Measures to reduce skin-effect losses in power cables with optimized conductor design and their evaluation by measurement

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ABSTRACT

The increasing rising power consumption *require cables with very high ampacity and consequently conductors with large cross sections.*

With large cross sections, the conductor (DC) resistance decreases accordingly. But for AC transmission, the growing impact of the skin effect prevents from utilizing the full cross section and leads to additional AC losses.

To minimize additional AC losses, conductor designs with low impact of skin effect become more and more important.

This paper reports measures to reduce skin effect losses in power cables with optimized conductor design and their evaluation by simulation and verification by measurement.

Simulation results and plausible verifications show, that the structure and the geometry of the measurement set-up for short conductor samples has to be carefully chosen in order to avoid inaccurate measurement results.

The presented investigations should help to better understand the impact of different parameters on the k_S-factor measurement results.

KEYWORDS

AC measurement, AC resistance, DC resistance, k_S-factor, power cables, conductor, skin effect, losses, ampacity, coaxial, FEM simulation

INTRODUCTION

Due to a rising power consumption, HV and EHV cables have to carry larger currents. This can be done by increasing the cross-section of the conductor. Therefore cable conductor designs with low impact of skin effect become indispensable to minimize additional losses caused by the conductor AC resistance.

Improved designs and constructions of the conductor decrease skin effect losses and hence increase the effective cross-section.

Obviously, AC-losses with improved designs can converge to the DC-losses.

In table 1 the AC resistance R_{AC} is calculated for a given DC resistance R_{DC}, which is based on a conductor cross-section with 2500 mm^2 copper and for different k_S-factors based on different conductor types as defined in the relevant international standard [1].

2500mm^2 copper conductor	**R_{DC}** μΩ	**R_{AC}** μΩ	**k_s**
Round, solid	7.2	12.23	1,00
Round, stranded	7.2	12.23	1,00
Milliken, bare unidirect. wires	7.2	10.15	0,62
Milliken, bare bi-direct. wires	7.2	11.23	0,80
Milliken, insulated wires	7.2	8.41	0,35

Table 1: R_{DC}, R_{AC} and k_s factor for different copper conductor types acc. to [1]

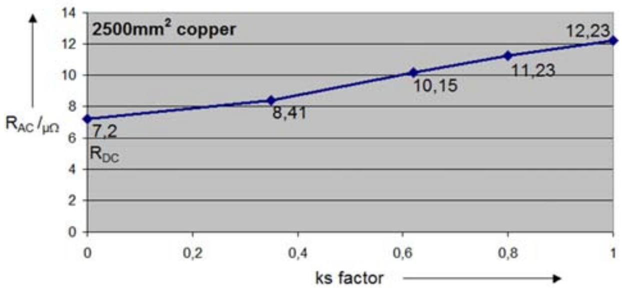

Fig. 1: AC resistance R_{AC} and k_S factor for different conductor types with cross-section 2500mm^2 copper

The values for a conductor cross-section 2500 mm^2, but different conductor types, are shown in figure 1.

Thus, the reduction of the AC losses presents in general a great potential for energy savings and/or an option to reduce the conductor cross section.

To evaluate recent and future optimized conductor designs, it is crucial to have an efficient measurement method.

One previous method used a calorimetric approach on cables of limited length, e.g. 10-20 m. Heavy currents (often more than 1000 A) drive the conductor into thermal steady state condition, so that no more joule heating occurs. There is no current flow in the cable screen. From measuring the conductor temperature one can derive the total losses produced by both DC- and AC-resistance. Beside high energy costs and long waiting times