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Title: BS EN IEC 60287-3-2 Electric cables - Calculation of the current rating

Part 3-2: Sections on operating conditions - Economic optimization of power cable size

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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UK Vote

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



20/2151/CD

COMMITTEE DRAFT (CD)

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IEC TC 20 : ELECTRIC CABLES

SECRETARIAT:

Germany

SECRETARY:

Mr Walter Winkelbauer

OF INTEREST TO THE FOLLOWING COMMITTEES:

PROPOSED HORIZONTAL STANDARD:



Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.

FUNCTIONS CONCERNED:

☐ EMC

☐ ENVIRONMENT

☐ QUALITY ASSURANCE

☐ SAFETY

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TITLE:

Electric cables - Calculation of the current rating - Part 3-2: Sections on operating conditions - Economic optimization of power cable size

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**ELECTRIC CABLES –
CALCULATION OF THE CURRENT RATING –****Part 3-2: Sections on operating conditions –
Economic optimization of power cable size**

FOREWORD

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IEC 60287-3-2 has been prepared by IEC technical committee 20: Electric cables. It is an International Standard.

This third edition cancels and replaces the second edition published in 2012. This edition constitutes a technical revision.

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

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

Draft	Report on voting
20/XX/XXXX	20/XX/XXXX

55
56 Full information on the voting for its approval can be found in the report on voting indicated in
57 the above table.

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

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

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

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

- 68 • reconfirmed,
- 69 • withdrawn,
- 70 • replaced by a revised edition, or
- 71 • amended.

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INTRODUCTION

0.1 General part

The procedure generally used for the selection of a cable size leads to the minimum admissible cross-sectional area, which also minimizes the initial investment cost of the cable. It does not take into account the cost of the losses that will occur during the life of the cable.

The increasing financial and environmental cost of energy, together with the energy losses which follow from conductors operating at high temperatures, requires that cable size selection be considered on wider grounds. Rather than minimizing the initial cost only, the sum of the initial cost and the cost of the losses over the anticipated operational life of the system should be minimized. For this latter condition, a larger size of conductor than would be chosen based on minimum initial cost will lead to a lower power loss for the same current. This, when considered over its anticipated operational life, will reduce the energy losses and the total cost of the system. Where thermal consideration dictates the use of the largest practical conductor size, the installation of a second parallel cable circuit can result in a reduction in the total cost over the life of the installation.

The formulae and examples given in this standard are arranged to facilitate the calculation of the economic conductor size after factors such as system voltage, cable route, cable configuration and sheath bonding arrangements have been decided. Although these factors are not considered in detail, they have an impact on both the installation and operating costs of a cable system. The effect of changing any of the above factors on the total cost over the anticipated operational life of the system can be determined using the principles set out in this standard.

Future costs of energy losses during the anticipated operational life of the cable can be calculated by making suitable estimates of load growth and cost of energy. The most economical size of conductor is achieved when the sum of the future costs of energy losses and the initial cost of purchase and installation are minimized.

The saving in overall cost, when a conductor size larger than that determined by thermal constraints is chosen, is due to the considerable reduction in the cost of the joule losses compared with the increase in cost of purchase. For the values of the financial and electrical parameters used in this standard, which are not exceptional, the saving in the combined cost of purchase and operation is of the order of 50 % (see A.2.5). Calculations for much shorter financial periods can show a similar pattern.

A further important feature, which is demonstrated by examples, is that the savings possible are not critically dependent on the conductor size when it is in the region of the economic value, see Figure A.3. This has two implications:

- a) the impact of errors on financial data, particularly those which determine future costs, is small. While it is advantageous to seek data having the best practicable accuracy, considerable savings can be achieved using data based on reasonable estimates;
- b) other considerations with regard to the choice of conductor size which feature in the overall economics of an installation, such as fault currents, voltage drop and size rationalization, can all be given appropriate emphasis, without losing too many of the benefits arising from the choice of an economic size.

The formulae given in this standard are written for a.c. systems but they are equally applicable to d.c. systems. Clearly, for d.c. systems, the d.c. resistance is used in place of the a.c. resistance and the sheath and armour loss factors are set to zero.

0.2 Economic aspects

In order to combine the purchase and installation costs with costs of energy losses arising during the anticipated operational life of a cable, it is necessary to express them in comparable economic values, that is values which relate to the same point in time. It is convenient to use the date of purchase of the installation as this point and to refer to it as the "present". The "future" costs of the energy losses are then converted to their equivalent "present values". This is done by the process of discounting, the discounting rate being linked to the cost of borrowing money.

In the procedure given here, inflation has been omitted on the grounds that it will affect both the cost of borrowing money and the cost of energy. If these items are considered over the same period of time and the effect of inflation is approximately the same for both, the choice of an economic conductor size can be made satisfactorily without introducing the added complication of inflation.

To calculate the present value of the costs of the losses it is necessary to choose appropriate values for the future development of the load, annual increases in kWh price and annual discounting rates over the anticipated operational life of the cable, which could be 25 years or more. It is not possible to give guidance on these aspects in this standard because they are dependent on the conditions and financial constraints of individual installations. Only the appropriate formulae are given: it is the responsibility of the designer and the user to agree on the economic factors to be used.

The formulae proposed in this standard are straightforward, but in their application due regard should be taken of the assumption that the financial parameters are assumed to remain unchanged during the anticipated operational life of the cable. Nevertheless, the above comments on the effect of the accuracy of these parameters is also relevant here.

There are two approaches to the calculation of the economic size, based on the same financial concepts. The first, where a series of conductor sizes is being considered, is to calculate a range of economic currents for each of the conductor sizes envisaged for particular installation conditions and then to select that size whose economic range contains the required value of the load. This approach is appropriate where several similar installations are under consideration. The second method, which may be more suitable where only one installation is involved, is to calculate the optimum cross-sectional area for the required load and then to select the closest standard conductor size.

0.3 Other criteria

Other criteria, for example short-circuit current and its duration, voltage drop and cable size rationalization, should also be considered. However, a cable chosen to have an economical size of conductor may well be satisfactory also from these other points of view, so that when sizing a cable, the following sequence may be advantageous:

- a) calculate the economic cross-sectional area;
- b) check by the methods given in IEC 60287-1-1, in IEC 60287-2-1 and in the IEC 60853 series that the size indicated by a) is adequate to carry the maximum load expected to occur at the end of the economic period without its conductor temperature exceeding the maximum permitted value;
- c) check that the size of cable selected can safely withstand the prospective short-circuit and earth fault currents for the corresponding durations;
- d) check that the voltage drop at the end of the cable remains within acceptable limits;
- e) check against other criteria appropriate to the installation.

To complete the field of economic selection, proper weight should be given to the consequences of interruption of supply. It may be necessary to use a larger cross-section of

169 conductor than the normal load conditions require and/or the economic choice would suggest,
170 or to adapt the network accordingly.

171 A further cost component may be recognized in the financial consequence of making a faulty
172 decision weighted by its probability. However, in doing so one enters the field of decision
173 theory which is outside the scope of this standard.

174 Thus, economic cable sizing is only a part of the total economic consideration of a system and
175 may give way to other important economic factors.

176 **0.4 Environmental impact**

177 When determining optimum size for a given circuit, consideration should also be given to
178 environmental impact. Based on the projected life of a circuit, the environmental impact of
179 operational losses may well outweigh all other impacts in the life cycle and may justify a
180 larger conductor size than that determined by economic factors alone. Further guidance can
181 be found in IEC 62125.

182

ELECTRIC CABLES – CALCULATION OF THE CURRENT RATING –

Part 3-2: Sections on operating conditions – Economic optimization of power cable size

1 Scope

This part of IEC 60287 sets out a method for the selection of a cable size taking into account the initial investments and the future costs of energy losses during the anticipated operational life of the cable.

Matters such as maintenance, energy losses in forced cooling systems and time of day energy costs have not been included in this standard.

Two examples of the application of the method to hypothetical supply systems are given in Annex A.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60228, *Conductors of insulated cables*

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 60853 (all parts), *Calculation of the cyclic and emergency current rating of cables*

3 Symbols

The symbols used in this standard and the quantities which they represent are given in the following list:

ΔI_a	annual increase in $I_{\max}$	%
C_{AL}	constant component of cost per unit length related to laying conditions, etc.	cu/m
C_{AS}	variable component of cost per unit length related to conductor size	cu/(m·mm ²)
b	annual increase in C_w , not covered by inflation	%
C_{B2}	auxiliary quantity defined by Formula (16)	–
$\Delta LLLF$	annual increase in loss load factor	%
C	capacitance per core	F/m

CI	installed cost of the length of cable being considered	cu
$CI(A_c)$	installed cost of a cable as a function of its cross-sectional area	cu
CI_1	installed cost of the next smaller standard size of conductor	cu
CI_2	installed cost of the next larger standard size of conductor	cu
CJ	present value of the cost of joule losses during N_y years	cu
CT	total cost of a system	cu
D	demand charge each year	cu/(W·year)
d_c	diameter of conductor, including screen, if any	mm
D_i	diameter over insulation	mm
f	system frequency	Hz
C_{F1}	auxiliary quantity defined by Formula (10)	cu/W
C_{F2}	auxiliary quantity defined by Formula (27)	–
g	factor used in calculation of charging current losses	–
i	discounting rate used to compute present values	%
$I(t)$	load as a function of time	A
I_c	charging current per unit length	A/m
$I_{\max}$	maximum load in first year i.e. the highest hourly mean value	A
L_c	cable length	m
N_y	period covered by financial calculations, also referred to as "anticipated operational life"	year
N_c	number of circuits carrying the same type and value of load	–
N_p	number of phase conductors per circuit	–
N_s	number of earthed sections in a single-core cable system	–
C_W	cost of one watt-hour at relevant voltage level	cu/(W·h)
C_{Q1}	auxiliary quantity defined by Formula (8)	–
Q_v	auxiliary quantity defined by Formula (28)	–
r	auxiliary quantity defined by Formula (9)	–
r_v	auxiliary quantity defined by Formula (29)	–
R_{AV}	a.c. resistance of conductor per unit length (considered to be a constant value at an average operating temperature, see Clause 4)	Ω/m
R_L	cable a.c. resistance per unit length, including the effect of λ_1 and λ_2 , $R_L = R_{AV} (1 + \lambda_1 \text{ and } \lambda_2)$	Ω/m
$R_L(A_c)$	a.c. resistance per unit length of a conductor as a function of its area, including the effect of λ_1 and λ_2	Ω/m
R_{L1}	a.c. resistance per unit length of next smaller standard conductor size, including the effect of λ_1 and λ_2	Ω/m
R_{L2}	a.c. resistance per unit length of next larger standard conductor size, including the effect of λ_1 and λ_2	Ω/m
R_s	a.c. resistance of sheath, or screen, per unit length	Ω/m

(considered to be a constant value at an average operating temperature)

A_c	cross-sectional area of a cable conductor	mm ²
S_{ec}	economic conductor size	mm ²
t	time	h
t_0	operating time at maximum joule loss	h/year
T_t	equivalent operating time at maximum loss, including dielectric loss	h/year
U_0	voltage between conductor and screen or sheath	V
W_{chc}	losses due to charging current in conductors	W
W_{chs}	losses due to charging current flowing in screen/armour	W
W_d	dielectric losses per unit length per phase	W/m
Y_p	proximity effect factor, see IEC 60287-1-1	–
Y_s	skin effect factor, see IEC 60287-1-1	–
α_{20}	temperature coefficient of conductor resistance at 20 °C	1/K
β	reciprocal of the temperature coefficient of resistivity of the conductor material at 0 °C. For aluminium $\beta = 228$, for copper $\beta = 234,5$	K
$\tan \delta$	loss factor of insulation	–
ε	is the relative permittivity of insulation	–
λ_1, λ_2	sheath and armour loss factors, see IEC 60287-1-1	–
LLF	loss load factor, see the IEC 60853 series	–
ρ_{20}	conductor resistivity at 20 °C, see 5.2	$\Omega \cdot m$
θ	maximum rated conductor operating temperature	°C
θ_a	ambient average temperature	°C
θ_u	mean operating conductor temperature	°C

213 The unit cu is an arbitrary currency unit.

214 4 Calculation of total costs

215 The total cost of installing and operating a cable during its anticipated operational life,
216 expressed in present values, is calculated as follows. Note that all financial quantities are
217 expressed in arbitrary currency units, (cu).

$$218 \qquad \qquad \qquad \text{The total cost} = CT = CI + CJ \text{ (cu)} \qquad \qquad \qquad (1)$$

219 where

220 CI is the cost of the installed length of cable, in cu;

221 CJ is the equivalent cost at the date the installation was purchased, i.e. the present value,
222 of the joule losses during an anticipated operational life of N_y years, in cu.

223 Evaluation of CJ

224 The total cost due to the losses is composed of two parts: a) the energy charge, and b) the
225 charge for the additional supply capacity to provide the losses.

226 a) Cost due to energy charge