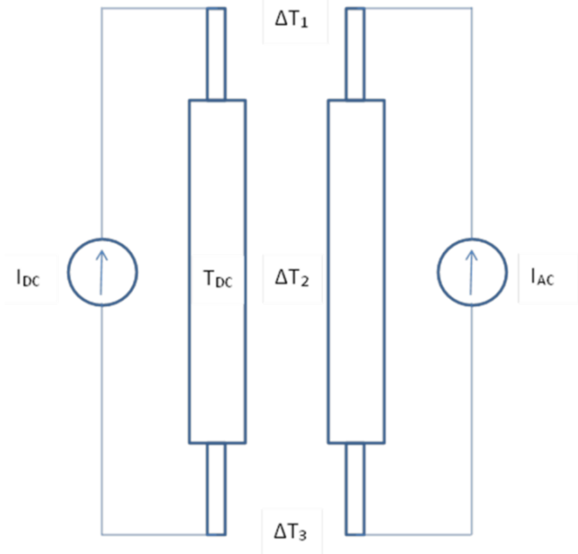

Fig. 1: Schematic drawing of the calorimetric measuring system.

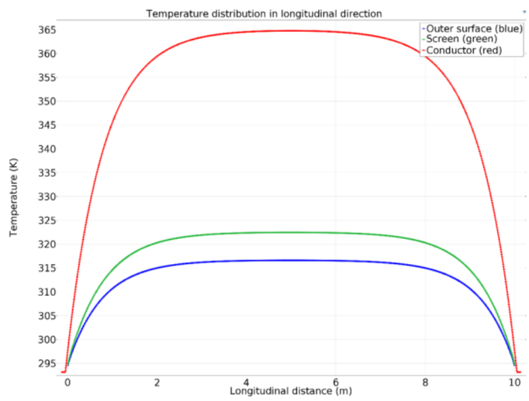

Fig. 2: Simulation of the temperature distribution in the cable conductor when AC current is applied.

The pre requisites for the accuracy of the calorimetric measuring system when using this procedure are:

- The temperature rise of the cable is due to self-heating only
- The correlation of the heat loss in the cables by maintaining the same ambient conditions during both AC and DC measurements
- The accuracy of the temperature measuring sensors. Thermocouples of type T (non-magnetic) are used and correction of the cold junction is made with the help of a Pt100-sensor. A thermocouple and the Pt100 are kept in a small oil bath which also gives a measure of the mean temperature of the environment.