IEC TR 61597

Edition 2.0 2021-06

TECHNICAL REPORT

Overhead electrical conductors – Calculation methods for stranded bare conductors

IEC TR 61597:2021-06(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC online collection - oc.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 18 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC

IEC TR 61597

Edition 2.0 2021-06

TECHNICAL REPORT

Overhead electrical conductors – Calculation methods for stranded bare conductors

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.240.20 ISBN 978-2-8322-9938-8

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

OVERHEAD ELECTRICAL CONDUCTORS – CALCULATION METHODS FOR STRANDED BARE CONDUCTORS

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of 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, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). 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. 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 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 IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TR 61597 has been prepared by IEC technical committee 7: Overhead electrical conductors. It is a Technical Report.

This second edition cancels and replaces the first edition published in 1995. This edition constitutes a technical revision.

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

a) Addition of Clause 2 and Clause 3 since the "Normative references" and "Terms and definitions" clauses are mandatory elements of the text according to the new IEC template.
b) In Clause 6, addition of new kinds of aluminium alloy and aluminium clad steel and their values of temperature coefficients of resistance.
c) In Clause 6, addition of guidelines for the calculation of AC resistance taken into account hysteresis and eddy current losses.

d) In Clause 7, addition of the values of coefficient of linear expansion of aluminium alloy conductor aluminium-clad steel reinforced series.

e) Deletion of Clause 8 "Calculation of maximum conductor length on drums" in the last version.

f) Annex A, replaced by "A practical example of CCC calculation".

g) Annex B, replaced by "Indicative conditions for CCC calculation".

The text of this Technical Report is based on the following documents:

Draft	Report on voting
7/704/DTR	7/707/RVDTR

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 Technical Report 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/standardsdev/publications.

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.

OVERHEAD ELECTRICAL CONDUCTORS – CALCULATION METHODS FOR STRANDED BARE CONDUCTORS

1 Scope

This document, which is a Technical Report, provides information with regard to conductors specified in IEC 61089 and other aluminium and aluminium steel conductors. Such information includes properties of conductors and useful methods of calculation. The following chapters are included in this document.

– current carrying capacity of conductors: Calculation method and typical example
– alternating current resistance, inductive and capacitive reactances
– elongation of conductors: Thermal and stress-strain data
– conductor creep
– loss of strength of aluminium wires due to high temperatures

It is noted that this document does not discuss all theories and available methods for calculating conductor properties, but provides users with simple methods that provide acceptable accuracies.

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 TR 60943:1998, *Guidance concerning the permissible temperature rise for parts of electrical equipment, in particular for terminals*
IEC TR 60943:1998/AMD1:2008

IEC 61089:1991, *Round wire concentric lay overhead electrical stranded conductors*
IEC 61089:1991/AMD1:1997

IEC 60104:1987, *Aluminium-magnesium-silicon alloy wire for overhead line conductors*

IEC 60889:1987, *Hard-drawn aluminium wire for overhead line conductors*

IEC 61232:1993, *Aluminium-clad steel wires for electrical purposes*

IEC 61395:1998, *Overhead electrical conductors – Creep test procedures for stranded conductors*

IEC 62004:2007, *Thermal-resistant aluminium alloy wire for overhead line conductor*

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological 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

4 Symbols, units and abbreviated terms

4.1 Symbols and units

A cross-sectional area of the conductor (mm^2)

A_a cross-sectional area of aluminium wires (mm^2)

A_s cross-sectional area of steel wires (mm^2)

D conductor diameter (m)

E modulus of elasticity of complete conductor (MPa)

E_a modulus of elasticity of aluminium wires(MPa)

E_s modulus of elasticity of steel wires(MPa)

f frequency (Hz)

F tensile force in the complete conductor (kN)

F_a tensile force in the aluminium wires

F_s tensile force in steel wires

I conductor current (A)

K_1 relative rigidity of steel to aluminium wires

K_c creep coefficient

K_e emissivity coefficient in respect to black body

K_g layer factor

Nu Nusselt number

P_{conv} convection heat loss (W/m)

P_j Joule losses (W/m)

P_{rad} radiation heat loss (W/m)

P_{sol} solar radiation heat gain (W/m)

r conductor radius (m)

R_e Reynolds number

R_T electrical resistance of conductor at a temperature T (Ω/m)

s Stefan-Boltzmann constant ($5,67 \times 10^{-8}$ $W \cdot m^{-2} \cdot K^{-4}$)

S_i intensity of solar radiation (W/m^2)

t time (h)

T temperature (K)

T_1 ambient temperature (K)

T_2 final equilibrium temperature (K)

v wind speed in m/s

X_c capacitive reactance, calculated for 0,3 m spacing (MΩ • km)

X_i inductive reactance calculated for a radius of 0,3 m (Ω/km)

α temperature coefficient of electrical resistance (K^{-1})

α_a ratio of aluminium area to total conductor area

α_s ratio of steel area to total conductor area

β coefficient of linear expansion of conductor in K^{-1}

β_a	coefficient of linear expansion for aluminium in K^{-1}
β_s	coefficient of linear expansion for steel in K^{-1}
Δx	general expression used to express the increment of variable *x*
ε	general expression of strain (unit elongation)
ε_a	elastic strain of aluminium wires
ε_c	creep and settlement strain of conductor
ε_s	elastic strain of steel wires
ε_T	thermal strain of conductor
Φ	coefficient for temperature (*T*) dependence in creep calculations
γ	solar radiation absorption coefficient
λ	thermal conductivity of air film in contact with the conductor ($W \cdot m^{-1} \cdot K^{-1}$)
μ	coefficient for time (*t*) dependence in creep calculations
σ	stress (MPa)
Ψ	coefficient for stress (σ) dependence in creep calculations

4.2 Abbreviated terms

CCC current carrying capacity (A)

GMR geometric mean radius of the conductor (m)

5 Current carrying capacity

5.1 General

The current carrying capacity (CCC) of a conductor is the maximum steady-state current inducing a given temperature rise in the conductor, for given ambient conditions.

The CCC depends on the type of conductor, its electrical resistance, the maximum allowable temperature rise and the ambient conditions.

5.2 Heat balance equation

The steady-state temperature rise of a conductor is reached whenever the heat gained by the conductor from various sources is equal to the heat losses. This is expressed by equation (1):

$$P_j + P_{\mathrm{sol}} = P_{\mathrm{rad}} + P_{\mathrm{conv}} \quad (1)$$

where

P_{j}	is the heat generated by Joule effect
P_{sol}	is the solar heat gain by the conductor surface
P_{rad}	is the heat loss by radiation of the conductor
P_{conv}	is the convection heat loss

Note that magnetic heat gain (see 6.1, 6.2 and 6.3), corona heat gain, or evaporative heat loss are not taken into account in equation (1).

5.3 Calculation method

In the technical literature there are many methods of calculating each component of equation (1). However, for steady-state conditions, there is reasonable agreement between the available methods and they all lead to current carrying capacities within approximately 10 % for classical conductor in operational conditions (for example, conductor temperature below 100 ℃).

NOTE Various methods were compared to IEC 60943, IEEE, practices in Germany, Japan, France, etc.

IEC TR 60943 provides a detailed and general method to compute temperature rise in electrical equipment. This method is used for calculating the current carrying capacity of conductors included in this document.

NOTE CIGRE has published a detailed method for calculating CCC in CIGRE TB 601 [4][1].

5.4 Joule effect

Power losses P_j (W/m), due to Joule effect are given by equation (2):

$$P_j = R_T \cdot I^2 \quad (2)$$

where

R_T is the electrical resistance of conductor at a temperature T (Ω/m)

I is the conductor current (A), AC or DC

5.5 Solar heat gain

Solar heat gain, P_{sol} (W/m), is given by equation (3):

$$P_{sol} = \gamma \cdot D \cdot S_i \quad (3)$$

where

γ is the solar radiation absorption coefficient

D is the conductor diameter (m)

S_i is the intensity of solar radiation (W/m²)

5.6 Radiated heat loss

Heat loss by radiation, P_{rad} (W/m), is given by equation (4):

$$P_{rad} = s \cdot \pi \cdot D \cdot K_e \cdot (T_2^4 - T_1^4) \quad (4)$$

where

s is the Stefan-Boltzmann constant (5,67x10^{-8} W·m^{-2}·K^{-4})

D is the conductor diameter (m)

K_e is the emissivity coefficient in respect to black body

T_1 ambient temperature (K)

---

[1] Numbers in square brackets refer to the bibliography.

T_2 final equilibrium temperature (K)

5.7 Convection heat loss

Only forced convection heat loss, P_{conv} (W), is taken into account and is given by equation (5):

$$P_{\text{conv}} = \lambda Nu(T_2 - T_1)\pi \quad (5)$$

where

λ is the thermal conductivity of the air film in contact with the conductor. If assumed constant, it is equal to: 0,0258 5 W × m^{-1} × K^{-1}. If assumed variable, such equations can be found in [4].

Nu is the Nusselt number, given by equation (6):

$$Nu = 0.65\, Re^{0.2} + 0.23\, Re^{0.61} \quad (6)$$

Another expression of the Nusselt Number could be used and found in [4].

R_e is the Reynolds number given by equation (7):

$$Re = 1{,}644 \times 10^9 v \cdot D \cdot [T_1 + 0.5(T_2 - T_1)]^{-1.78} \quad (7)$$

v is the wind speed in m/s

D is the conductor diameter (m)

T is the temperature (K)

- T_1 ambient temperature (K)
- T_2 final equilibrium temperature (K)

5.8 Method to calculate current carrying capacity (CCC)

From equation (1) the maximum permissible steady-state current carrying capacity can be calculated:

$$I_{\max} = [(P_{\text{rad}} + P_{\text{conv}} - P_{\text{sol}})/R_T]^{1/2} \quad (8)$$

where

R_T is the electrical resistance of conductor at a temperature *T* (Ω/m)

P_{sol}, P_{rad} and P_{conv} are calculated from equations (3), (4), and (5).

5.9 Determination of the maximum permissible aluminium temperature

The maximum permissible aluminium temperature is determined either from the economical optimization of losses or from the maximum admissible loss of tensile strength in aluminium.

In all cases, appropriate clearances under maximum temperature have to be checked and maintained.

If needed, the equation of core temperature versus surface temperature can be found in [4].