AC resistance measurements on skin-effect reduced large conductor power cables with standard equipment

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ABSTRACT

The increasing demand for HV/EHV cables with very high ampacity require conductors having large cross sections. Furthermore cable conductor designs with low impact of skin effect become more and more relevant to minimize additional losses caused by the conductor AC resistance.

For this reason improved conductors designs with special features e.g. additional insulation between the stranded wires, oxidised or enamelled wires are used in order to reduce the skin effect.

This paper reports the progress and experiences of the development of a new and available measurement system in order to determine the AC resistance of cable conductors with large cross sections having a reduced skin effect.

Investigation results and plausible verifications show, that the new measurement system is suitable to use to determine the AC resistance and respectively the k_s factor.

KEYWORDS

AC resistance, DC resistance, large conductors, skin effect, eddy current losses, k_s factor, Milliken, oxidized wires, enamelled wires

INTRODUCTION

The actual international standards IEC 60840 and IEC 62067 require the identification of cable characteristics. In terms of AC resistance the presence, if any, and nature of measures taken to reduce skin effect shall be declared. If so, one approach to do this is an ac-resistance measurement in order to verify the specified properties of the cable [1] [2].

Currently measurement procedure is not standardized, but generally accepted method to describe the behaviour of the skin effect and eddy current losses is the expression by the well known k_s-factor, as described in the international standard IEC 60287-1-1 [3]. In IEC 60228 the conductors for cables are defined [4].

The standard IEC 60287-1-1 has been revised recently and is now available in IEC 60287-1-1-am1 (2014-11) Ed. 2.0.

In the standard new formulas for the skin effect factor y_s have been established. They replace the existing subclause by three ranges for x_s.

- for $0 < x_s \leq 2.8$
- for $2.8 < x_s \leq 3.8$
- for $x_s > 3.8$

Further more it should be noted, that table 2 in IEC 60287-1-1 has been replaced.

In terms of large conductor XLPE power cables the important changes are new definitions for the k_s factor with respect to the construction or type of the conductor.

type of the conductor (copper)	k_s
Round, solid	1
Round, stranded	1
Round, Milliken (insulated wires)	0,35
Round, Milliken (bare uni-directional wires)	0,62
Round, Milliken (bare bi-directional wires)	0,80

Table 1 k_s factor for different copper conductor types acc. to IEC 60287-1-1-am1 (2014-11) Ed. 2.0 for extruded conductor insulation systems

type of the conductor (aluminium)	k_s
Round, solid	1
Round, stranded	1
Round, Milliken	0,25

Table 2 k_s factor for different aluminium conductor types acc. to IEC 60287-1-1-am1 (2014-11) Ed. 2.0 for extruded conductor insulation systems

Milliken conductors are defined as a stranded conductor comprising an assembly of shaped stranded conductors, with each segment lightly insulated from each other. The individual strands may be either insulated (e.g. enamelled or oxidised) or bare.

The following notes in the standard have to be considered:

- The tabulated values of k_s for large stranded conductors have generally been derived from those given in CIGRE Technical brochure Ref. N° 272 [5], Large cross-sections and composite screens design.