

Short-circuit currents in DC auxiliary installations in power plants and substations —

Part 2: Calculation of effects

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ICS 29.240.01

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 36 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Amendments issued since publication

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Contents

	Page
National foreword	Inside front cover
Foreword	2
Text of EN 61660-2	5

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English version

Short-circuit currents in d.c. auxiliary installations
in power plants and substations
Part 2: Calculation of effects

(IEC 61660-2:1997)

Courants de court-circuit dans les
installations auxiliaires alimentées
en courant continu dans les centrales
et les postes
Partie 2: Calcul des effets
(CEI 61660-2:1997)

Kuzschlußströme in
Gleichstrom-Eigenbedarfsanlagen
in Kraftwerken und Schaltanlagen
Teil 2: Berechnung der Wirkungen
(IEC 61660-2:1997)

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Foreword

The text of document 73/85/FDIS, future edition 1 of IEC 61660-2, prepared by IEC TC 73, Short-circuit currents, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61660-2 on 1997-07-01.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1998-04-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 1998-04-01

Annexes designated “normative” are part of the body of the standard.

Annexes designated “informative” are given for information only.

In this standard, Annex ZA is normative and Annex A and Annex B are informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61660-2:1997 was approved by CENELEC as a European Standard without any modification.

Contents

		Page		Page
Foreword		2	Table 1 — Effective distance a_s between subconductors in metres, for rectangular cross-section dimensions	18
1 General		5	Table 2 — Maximum possible values of V_σ , $V_{\sigma s}$ and V_F	19
1.1 Scope		5	Table 3 — Factors α , β and γ for different busbar support arrangements	19
1.2 Normative references		5	Table 4 — Factor q	20
1.3 Symbols and units		5	Table 5 — Section moduli Z of main conductors with two or more stiffening elements between two adjacent supports	20
1.4 Definitions		8	Table 6 — Recommended highest temperatures for mechanically stressed conductors during a short circuit	21
2 Electromagnetic effect on rigid conductors		9		
2.1 General		9		
2.2 Calculation of electromagnetic forces		10		
2.3 Calculation of stresses in rigid conductors and forces on supports		11		
2.4 Design load for post insulators, their supports and connectors		16		
3 Thermal effect on bare conductors and electrical equipment		16		
3.1 General		16		
3.2 Calculation of temperature rise		16		
Annex A (informative) Equations for calculations of diagrams		31		
Annex B (informative) Bibliography		35		
Annex ZA (normative) Normative references to international publications with their corresponding European publications		36		
Figure 1 — Factor k_{1s} for calculating the effective conductor distance		21		
Figure 2 — Loading direction and bending axis for multiple conductor arrangements		22		
Figure 3 — Factor c for the influence of connecting pieces in equation (16)		23		
Figure 4 — Standard approximation function for the current defined and substitute rectangular function		24		
Figure 5 — Factors $m_{\theta 1}$ and $m_{\theta 2}$		25		
Figure 6 — Factors m_{g1} and m_{g2}		26		
Figure 7 — Factors m_{lg1} and m_{lg2}		27		
Figure 8 — Parameters of the rectangular substitute function for the squared current as a result of an exponentially rising current		28		
Figure 9 — Factors V_F , V_σ and $V_{\sigma s}$ for calculation of dynamic insulator forces and conductor stresses		29		
Figure 10 — Relation between rated short-time withstand current density ($T_{kr} = 1$ s) and conductor temperature		30		

1 General

1.1 Scope

This part of IEC 61660 describes a method for calculation of the mechanical and thermal effects on rigid conductors caused by short-circuit currents in d.c. auxiliary installations in power plants and substations. Such systems may contain the following items of equipment which act as sources, as well as contributing to the short-circuit currents:

- rectifiers in three-phase a.c. bridge connection for 50 Hz;
- stationary lead-acid batteries;
- smoothing capacitors;
- d.c. motors with independent excitation.

This standard provides a method which has wide application, and which gives results of sufficient accuracy. The calculation method is based on substitute functions, which cause approximately the same maximum stresses in the conductors and the same forces on the supports as the actual electromagnetic force.

The standardized calculation procedures of clauses 2 and 3 are applicable for the electromagnetic effect on rigid conductors and the thermal effect on bare conductors and electrical equipment, respectively.

For cables and insulated conductors, however, reference is made to IEC 60949 and IEC 60986, for example. Only d.c. auxiliary installations in power plants and substations are dealt with in this standard.

In particular, the following points should be noted:

- The calculation of short-circuit currents should be based on IEC 61660-1.
- Short-circuit duration used in this standard depends on the protection concept, and should be considered in that sense.
- These standardized procedures are adjusted to practical requirements, and contain simplifications with safety margins. Testing or more detailed methods of calculation or both may be used.
- In clause 2 of this standard, only the stresses caused by short-circuit currents are calculated. Furthermore, other stresses can exist, such as those caused by dead-load, operating forces, or earthquakes. The combination of these loads with the short-circuit loading should be part of an agreement and/or given by standards, for example erection codes.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text constitute provisions of this part of IEC 61660. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 61660 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60865-1:1993, *Short-circuit currents — Calculation of effects — Part 1: Definitions and calculation methods*.

IEC 60865-2:1994, *Short-circuit currents — Calculation of effects — Part 2: Examples of calculation*.

IEC 60949:1988, *Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects*.

IEC 60986:1989, *Guide to the short-circuit temperature limits of electric cables with a rated voltage from 1,8/3 (3,6) kV to 18/30 (36) kV*.

IEC 61660-1:1997, *Short-circuit currents in d.c. auxiliary installations in power plants and substations — Part 1: Calculation of short-circuit currents*.

1.3 Symbols and units

All equations used in this standard are quantity equations in which quantity symbols represent physical quantities possessing both numerical values and dimensions.

The symbols used in this standard and their exemplary SI units are given in the following lists.

1.3.1 Symbols for clause 2: electromagnetic effects

A_i	Impulse for determining the parameters of the substitute rectangular function	A^2s
A_s	Cross-section of one subconductor	m^2
a	Centre line distance between conductors	m
a_m	Effective distance between neighbouring main conductors	m
a_s	Effective distance between subconductors	m
a_{1n}	Centre line distance between subconductor 1 and subconductor n	m
a_{1s}	Centre line distance between subconductors	m
b	Dimension of a subconductor perpendicular to the direction of the force	m
b_m	Dimension of a main conductor perpendicular to the direction of the force	m
c	Factor for the influence of connecting pieces	1
D	Outer diameter of tubular conductor	m
d	Dimension of a subconductor in the direction of the force	m
d_m	Dimension of a main conductor in the direction of the force	m
E	Young's modulus	N/m^2
F	Force acting between two, parallel, long conductors during a short circuit	N
F_R	Force between main conductors caused by the substitute rectangular function	N
F_{Rs}	Force between subconductors caused by the substitute rectangular function	N
F_d	Force on support (peak value)	N
F_m	Force between main conductors during a short circuit (peak value)	N
F_s	Force between subconductors during a short circuit	N
f_c	Relevant natural frequency of a main conductor	Hz
f_{cs}	Relevant natural frequency of a subconductor	Hz
g_n	Value of acceleration of gravity	m/s^2
I_g	Value for determining of the parameters of the substitute rectangular function	A^2s^3
I_R	Current of the substitute rectangular function for the calculation of the force between main conductors	A
I_{Rs}	Current of the substitute rectangular function for the calculation of the force between subconductors	A
I_k	Quasi steady-state short-circuit current	A
i_p	Peak short-circuit current	A
i_1, i_2	Instantaneous values of current in conductors in the sections of the standard approximation function	A
i_{L1}, i_{L2}	Instantaneous values of currents in the conductors L1 and L2	A
J	Second moment of main conductor area	m^4
J_s	Second moment of subconductor area	m^4
k	Number of sets of spacers or stiffening elements	1
k_{1n}	Factor for effective conductor distance between subconductor 1 and subconductor n	1
k_{1s}	Factor for effective conductor distance	1
l	Centre line distance between supports	m
l_s	Centre line distance between connecting pieces	m
m'	Mass per unit length of main conductor	kg/m

m'_s	Mass per unit length of subconductor	kg/m
m_z	Total mass of one set of connecting pieces	kg
$m_{g1}, m_{g2},$ $m_{lg1}, m_{lg2},$ $m_{\theta1}, m_{\theta2}$	Factors for determining the parameters of the substitute rectangular function	1
n	Number of subconductors of a main conductor	1
p	Ratio I_k/i_p	1
q	Factor of plasticity	1
$R_{p0.2}$	Stress corresponding to the yield point	N/m ²
s	Wall thickness of tubes	m
T_k	Short-circuit duration	s
T_{me}	Vibration period of the main conductor	s
T_{mes}	Vibration period of the subconductor	s
t_p	Time to peak	s
t_R	Time of substitute rectangular function for the calculation of the force between main conductors	s
t_{Rs}	Time of the substitute rectangular function for the calculation of the force between subconductors	s
V_F	Ratio of dynamic and static force on supports	1
V_σ	Ratio of dynamic and static main conductor stress	1
$V_{\sigma s}$	Ratio of dynamic and static subconductor stress	1
Z	Section modulus of main conductor	m ³
Z_s	Section modulus of subconductor	m ³
α	Factor for force on support	1
β	Factor for main conductor stress	1
γ	Factor for relevant natural frequency estimation	1
μ_0	Magnetic constant, permeability of vacuum	H/m
σ_m	Bending stress caused by the forces between main conductors	N/m ²
σ_s	Bending stress caused by the forces between subconductors	N/m ²
σ_{tot}	Resulting conductor stress	N/m ²
τ_1	Rise-time constant	s
τ_2	Decay-time constant	s

1.3.2 Symbols for clause 3: Thermal effects

A	Main conductor cross-section	m ²
A_i	Impulse for determining of the parameters of the substitute rectangular function	A ² s
I_{th}	Thermal equivalent short-time current (r.m.s.)	A
I_{thr}	Rated short-time withstand current (r.m.s.)	A
K	Factor for calculating S_{thr}	As ^{0.5} /m ²
S_{th}	Thermal equivalent short-time current density (r.m.s.)	A/m ²
S_{thr}	Rated short-time withstand current density (r.m.s.)	A/m ²
T_k	Short-circuit duration	s
T_{kr}	Rated short-time	s

t_p	Time to peak	s
θ_b	Conductor temperature at the beginning of the short circuit	°C
θ_e	Conductor temperature at the end of the short circuit	°C

1.4 Definitions

For the purpose of this part of IEC 61660, the following definitions apply.

1.4.1 Definitions for clause 2: electromagnetic effects

1.4.1.1

main conductor

a conductor, or an arrangement composed of a number of conductors, which carries the total current

1.4.1.2

subconductor

a single conductor which carries a certain part of the total current and is a part of the main conductor

1.4.1.3

fixed support

a support of a conductor which does not permit the conductor to move angularly at the point of the support

1.4.1.4

simple support

a support of a conductor which permits angular movement at the point of support

1.4.1.5 connecting piece

any additional mass within a span which does not belong to the uniform conductor material. This includes among others: spacers, stiffening elements, bar overlappings, branchings, etc.

1.4.1.5.1

spacer

a mechanical element between subconductors which, at the point of installation, maintains the clearance between subconductors

1.4.1.5.2

stiffening element

a special spacer intended to reduce the mechanical stress

1.4.1.6

short-circuit duration, T_k

the time interval between the initiation of the short circuit and the breaking of the current

1.4.1.7

standard approximation function

a curve, calculated according to IEC 61660-1, describing the momentary value of the short-circuit current, including the value of rise-time constant τ_1 , decay-time constant τ_2 , duration of the short-circuit current flow T_k and the time to peak t_p

NOTE For further information, see IEC 61660-1.

1.4.1.8

squared standard approximation function

a curve representing the momentary value of the square of the standard approximation function. It represents the form of the momentary value of the electromagnetic force caused by the short-circuit current as well as the envelope for the Joule integral

NOTE For further information, see [1]¹⁾, in which Figure 8 also represents $i^2(t)$ multiplied by the factor $\frac{\mu_0}{2\pi a}$ giving $F'(t)$.

¹⁾ Figures in square brackets refer to the bibliography given in Annex B.

1.4.1.9**substitute rectangular function**

a function with rectangular form representing a current that causes the same mechanical stresses and forces as the squared standard approximation function

NOTE For further information, see [1] in which Figure 8 also represents I_R^2 multiplied by the factor $\frac{\mu_0}{2\pi a}$ giving F_R .

1.4.2 Definitions for clause 3: thermal effects**1.4.2.1****thermal equivalent short-time current, I_{th}**

the r.m.s. value of current having the same thermal effect and the same duration as the actual short-circuit current

1.4.2.2**rated short-time withstand current, I_{thr}**

the r.m.s. value of current that the electrical equipment can carry during a rated short time under prescribed conditions of use and behaviour

NOTE 1 It is possible to state several pairs of values of rated short-time withstand current and rated short time; for thermal effect 1 s is used in most IEC specifications.

NOTE 2 The rated short-time withstand current, as well as the corresponding rated short time, are stated by the manufacturer of the equipment.

1.4.2.3**thermal equivalent short-time current density, S_{th}**

the ratio of the thermal equivalent short-time current and the cross-section area of the conductor

1.4.2.4**rated short-time withstand current density, S_{thr} for conductors**

the r.m.s. value of the current density which a conductor is able to withstand for the rated short time

NOTE The rated short-time withstand current density is determined according to 3.2.

1.4.2.5**short-circuit duration, T_k**

the time interval between the initiation of the short circuit and the breaking of the current

1.4.2.6**rated short time, T_{kr}**

the time duration for which:

- an electrical equipment can withstand a current equal to its rated short-time withstand current;
- a conductor can withstand a current density equal to its rated short-time withstand current density.

2 Electromagnetic effect on rigid conductors**2.1 General**

The time patterns of short-circuit currents in d.c. auxiliary installations are manifold. A standard approximation function is defined in IEC 61660-1 by six parameters: i_p , I_k , t_p , τ_1 , τ_2 , T_k (see Figure 4a). A variation of any parameter will result in a variation of stress. For practical use, a substitute rectangular function is introduced for the square of the current, and therefore for the electromagnetic force, which leads to the same mechanical stresses and forces as the real short-circuit current. Figure 4b shows the square of the standard approximation function of the short-circuit current and its substitute rectangular function which is defined by two parameters: I_R^2 and t_R .

With the calculation method presented in this clause

- stresses in rigid conductors, and
- forces on insulators and substructures, which result in bending, tension and/or compression,

can be estimated.

Electromagnetic forces are induced in conductors by the currents flowing through them. Where such electromagnetic forces interact on parallel conductors, they cause stresses which have to be taken into account at the auxiliary installations. For this reason: