

# Electric cables — Calculation of the current rating —

**Part 1-3: Current rating equations  
(100 % load factor) and calculation of  
losses — Current sharing between  
parallel single-core cables and  
calculation of circulating current losses**

ICS 29.060.20

# National foreword

This British Standard reproduces verbatim IEC 60287-1-3:2002 and implements it as the UK national standard.

The UK participation in its preparation was entrusted by Technical Committee GEL/20, Electric cables, to Subcommittee GEL/20/16, MV/HV cables, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

## Cross-references

The British Standards which implement international publications referred to in this document may be found in the *BSI Catalogue* under the section entitled “International Standards Correspondence Index”, or by using the “Search” facility of the *BSI Electronic Catalogue* or of British Standards Online.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

**Compliance with a British Standard does not of itself confer immunity from legal obligations.**

## Summary of pages

This document comprises a front cover, an inside front cover, the IEC title page, pages 2 to 20, an inside back cover and a back cover

The BSI copyright notice displayed in this document indicates when the document was last issued.

## Amendments issued since publication

| Amd. No. | Date | Comments |
|----------|------|----------|
|          |      |          |
|          |      |          |
|          |      |          |
|          |      |          |

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 15 October 2003

© BSI 15 October 2003

**NORME  
INTERNATIONALE  
INTERNATIONAL  
STANDARD**

**CEI  
IEC**

**60287-1-3**

Première édition  
First edition  
2002-05

---

---

**Câbles électriques –  
Calcul du courant admissible –**

**Partie 1-3:  
Equations de l'intensité du courant admissible  
(facteur de charge 100 %) et calcul des pertes –  
Répartition du courant entre des câbles unipolaires  
disposés en parallèle et calcul des pertes  
par courant de circulation**

**Electric cables –  
Calculation of the current rating –**

**Part 1-3:  
Current rating equations (100 % load factor)  
and calculation of losses –  
Current sharing between parallel single-core cables  
and calculation of circulating current losses**



Numéro de référence  
Reference number  
CEI/IEC 60287-1-3:2002

CONTENTS

FOREWORD.....3

INTRODUCTION.....4

1 Scope .....5

2 Normative references.....5

3 Symbols.....5

4 Description of method .....6

4.1 General .....6

4.2 Outline of method .....7

4.3 Matrix solution .....10

Annex A (informative) Example calculations .....11

Annex B (informative) Example of the computation of the coefficient  $\alpha$  for hollow core conductors ... 19

Bibliography .....20

Figure B.1 . Representation of a hollow core conductor .....19

Table 1 . Values of  $\alpha$  for conductors .....9

Table A.1 . Calculated values of  $d_{j,k}$  .....15

Table A.2 . Calculated values of  $zz$ ..... 15

Table A.3 . Array  $[Z]$  including coefficients for currents..... 16

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

---

**ELECTRIC CABLES –  
CALCULATION OF THE CURRENT RATING –**
**Part 1-3: Current rating equations (100 % load factor)  
and calculation of losses –  
Current sharing between parallel single-core cables  
and calculation of circulating current losses**

## FOREWORD

- 1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.
- 3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
- 4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
- 5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.
- 6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60287-1-3 has been prepared by IEC technical committee 20: Electric cables.

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

| FDIS        | Report on voting |
|-------------|------------------|
| 20/522/FDIS | 20/535/RVD       |

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annexes A and B are for information only.

The committee has decided that this publication remains valid until 2008. At this date, in accordance with the committee's decision, the publication will be

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

## INTRODUCTION

When single-core cables are installed in parallel the load current may not share equally between the parallel cables. The circulating currents in the sheaths of the parallel cables will also differ. This is because a significant proportion of the impedance of large conductors is due to self reactance and mutual reactance. Hence the spacing and relative location of each cable will have an effect on the current sharing and the circulating currents. The currents are also affected by phase rotation. The method described in this standard can be used to calculate the current sharing between conductors as well as the circulating current losses.

There is no simple rule by which the circulating current losses of parallel cables can be estimated. Calculation for each cable configuration is necessary. The principles and impedance formulae involved are straightforward but the difficulty arises in solving the large number of simultaneous equations generated. The number of equations to be solved generally precludes the use of manual calculations and solution by computer is recommended. For  $n$  cables per phase having metallic sheaths in a three-phase system there are six  $n$  equations containing the same number of complex variables.

For simplicity the equations set out in this standard assume that the parallel conductors all have the same cross-sectional area. If this is not the case, the equations may be adapted to allow for different resistances for each conductor. The effect of neutral and earth conductors can also be calculated by including these conductors in the appropriate loops. The method set out in this standard does not take account of any portion of the sheath circulating currents that may flow through the earth or other extraneous paths.

The conductor currents and sheath circulating currents in parallel single-core cables are unlikely to be equal. Because of this, the external thermal resistance for buried parallel cables should be calculated using the method set out in 3.1 of IEC 60287-2-1. Because the external thermal resistance and sheath temperatures are functions of the power dissipation from each cable in the group it is necessary to adopt an iterative procedure to determine the circulating current losses and the external thermal resistance.

## ELECTRIC CABLES – CALCULATION OF THE CURRENT RATING –

### Part 1-3: Current rating equations (100 % load factor) and calculation of losses – Current sharing between parallel single-core cables and calculation of circulating current losses

## 1 Scope

This part of IEC 60287 provides a method for calculating the phase currents and circulating current losses in single-core cables arranged in parallel.

The method described in this standard can be used for any number of cables per phase in parallel in any physical layout. The phase currents can be calculated for any arrangement of sheath bonding. For the calculation of sheath losses, it is assumed that the sheaths are bonded at both ends. A method for calculating sheath eddy current losses in two circuits in flat formation is given in IEC 60287-1-2.

## 2 Normative references

The following referenced documents are indispensable for the application 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 60287-1-2:1993, *Electric cables – Calculation of the current rating – Part 1: Current rating equations (100 % load factor) and calculation of losses – Section 2: Sheath eddy current loss factors for two circuits in flat formation*

IEC 60287-2-1:1994, *Electric cables – Calculation of the current rating – Part 2: Thermal resistance – Section 1: Calculation of thermal resistance*

## 3 Symbols

|          |                                                    |
|----------|----------------------------------------------------|
| $d_c$    | diameter of the conductor, mm                      |
| $d_s$    | mean diameter of the sheath, mm                    |
| $f$      | frequency, Hz                                      |
| $i, k$   | elements in the series of conductors               |
| $m, n$   | elements in the series of cables                   |
| $p$      | number of cables per phase                         |
| $D_{mn}$ | axial spacing between conductors, mm               |
| $I_p$    | current in the conductor of cable $p$ , A          |
| $I_{sp}$ | circulating current in the sheath of cable $p$ , A |
| $R$      | resistance of a conducting element, $\Omega/m$     |

|              |                                                                                  |
|--------------|----------------------------------------------------------------------------------|
| $R_c$        | a.c. resistance of conductor at maximum operating temperature, $\Omega/\text{m}$ |
| $R_s$        | resistance of sheath at operating temperature, $\Omega/\text{m}$                 |
| $X_{i,k}$    | apparent mutual reactance of a pair of conductors                                |
| $\Delta V$   | conductor voltage drop                                                           |
| $\alpha$     | coefficient depending on the construction of the conductor                       |
| $\lambda'_p$ | sheath loss factor of cable p due to circulating currents                        |
| $\omega$     | angular frequency of system ( $2\pi f$ ), $\text{s}^{-1}$                        |

## 4 Description of method

### 4.1 General

The method calculates the proportion of the phase current carried by each parallel conductor and the circulating current in the sheath of each cable. The loss factor ( $\lambda$ ) for each case is then calculated as the ratio of the losses in a sheath caused by circulating currents to the losses in the conductor of that cable.

The method of calculation set out below only considers voltage drop along the conductors. Any unbalance in the load which would lead to unbalanced phase currents is ignored.

The equations to be solved for the unknown currents in the parallel conductors and their sheaths are built up from a consideration of the basic formulae for the impedance associated with a loop consisting of two long conductors lying parallel to each other and the formulae for the mutual impedance between a loop and an adjacent conductor. Consideration of these equations leads to a system of simultaneous equations for the impedance voltage for all the conductors and sheaths in a three-phase parallel cable system. The impedance voltages for all conductors in parallel in the same phase are equal. Also for the conductors representing the bonded sheaths the voltages are equal. Hence the impedance voltages can be eliminated from the equations. The sum of the currents in the parallel conductors is equal to either the known phase current or zero for the sheaths. This provides the additional information needed for solution of the simultaneous equations.

It should be noted that all the currents are complex quantities containing both real and imaginary parts.

The mutual impedance between conductors is a function of their relative positions. Hence, if the relative positions of the cables vary along the route, or the sheaths are cross-bonded, then the impedance for each section shall be calculated individually and the vector results summed in order to obtain the total impedance of each loop. If the route length is very short, then significant errors may occur in the calculated result due to the change in the relative positions of the cables as they approach the terminations.

The equations set out in this standard can also be used to calculate the current sharing between cables without a metallic sheath or armour and between cables with the sheaths connected together at one end only, single-point bonded. For such calculations, the circulating current in each sheath is zero. Where cable sheaths are bonded at one end only, the standing voltage at the open circuit end of the sheath can also be determined using this method of calculation.

For the method set out in this standard, it is recommended that the solution of the equations is achieved by a process of matrix algebra. This has the advantage that the solution achieved is unique and not a function of an iterative process.