IEC 60853-2

Edition 1.0 2008-10

INTERNATIONAL STANDARD

NORME INTERNATIONALE

AMENDMENT 1
AMENDEMENT 1

Calculation of the cyclic and emergency current rating of cables – Part 2: Cyclic rating of cables greater than 18/30 (36) kV and emergency ratings for cables of all voltages

Calcul des capacités de transport des câbles pour les régimes de charge cycliques et de surcharge de secours – Partie 2: Régime cyclique pour des câbles de tensions supérieures à 18/30 (36) kV et régimes de secours pour des câbles de toutes tensions

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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

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Email: csc@iec.ch
Tél.: +41 22 919 02 11
Fax: +41 22 919 03 00

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FOREWORD

This amendment has been prepared by IEC technical committee 20: Electric cables.

The text of this amendment is based on the following documents:

FDIS	Report on voting
20/965/FDIS	20/991/RVD

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

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

PREFACE

Replace the quoted IEC publication "287(1982)", by the following:

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

IEC 60287-2-1, *Electric cables – Calculation of the current rating – Part 2-1:Thermal resistance – Calculation of thermal resistance*

IEC 60287-3-1, *Electric cables – Calculation of the current rating – Part 3-1:Sections on operating conditions – Reference operating conditionsand selection of cable type*

Throughout the standard, replace all references to "IEC Publication 287" *by* "the IEC 60287 series".

Add the following new reference:

IEC 60853-3, *Calculation of the cyclic and emergency current rating of cables – Part 3: Cyclic rating factor for cables of all voltages, with partial drying of the soil*

1.1 General

Replace the first paragraph by the following:

This standard gives manual methods for calculating cyclic rating factors for cables whose internal thermal capacitance cannot be neglected; in general this applies to cables for voltages greater than 18/30 (36) kV. It also gives a method for calculating the emergency rating for cables of any voltage. IEC 60853-1 deals with cyclic rating factors for cables of voltages not greater than 18/30 (36) kV where the internal thermal capacitance could be neglected. IEC 60853-3 deals with cyclic rating factors for cables of all voltages when partial drying of the soil occurs.

Delete the fourth paragraph.

Add the following three new paragraphs at the end of 1.1:

When the load current changes in discrete and multiple steps the method set out in Clause 4 can be used to determine the temperature response of the cable.

This method shall be used carefully where a large number of steps is considered, or long duration steps are dealt with, or large variations of the load current occur.

As the method involves an iterative process, the convergence criterion shall be adapted to the different situations.

2 Symbols

Replace the word "sheath" *by* "metallic sheath or screen" *under definitions* Q_s, q_a , q_j and q_s.

Throughout the text, starting with the "Unit" *column, replace* "J/m.K" with "J/Km" also replace "K.m/W" with "Km/W".

Replace the definition for N *with* "N = number of cables in a group, or, for touching cables, the number of circuits, see 7.4 b)"

Replace "δ" *by* "σ" *in order to align with the French version. Also in the* "Unit" *column, replace* "J/K.m^3" *by* "J/Km^3".

Add the following new definition:

$\Delta\theta_d$	Steady-state conductor temperature rise above ambient due to dielectric losses	K

4.2.1.1 Single-core cables

Replace, in the second line, the word "sheath" *by* "metallic sheath or screen".

4.2.1.2 Three-core cables

Replace the existing Equation (4-2) by the following new Equation (4-2):

$$d_c = D_i e^{-\left(\frac{2\pi T_1}{\rho_i}\right)} \tag{4-2}$$

Replace, in the first line after Equation (4-2) and in the first line of 4.2.1.2 b), the word "sheath" *by* "metallic sheath or screen".

4.2.2.1 General

Add, at the end of the subcause, a third paragraph as follows:

For single-core cables in trefoil formation, the values of T_1 and T_3 are adjusted by the appropriate factors given in IEC 60287-2-1.

4.2.2.2 Representation of common types of cable

Replace, after Equation (4-6), in the definition for Q_s *and twice in the definition for* q_s*, the word* "sheath" *by* "metallic sheath or screen".

4.2.4.1 Buried cables (directly or in ducts)

Replace the existing Equation (4-36) by the following new Equation (4-36):

$$\theta_e(t) = \frac{\rho_T W_I}{4\pi}\left\{\left[-Ei\left(\frac{-D_e^2}{16t\delta}\right) - \left[-Ei\left(\frac{-L^2}{t\delta}\right)\right]\right] + \sum_{k=1}^{k=N-1}\left[-Ei\left(\frac{-(d_{pk})^2}{4t\delta}\right) - \left[-Ei\left(\frac{-(d'_{pk})^2}{4t\delta}\right)\right]\right]\right\} \quad (4\text{-}36)$$

Replace the final sentence of 4.2.4.1 beginning "This formula has been simplified … " *by the following new paragraph:*

Equation (4-36) is the general equation for the transient response of buried cables and its application for cyclic rating purposes is given in Clause 7. It is noted that this equation cannot be used directly for cables in unfilled troughs.

4.3.2.1 General

Add, at the end of this subclause, a new paragraph as follows:

For single-core cables in trefoil formation the values of T_1 and T_3 are adjusted by the appropriate factors given in IEC 60287-2-1.

4.3.2.2 Representation of common types of cable

Replace the existing Equation (4-47) by the following new equation:

$$T_B = \frac{1}{2}T_1 + q_s T_f + q_a T_2 + q_j T_3 \quad (4\text{-}47)$$

4.4.1 Transient temperature response

Add the following new text after item b).

When the temperature response to a current that changes in discrete and multiple steps is calculated, the calculations described in this clause should be repeated for every partial step of the current. In the calculation of these partial transients, the correct heat source (the heat gained or lost in the partial current step) and the correct temperatures (for the calculation of electrical resistances) shall be used in the formulas above. One way of accomplishing this is to perform iterative calculations for each load step as follows:

1) Start with the temperature achieved at the end of the previous load step.
2) Calculate the electrical resistances corresponding to this temperature and obtain power losses.
3) With these losses calculate the temperature at the end of the time step.
4) Use this temperature to recalculate the electrical resistances and power losses and go to step 3.
5) Repeat steps 3 and 4 until convergence is achieved and go to the next load step.

The total temperature response per partial step will be found by using the appropriate formulae in this clause. The complete total temperature response of the cable circuit will be found by adding all the partial transients, thereby taking the time differences between the partial steps into account.

4.4.1.2 Cables in air

Replace the last paragraph by the following:

T_4 is the external thermal resistance due to air in the steady-state, calculated according to IEC 60287-2-1, and shall be expressed as a quantity per conductor or equivalent conductor.

4.4.2 Correction to transient temperature response for variation in conductor losses with temperature (emergency ratings only)

Replace the heading of this subclause with the words "Not used".

Delete the text of this subclause, including Equation (4-73).

4.4.3.2 Cables at voltages higher than 275 kV

Replace, in the third line, and in the penultimate paragraph, the word "sheath" *by* "metallic sheath or screen".

Add, at the end of the subclause, the following new text:

Information on the voltages above which dielectric losses should be considered is given in IEC 60287-1-1.

5.1 General

Replacethe existing Equation (5-1) by the following new Equation (5-1):

$$\begin{aligned}\theta_{\max} = {} & Y_0\theta_R(1) + Y_1\left[\theta_R(2) - \theta_R(1)\right] + Y_2\left[\theta_R(3) - \theta_R(2)\right] \\ & + Y_5\left[\theta_R(6) - \theta_R(5)\right] + \mu\left[\theta_R(\infty) - \theta_R(6)\right]\end{aligned} \quad (5\text{-}1)$$

5.2.1 Any load cycle of known shape

Replace the existing Equation (5-3) by the following new Equation (5-3):

$$M = \frac{1}{\left(\sum_{i=0}^{5} Y_i\left[\frac{\theta_R(i+1)}{\theta_R(\infty)} - \frac{\theta_R(i)}{\theta_R(\infty)}\right] + \mu\left[1 - \frac{\theta_R(6)}{\theta_R(\infty)}\right]\right)^{1/2}} \quad (5\text{-}3)$$

5.2.2 Flat top load cycle

Replace the existing Equation (5-5) by the following new Equation (5-5):

$$M = \left[\frac{1}{\left(1 - (1-\mu)\left[1 - \alpha(6) + k\alpha(6)\ \{1 - \beta(6)\}\right]\right)}\right]^{1/2} \quad (5\text{-}5)$$

7.2 Single isolated circuit

Under item a) 1), *replace* " … for cables in ducts, in trefoil or flat touching formation…." *by* "….for cables in trefoil or flat touching formation or in ducts… "

7.4 Group of "*N*" circuits, each of three single-core identical touching cables or ducts, all cables having equal losses

Replace the existing title and text of this subclause by the following:

7.4 Group of circuits, each of three single-core identical touching cables or ducts, all cables having equal losses

The methods are the same as those given in 7.3 above, except that:

a) The external thermal resistance T_4, on which the value of k_1 is dependent, relates to

$$T_4 = \frac{1{,}5}{\pi} \rho_T \left[\ln\left(\frac{4L}{D_e}\right) - 0{,}630 \right] \tag{7-13}$$

for metallic sheathed and part-metallic covered cables (where helically laid armour or screen wires cover from 20 % to 50 % of the cable circumference),

or

$$T_4 = \frac{1}{2\pi} \rho_T \left[\ln\left(\frac{4L}{D_e}\right) + 2 \ln\left(\frac{2_L}{D_e}\right) \right] \tag{7-14}$$

for non-metallic sheathed cables

where

ρ_T is the soil thermal resistivity, in Km/W;

L is the depth of laying, in metres (m);

D_e is the external diameter of cable or duct, in metres (m).

b) The symbols N, d'_{pk} and d_{pk} used for the calculation of $\gamma(i)$, F and d_f in equations (7-7), (7-8) and (7-9) are defined as:

– N is the number of circuits (of three single-core cables per circuit)

– d_{pk} is the distance from the centre of circuit k to the centre of the circuit containing the hottest cable;

– d'_{pk} is the distance of the image of the centre of circuit k to the centre of the circuit containing the hottest cable.

c) Additional external thermal resistance caused by heating from other cables in a group is expressed by:

$$\Delta T_4 = \frac{3\rho_T \ln F}{2\pi} \tag{7-15}$$

where F is given by item b) above.

d) W_1 is the total loss per unit length per single cable or duct.

e) The value of the cable or duct diameter to be assumed for the calculation of $\gamma(i)$ is that of an isolated cable or duct.

8.1 Thermally isolated circuits

Replace, against definition $\theta_R(t)$ "$\theta_R(t)$ is calculated in Sub-clause 4.4" *by* "see the calculation for $\theta(t)$ in 4.4"

Insert, immediately after Equation (8-1), the following new paragraph:

This equation takes account of the variation of conductor resistance with temperature. Thus Equation (8-3) should not be applied when Equation (8.1) is used. Where armour, screen or metallic sheath losses are high, it is recommended that the losses at the final armour, screen or metallic sheath temperature are used in determination of the transient temperature response.

After Equation (8-2), *replace* "(See IEC Publication 287, Clause 3)" *by* "(See IEC 60287-1-1.)"

8.2 Groups of circuits

Add, after 8.2, a new subclause 8.3 as follows:

8.3 *Correction to transient temperature response to take account of variation in conductor losses with temperature*

The change in conductor resistance with temperature during the transient period results in conductor losses being variable with time. Allowance for the variation of conductor loss with temperature gives the corrected temperature rise:

$$\theta_{\alpha}(t) = \frac{\theta(t)}{1+\alpha\big(\theta(\infty)-\theta(t)\big)} \tag{8-3}$$

where

$\theta(t)$ is the conductor transient temperature rise above ambient without correction for variation in conductor loss, and is based on the conductor resistance at the end of the transient period;

$\theta(\infty)$ is the conductor steady-state temperature rise above ambient;

α is the temperature coefficient of electrical resistivity of the conductor material at the start of the transient.

NOTE $\alpha = \dfrac{1}{\beta+\theta_i}$

where

β is the reciprocal of temperature coefficient at 0 °C (see Table E.2);

θ_i is the conductor temperature at the start of the transient period.

Appendix E – Physical constants of materials

In the second footnote beneath Table E.1, replace "in Sub-clause 9.7.1 of IEC Publication 287" *by* "in IEC 60287-2-1".

F.2 Cable and installation details

Replace, in the third line of the first paragraph, "1 580 A" by "1 550 A".

Table F.1 – Cable details

Replace, in the fifth column, "13,35" by "14,75" *against the item* "Dielectric".

Replace, in the summation row, "45,75" *by* "47,15".

F.3 Derivation of thermal circuit of the cable

Replace, in the fifth line "T_i" *by* "T_1".

Replace, In the equations labelled "(from equation (4-1))" *and* "(from equation (4-6))", *the symbol* "ρ" by "p".

Replace "(from equation 4-6))" *by* "(from equation 4-7))".

Replace "(from equation 4-7))" *by* "from equation 4-6))".

F.4 Example of the calculation of the transient response

Add, at the end of the first paragraph, the following new paragraph:

In the following example, the transient response is based on the formulae in 4.2 for a transient of long duration. As the first time step chosen is less than one-third of the time constant of the cable, the use of the formulae in 4.3 could be justified for the first time step. However, this would lead to a discontinuity in the temperature rise curve that cannot be justified.

F.4.1 Calculation of the response of the cable circuit

Replace the equation for T_a by the following:

$$T_a = \frac{1}{\left(2{,}48\times10^{-3} - 1{,}45\times10^{-4}\right)}\left[\frac{1}{12{,}966} - 1{,}45\times10^{-4}\left(0{,}488 + 0{,}04\right)\right] = 2{,}42\times10^{-4}\ \text{Km/W}$$

F.4.3 Calculation of the complete temperature transient

Replace the line that starts "Correcting for variation … " *as follows:*

Correcting for variation of conductor losses using equation (8-3):

Replace the equation as follows: :

$$\theta_a(1) = \frac{7{,}1}{1 + \dfrac{1}{234{,}5 + 31{,}3}(85 - 31{,}3 - 7{,}1)} = 6\ \text{K} \qquad (8\text{-}3)$$

Replace the existing note by the following new note:

NOTE Initial temperature = 31,3 °C due to 21,3 K dielectric loss contribution. Actual conductor temperature = 31,3 °C + 5,6 °C = 36,9 °C.

Table F.3 – Summary of temperature transient components

Replace the temperatures given in columns (6) and (7) by the following new values:

(6)	(7)
6,0	37,0
10,4	41,8
13,5	44,8

15,6	46,9
17,0	48,3
18,1	49,4
21,3	52,7
24,8	56,1

F.5.1 Cyclic load details

Add the following new paragraph after the equation for μ.

From an examination of the load cycle, Figure 8, it has been estimated that the highest conductor temperature will occur at 17 h.

F.5.6 Cyclic rating factor M

Replace, in the last line, "1.28 × 1 580 = 2 022 A" *by* "1.28 × 1 550 = 1 984 A"

Add, after the equation, the following new paragraph:

Repeat calculations for other assumed times of maximum temperature show that the actual time of maximum temperature is at 12 h. The cyclic rating factor based on this time is 1,27.

F.6.2 Emergency current rating

Replace "I_R = 1 580 A" *by* "I_R = 1 550 A"

Replace the last three lines that follow the symbol R_R by the following:

Temperature due to dielectric loss = 21,3 K

Steady-state temperature rise due to joule losses = 85 – 10 – 21,3 = 53,7 K

$\theta_R(6) = \theta a(6) = 18{,}1$ K (see Table F.3, column 6) for application of a step function of rated current.

Replace the existing equation for I_2 by the following new equation:

$$I_2 = 1\,550\left[0{,}771^2\,\frac{11{,}625}{12{,}612} + \frac{1\left[1 - 0{,}771^2\,\frac{11{,}625}{12{,}612}\right]}{\left(\frac{18{,}1}{53{,}7}\right)}\right]^{0{,}5} = 2\,131\text{ A} \qquad \text{(from equation (8-1))}$$

Figure 6

Replace, in the figure title, "$0.30 \le x \le 0.1$" *by* "$0{,}1 \le x \le 0{,}3$"