IEC 60287-1-2

Edition 2.0 2023-05

INTERNATIONAL STANDARD

**Electric cables – Calculation of the current rating –
Part 1-2: Current rating equations (100 % load factor) and calculations of losses –
Sheath eddy current loss factors for two circuits in flat formation**

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IEC 60287-1-2 has been prepared by IEC technical committee 20: Electric cables. It is an International Standard.

This second edition cancels and replaces the first edition published in 1993. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) the symbols have been harmonized and aligned with the symbols used in the IEC 60287 and IEC 60853 series.

The text of this International Standard is based on the following documents:

Draft	Report on voting
20/2097/FDIS	20/2104/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 60287 series, published under the general title *Electric cables – Calculation of the current rating*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

ELECTRIC CABLES –
CALCULATION OF THE CURRENT RATING –

Part 1-2: Current rating equations (100 % load factor) and calculation of losses – Sheath eddy current loss factors for two circuits in flat formation

1 Scope

This part of IEC 60287 provides a method for calculating the eddy current losses in the metallic sheaths of single-core cables arranged as a three-phase double circuit in flat formation. The sheaths are bonded at one point or are cross-bonded so that there are no significant sheath circulating currents. Where metallic sheaths are bonded at both ends there are significant circulating currents which result in a lower current-carrying capacity. A method of calculating circulating current losses for double circuits is provided in IEC 60287-1-3.

The method descibed in this document provides coefficients which are applied as corrections to the loss factors for the sheaths of one isolated three-phase circuit. These corrections are negligible for cables where the parameter m is less than approximately 0,1 ($m = \omega/(R_s \cdot 10^7)$), which corresponds to a sheath longitudinal resistance higher than 314 μΩ/m at 50 Hz.

Consequently, the method is used for most sizes of aluminium-sheathed cables, but is not required for lead-sheathed cables unless they are unusually large.

The coefficients are provided in tabular form and have been computed from fundamental formulae for sheath losses, the evaluation of which calls for expertise in computer programming which will possibly not be readily available in general commercial situations. The development of simplified formulae for some of the tabulated coefficients is under consideration.

Losses for cables in a single circuit is covered in IEC 60287-1-1.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60287-1-1:2023, *Electric cables – Calculation of the current rating – Part 1-1: Current rating equations (100 % load factor) and calculation of losses – General*

3 Terms, definitions and symbols

3.1 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.2 Symbols

C_{A0}, C_{B0}, C_{C0}, C_{D0}	coefficients used to interpolate for C_H *and* C_J	
C_{H1}, C_{H2}, C_{H3}	coefficients which correct for sheath resistance, the values obtained relate to cables 1, 2 or 3 in a single circuit	
C_{N1}, C_{N2}, C_{N3}, C_{N4}, C_{N5}, C_{N6}	coefficients which introduce the mutual influences between circuits and are therefore dependent on the relative phase sequences of cables 1 to 3 and 4 to 6	
C_{J1}, C_{J2}, C_{J3}, C_{J4}, C_{J5}, C_{J6}	coefficients which depend on the cable positions 1 to 3 and 4 to 6 in each circuit	
C_{M0}, C_{Z0}	coefficients used for calculation of coefficients C_H	
C_S, C_T, C_U, C_V	coefficients used to interpolate for C_J	
C_Y	coefficient used for calculation of coefficients C_J	
$C_{ß1}$	coefficient used for calculation of coefficients G_s and g_s	
D_s	external diameter of the metal sheath	(mm)
D_{it}	the diameter of the imaginary cylinder which just touches the inside surface of the troughs of a corrugated sheath	(mm)
D_{oc}	the diameter of the imaginary coaxial cylinder which just touches the crests of a corrugated sheath	(mm)
G_s	coefficient which accounts for losses due to eddy currents across the thickness of the sheath due to the current in the conductor	
R_c	alternating current resistance of the conductor at its maximum operating temperature	(Ω/m)
R_s	resistance of the sheath	(Ω/m)
c_1	distance between centres of cables in adjoining circuits	(mm)
d	mean diameter of sheath or screen	(mm)
f	system frequency	(Hz)
g_s	coefficient which accounts for losses due to eddy currents across the thickness of the sheath, due to currents in adjacent cables	
m	parameter used in calculation of loss factor	
s	distance between centres of cables in the same circuit	(mm)
t_s	thickness of the sheath	(mm)
y_1	equal to s/c_1	
z	equal to $d/2 \cdot s$	
λ_{0s}	sheath loss factor for a high-resistance sheath in a single circuit	
λ_{1s}''	sheath loss factor for a low-resistance sheath in a single circuit	
λ_{1d}''	sheath loss factor for a low-resistance sheath in a double circuit	
ρ_s	electrical resistivity of sheath material at operating temperature	(Ω · m)
ω	angular frequency of system ($2\pi f$)	(l/s)

4 Description of method

4.1 General

The method proceeds in a way similar to that used for single circuits in IEC 60287-1-1. There, formulae for loss factors applicable to sheaths having a longitudinal resistance such that m is less than 0,1 (R_s = 314 μΩ/m at 50 Hz) are given, together with empirical formulae to calculate the correction coefficient for lower resistance sheaths.

However, for double circuits, accurate empirical formulae covering the complete range of coefficients would contain so many terms that their use would show little or no advantage over the use of precise, tabulated coefficients with interpolation, as necessary. This latter course has the advantage that the accuracy of the loss factors can be closely equal to that of the original calculations and is better than 1 %.

The development of empirical formulae for a limited range of coefficients is under consideration.

In order to explain the method, it is described here in a way appropriate to manual evaluation of the arithmetic. However, because of the appreciable effort required to provide loss factors for six cables, it is to be expected that calculations will usually be effected by means of a computer. Under these circumstances, the decision to use interpolation (as necessary) between tabulated values is fully justified.

However, in many cases, values of the relevant parameters will be such that interpolation is unnecessary or can be accomplished with sufficient accuracy by inspection.

Corrections to cover the effect of eddy currents circulating within the thickness of a sheath are derived with the use of the same formulae as those used in IEC 60287-1-1.

4.2 Outline of method

The loss factor for the sheath of a given cable in a double-circuit flat formation (see Figure 1) is evaluated as follows:

$$\lambda''_{1d} = \frac{R_s}{R_c}\left[\lambda_{0s} \cdot C_H(1 \text{ to } 3) \cdot C_N(1 \text{ to } 6) \cdot C_J(1 \text{ to } 6) \cdot g_s + G_s\right]$$

The tasks performed by coefficients C_N and C_J are not directly related to any physical function but have been selected to simplify the tabulation. The nomenclature is arbitrary.

Values of C_H, C_N and C_J are obtained from Table 1 to Table 11 and are chosen according to the following parameters together with the position of the cable and the phase sequence of the currents in the conductors.

$$m = \frac{\omega}{R_s} \times 10^{-7}$$

$$\omega = 2\pi f$$

$$z = \frac{d}{2s}$$

$$y_1 = \frac{s}{c_1}$$

where

c_1 is the distance between the centres of cables in adjoining circuits (see Figure 1) (mm).

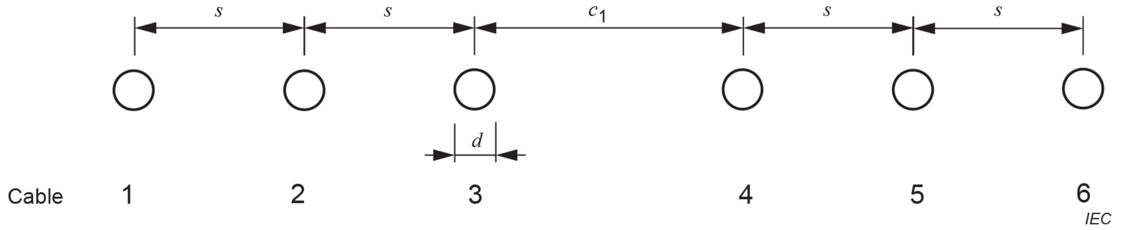

Figure 1 – Cable configuration

NOTE The factors for a single circuit having low-resistance sheaths can be obtained by using the coefficients C_H (1, 2 and 3) only, as follows:

$$\lambda''_{1s} = \frac{R_s}{R_c}\left[\lambda_{0s} \cdot C_H(1 \text{ to } 3) \cdot g_s + G_s\right]$$

4.3 Criteria for use of formulae and coefficients

For sheaths for which the value of m is less than 0,1, which includes most lead-sheathed cables, it can be assumed that the coefficients C_H, C_N, C_J and g_s are unity and G_s is zero. In such circumstances, λ_{0s} can be used for twin circuits without correction.

When the value of m is equal to 0,1 or greater, which is generally the case for all but the smaller aluminium-sheathed cables, values for C_H, C_N, C_J and g_s shall be calculated. The coefficient G_s is important only when the value of m is 1,0 or higher.

5 Formulae for sheath loss factors for high-resistance sheaths in a single circuit, λ_{0s}

The sheath loss factor λ_{0s} is given by

$$\lambda_{0s} = C_{C0}\frac{m^2}{\left(1+m^2\right)}\left[\frac{d}{2s}\right]^2$$

For three single-core cables in flat formation, the coefficient C_{C0} is given by:

Cable	Coefficient C_{C0}
Centre cable	6
Outer cables	1,5

6 Calculation of the coefficients C_H, C_N and C_J

6.1 Allocation of coefficients to each cable, time sequence and phase identification

It is important to note the way in which the coefficients C_H, C_N and C_J are dependent on the time sequence of the currents and the physical position of the conductors.

The cables shall be numbered according to Figure 1.

The coefficients C_{H1}, C_{H2} and C_{H3} of Table 1 are allocated on a basis of time sequence associated with the positions of the cables, so that the following single-circuit arrangements have the same time sequence:

Cable number	1	2	3
Sequence	R	S	T
Or	S	T	R
Or	T	R	S
With coefficients	C_{H1}	C_{H2}	C_{H3}

In the above example, cable 1 is always the outer conductor on a leading phase and takes coefficient C_{H1}. Cable 3 is the outer conductor on a lagging phase and takes coefficient C_{H3}.

It will be seen that, for these cases, the phase identification implied by the letters R, S and T is not important, it is only the time sequence which is of significance.

In double circuits, if either circuit has a reversed sequence, the values of C_H shall be allocated to the cables in the reverse order. The allocation of coefficient C_H is dependent on the time sequence within each circuit.

In a double-circuit configuration, the phase identification implied by the symbols is significant to the extent that the phase identification in relation to the cable position in one circuit shall be either the same as, in the forward sequence, or a mirror image of, in the reverse sequence, that in the other.

Two sets of coefficients C_{N1} to C_{N6} are given in Table 2 corresponding to the forward and reverse sequences. If the cable positions are labelled sequentially and the phase identification rules are adhered to, the coefficients are allocated on the same basis as coefficient C_H. Note that the values for cables 4, 5 and 6 in the reversed sequence are a reflection of the values for cables 1, 2 and 3.

The number of input parameters involved for the coefficients C_{J1} to C_{J6} makes it desirable to use several tables. Table 3 to Table 8 are for each cable for the forward sequence installation. For the reverse sequence, Table 9 to Table 11 are provided and the coefficients for cables 1 to 3 are also used for cables 6 to 4, in that order. The allocation is on the same lines as those for coefficient C_N.

The following tables give examples of four common cases, where letters R, S, T are used for convenience and are equivalent to other well-known sets of symbols to denote time sequence and phase identification, such as L1, L2, L3; a, b, c; R, Y, B.

a) Forward sequence

Cable number	1	2	3	4	5	6	
Sequence	R	S	T	R	S	T	
Allocation C_H	C_{H1}	C_{H2}	C_{H3}	C_{H1}	C_{H2}	C_{H3}	Table 1
Allocation C_N	C_{N1}	C_{N2}	C_{N3}	C_{N4}	C_{N5}	C_{N6}	Table 2, forward
Allocation C_J	C_{J1}	C_{J2}	C_{J3}	C_{J4}	C_{J5}	C_{J6}	Table 3 to Table 8, forward

b) Forward sequence

Cable number	1	2	3	4	5	6	
Sequence	T	S	R	T	S	R	
Allocation C_H	C_{H3}	C_{H2}	C_{H1}	C_{H3}	C_{H2}	C_{H1}	Table 1
Allocation C_N	C_{N6}	C_{N5}	C_{N4}	C_{N3}	C_{N2}	C_{N1}	Table 2, forward
Allocation C_J	C_{J6}	C_{J5}	C_{J4}	C_{J3}	C_{J2}	C_{J1}	Table 3 to Table 8, forward

c) Reverse sequence

Cable number	1	2	3	4	5	6	
Sequence	R	S	T	T	S	R	
Allocation C_H	C_{H1}	C_{H2}	C_{H3}	C_{H3}	C_{H2}	C_{H1}	Table 1
Allocation C_N	C_{N1}	C_{N2}	C_{N2}	C_{N4}	C_{N5}	C_{N6}	Table 2, forward
Allocation C_J	C_{J1}	C_{J2}	C_{J3}	C_{J4}	C_{J5}	C_{J6}	Table 9 to Table 11, forward

d) Reverse sequence

Cable number	1	2	3	4	5	6	
Sequence	T	S	R	R	S	T	
Allocation C_H	C_{H1}	C_{H2}	C_{H3}	C_{H3}	C_{H2}	C_{H1}	Table 1
Allocation C_N	C_{N6}	C_{N5}	C_{N4}	C_{N3}	C_{N2}	C_{N1}	Table 2, forward
Allocation C_J	C_{J6}	C_{J5}	C_{J4}	C_{J3}	C_{J2}	C_{J1}	Table 9 to Table 11, forward

6.2 Calculation of coefficients C_H (1, 2 and 3), Table 1

Each coefficient C_H is obtained from Table 1 using the parameters m and z as well as the position of each cable (see 6.1).

When values of m and z involve interpolation between values in Table 1, the following procedure should be used where interpolation by inspection is not desired.

From the relevant part of Table 1, values for C_H (a, b, c, d) are obtained as shown in the following diagram:

	z_0	z	z_1
m_0	C_{Ha}		C_{Hc}
m		C_H	
m_1	C_{Hb}		C_{Hd}

where m_0, m_1, z_0 and z_1 are tabulated values smaller and larger than the values of m and z.