

Short-circuit currents in d.c auxiliary installations in power plants and substations —

Part 1: Calculation of short-circuit currents

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National foreword

This British Standard is the UK implementation of EN 61660-1:1997. It is identical with IEC 61660-1:1997, incorporating corrigenda March 1999 and March 2000.

The UK participation in its preparation was entrusted to Technical Committee PEL/73, Short-circuit currents.

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

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Short-circuit currents in d.c. auxiliary installations in
power plants and substations
Part 1: Calculation of short-circuit currents

(IEC 61660-1:1997)

Courants de court-circuit dans les installations
auxiliaires alimentées en courant continu dans
les centrales et les postes
Partie 1: Calcul des courants de court-circuit
(CEI 61660-1:1997)

Kurzschlußströme in
Gleichstrom-Eigenbedarfsanlagen in
Kraftwerken und Schaltanlagen
Teil 1: Berechnung der Kurzschlußströme
(IEC 61660-1:1997)

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European Committee for Electrotechnical Standardization
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Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 73/84/FDIS, future edition 1 of IEC 61660-1, prepared by IEC TC 73, Short-circuit currents, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61660-1 on 1997-07-01.

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- 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- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 1998-04-01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 is informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61660-1:1997 was approved by CENELEC as a European Standard without any modification.

Contents

	Page
Foreword	2
1 General	5
1.1 Scope and object	5
1.2 Normative references	5
1.3 Definitions	5
1.4 Symbols and subscripts	7
2 Calculation of short-circuit currents	9
2.1 General	9
2.2 Calculating methods	11
2.3 Resistance and inductance of conductor	13
2.4 Rectifier	14
2.5 Battery	17
2.6 Capacitor	19
2.7 DC motor with independent excitation	24
3 Calculation of the total short-circuit current	30
3.1 Correction factor	30
3.2 Superimposing the partial short-circuit currents at the short-circuit location	32
3.3 Standard approximation function	32
Annex A (informative) Equations for the calculation of λ_D , κ_D , κ_C and t_{pC}	34
Annex ZA (normative) Normative references to international publications with their corresponding European publications	36
Figure 1 — Diagrams of typical short-circuit currents	10
Figure 2 — Standard approximation function	11
Figure 3 — Equivalent circuit diagram for calculating the partial short-circuit currents	12
Figure 4 — Bolted joint	13
Figure 5 — Loop inductance per unit length	13
Figure 6 — Equivalent circuit diagram of the rectifier for the calculation of short-circuit currents	14
Figure 7 — Factor λ_D determining the quasi steady-state short-circuit current I_{kD}	16
Figure 8 — Factor κ_D for determining the peak short-circuit current i_{pD}	17
Figure 9 — Equivalent circuit diagram of the stationary lead-acid battery for the calculation of short-circuit currents	17
Figure 10 — Time to peak t_{pB} and rise-time constant τ_{1B}	19

	Page
Figure 11 — Equivalent circuit diagram of the capacitor for the calculation of short-circuit currents	19
Figure 12 — Factor κ_C for determining the peak short-circuit current i_{pC}	21
Figure 13 — Time to peak t_{pC}	22
Figure 14 — Factor k_{1C} for determining the rise-time constant τ_{1C}	23
Figure 15 — Factor k_{2C} for determining the decay-time constant τ_{2C}	24
Figure 16 — Equivalent circuit diagram of an independently excited d.c. motor for the calculation of short-circuit currents	24
Figure 17 — Factor κ_M for determining the peak short-circuit current i_{pM} with $\tau_{mec} < 10 \tau_F$	26
Figure 18 — Factors k_{1M} and k_{2M} for determining the time t_{pM} and the rise-time constant τ_{1M} for nominal and decreasing speed with $\tau_{mec} \geq 10 \tau_F$	27
Figure 19 — Time to peak t_{pM} for decreasing speed with $\tau_{mec} < 10 \tau_F$	28
Figure 20 — Factor k_{3M} for determining the rise-time constant τ_{1M} for decreasing speed with $\tau_{mec} < 10 \tau_F$	29
Figure 21 — Factor k_{4M} for determining the decay-time constant τ_{2M} for decreasing speed with $\tau_{mec} < 10 \tau_F$	30
Figure 22 — Typical time curves of the total short-circuit current	33

1 General

1.1 Scope and object

This part of IEC 61660 describes a method for calculating short-circuit currents in d.c. auxiliary systems in power plants and substations. Such systems can be equipped with the following equipment, acting as short-circuit current sources:

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

NOTE Rectifiers in three-phase a.c. bridge connection for 60 Hz are under consideration. The data of other equipment may be given by the manufacturer.

This standard is only concerned with rectifiers in three-phase a.c. bridge connection. It is not concerned with other types of rectifiers.

The purpose of the standard is to provide a generally applicable method of calculation which produces results of sufficient accuracy on the conservative side. Special methods, adjusted to particular circumstances, may be used if they give at least the same precision. Short-circuit currents, resistances and inductances may also be ascertained from system tests or measurements on model systems. In existing d.c. systems the necessary values can be ascertained from measurements taken at the assumed short-circuit location. The load current is not taken into consideration when calculating the short-circuit current. It is necessary to distinguish between two different values of short-circuit current:

- the maximum short-circuit current which determines the rating of the electrical equipment;
- the minimum short-circuit current which can be taken as the basis for fuse and protection ratings and settings.

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 edition indicated was 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 60038:1983, *IEC standard voltages*.

IEC 60050(151):1978, *International Electrotechnical Vocabulary (IEV) — Chapter 151: Electrical and magnetic devices*.

IEC 60050(441):1984, *International Electrotechnical Vocabulary (IEV) — Chapter 441: Switchgear, controlgear and fuses*.

IEC 60896-1:1987, *Stationary lead-acid batteries — General requirements and methods of test — Part 1: Vented types*.

Amendment 1 (1988)

Amendment 2 (1990)

IEC 60909:1988, *Short-circuit current calculation in three-phase a.c. systems*.

IEC 61660-2:1997, *Short-circuit currents in d.c. auxiliary installations in power plants and substations — Part 2: Calculation of effects*.

1.3 Définitions

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

1.3.1

short circuit

the accidental or intentional connection, by a relatively low resistance or impedance, of two or more points in a circuit which are normally at different voltages [IEV 151-03-41]

NOTE In this standard the connection is assumed to have zero impedance.

1.3.2

short-circuit current

an over-current resulting from a short circuit due to a fault or an incorrect connection in an electric circuit [IEV 441-11-07]

NOTE It is necessary to distinguish between the short-circuit current at the short-circuit location and in the network branches.

1.3.3

partial short-circuit current

the short-circuit current at the short-circuit location being fed from one source with all other sources disconnected

1.3.4

common branch

a network branch with several partial short-circuit currents from different sources

1.3.5

initial symmetrical short-circuit current I'_k

the r.m.s. value of the a.c. symmetrical component of a prospective short-circuit current applicable at the instant of short circuit if the impedance remains at zero time value

1.3.6

peak short-circuit current i_p

the maximum possible instantaneous value of the prospective short-circuit current at the d.c. side (Figure 1 and Figure 2)

1.3.7

quasi steady-state short-circuit current I_k

the value of the short-circuit current at the d.c. side 1 s after the beginning of the short circuit

1.3.8

time to peak t_p

the interval between the initiation of the short circuit and the peak value of the short-circuit current (Figure 1 and Figure 2)

1.3.9

short-circuit duration T_k

the time interval between the initiation of the short circuit and the breaking of the d.c. short-circuit current

1.3.10

nominal system voltage U_n

voltage (line-to-line) by which a three-phase a.c. system is designated and to which certain operating characteristics are referred. Values are given in IEC 60038

1.3.11

nominal voltage U_{nB} of a lead-acid battery

the nominal voltage of a lead-acid battery is given by the manufacturer. If the value is unknown, then the nominal voltage of one cell 2,0 V multiplied by the number of cells in series may be used

1.3.12

stationary battery

a battery designed for service in a fixed location and which is permanently connected to the load and to the associated battery charging circuit (see IEC 60896-1)

1.3.13

final voltage of a battery (end-of-discharge voltage)

the minimum permissible voltage after a specified discharge time

1.4 Symbols and subscripts

All equations are written without specifying units. The symbols represent quantities possessing both numerical values and dimensions that are independent of units, provided a coherent unit system is chosen, for example the International System of Units (SI).

1.4.1 Symbols

A	Conductor cross-section
a	Centre-line distance between conductors
d	Thickness of rectangular conductor
C	Capacitance
c	Voltage factor according to IEC 60909
$cU_n/\sqrt{3}$	Equivalent voltage source according to IEC 60909
E_B	Open-circuit voltage of a battery
f	System frequency
b	Height of rectangular conductor
I''_k	Three-phase initial symmetrical short-circuit current
I_k	Quasi steady-state short-circuit current
I_r	Rated current
i	Instantaneous value of current
i_1, i_2	Sections of the standard approximation function
i_{Br}	Short-circuit current in a branch
i_p	Peak short-circuit current
i_{cor}	Corrected current
J	Moment of inertia of the whole rotating part
k_{1C}, k_{2C}	Factors for calculating the rise-time and decay-time constant of the capacitor current
k_{1M}	Factor for calculating the time to peak of the motor current
k_{2M}, k_{3M}	Factors for calculating the rise-time constant of the motor current
k_{4M}	Factor for calculating the decay-time constant of the motor current
L, L'	Inductance, inductance per unit length
L_F	Equivalent saturated inductance of the field circuit at short circuit
L_{OF}	Equivalent unsaturated inductance of the field circuit at no-load
l	Length
M_r	Rated torque of the motor
n, n_o, n_n	Motor speed, no-load motor speed, nominal motor speed
p	Ratio I_k/i_p
R, R'	Resistance, resistance per unit length
R_{joint}	Joint resistance
r	Radius of the conductor
T_k	Short-circuit duration
t	Time
t_p	Time to peak
U	Voltage at the short-circuit location before short circuit
U_n	Nominal system voltage of the three-phase a.c. system, line-to-line (r.m.s.)
U_{nB}	Nominal voltage of a battery
X	Reactance
Z_N	Impedance of the three-phase a.c. network

δ	Decay coefficient
κ	Factor for calculating the peak short-circuit current
λ_D	Factor for calculating the quasi steady-state short-circuit current of the rectifier
μ_0	Absolute permeability of vacuum, $\mu_0 = 4 \pi \cdot 10^{-7}$ H/m
ρ	Resistivity
σ	Correction factor for the partial short-circuit current
τ_M	Armature time constant of the motor
τ_F	Field circuit time constant of the motor
τ_{mec}	Mechanical time constant of the motor
τ_1, τ_2	Rise-time, decay-time constants of the standard approximation function
ω_o, ω_d	Undamped, damped natural angular frequency

1.4.2 Subscripts

a.c.	Alternating current
B	Battery
Br	Branch on the d.c. side
C	Capacitor
cor	Corrected
D	Rectifier
d.c.	Direct current
F	Short-circuit location
F	Field circuit of the motor
HV, LV	High voltage, low voltage
i	Internal
j, m	Numeral/number of the voltage source
k	Short circuit
L	Line
M	Motor
max, min	Maximum, minimum
mec	Mechanical
N	Three-phase a.c. network
n	Nominal
p	Peak
P	Power cable
Q	Feeder connection point according to IEC 60909
R	Commutation reactor
r	Rated
res	Residual
S	Smoothing reactor
T	Transformer
Y	Common branch
O	No load/undamped

2 Calculation of short-circuit currents

2.1 General

A complete calculation of the short-circuit currents provides details of the time variation of the currents at the short-circuit location, from the initiation of the short circuit to its end. Due to many variations of current and the non-linearity of equipment, such calculations can only be performed by numerical means. The expense is very high, especially since there are no universal methods of calculation. For this reason only calculation of characteristic quantities is dealt with.

Figure 1 shows the typical short-circuit currents of various sources. The total short-circuit current at the short-circuit location may be produced by the action of several different sources.

Figure 2 shows the standard approximation function which covers the different current variations. The function is described by equations (1) to (3).

$$i_1(t) = i_p \frac{1 - e^{-t/\tau_1}}{1 - e^{-t_p/\tau_1}} \quad 0 \leq t \leq t_p \quad (1)$$

$$i_2(t) = i_p \left((1-p) e^{-(t-t_p)/\tau_2} + p \right) \quad t_p \leq t \quad (2)$$

$$p = \frac{I_k}{i_p} \quad (3)$$

where

- i_p is the peak short-circuit current;
- I_k is the quasi steady-state short-circuit current;
- t_p is the time to peak;
- τ_1 is the rise-time constant;
- τ_2 is the decay-time constant.

If there is no defined maximum current present, then $i_p = I_k$ and $t_p = T_k$; equation (1) then describes the whole time variation of the short-circuit current.

By calculation of the characteristic quantities for the time variation of the short-circuit current according to Figure 2, the mechanical and thermal short-circuit stresses can be ascertained. If only the quasi steady-state short-circuit currents are required, the equations (13), (22), (36) and (37) should be used.

The assumptions that the impedance is zero between points of different potential at the short-circuit location and that the load resistances (shunt resistors) can be ignored, are valid for calculation of both the maximum and minimum short-circuit currents.

When calculating the maximum short-circuit currents the following switching and operating conditions shall be taken into account so that the maximum short-circuit current is flowing:

- the conductor resistances are referred to a temperature of 20 °C;
- the joint resistances of the busbars are neglected;
- the control for limiting the rectifier current is not effective;
- any diodes for decoupling parts of the system are neglected;
- the battery is charged to full capacity;
- the current-limiting effect of fuses or other protective devices shall be taken into account.

When calculating the minimum short-circuit currents the following switching and operating conditions shall be taken into account so that the minimum short-circuit current is flowing:

- the conductor resistances are referred to the maximum operating temperature;
- the joint resistances shall be taken into account (see 2.3.1);
- the contribution of the rectifier is the rated short-circuit current;

- the battery is at the final voltage as specified by the manufacturer;
- any diodes for decoupling parts of the system are taken into account;
- the current-limiting effect of fuses or other protective devices shall be taken into account.

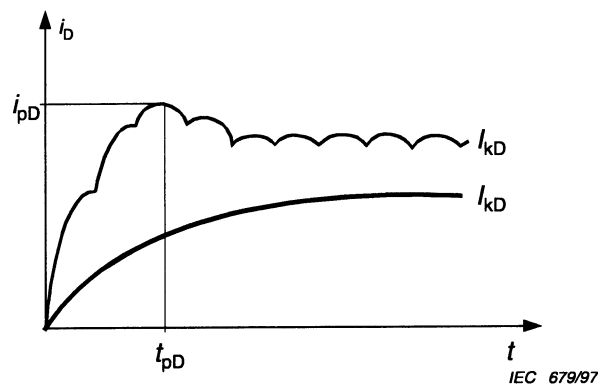


Figure 1a — Rectifier without and with smoothing reactor

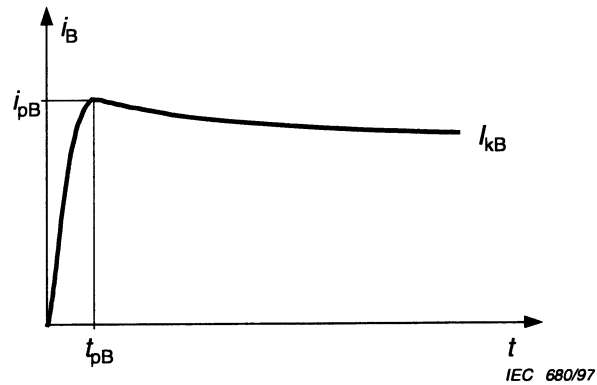


Figure 1b — Battery

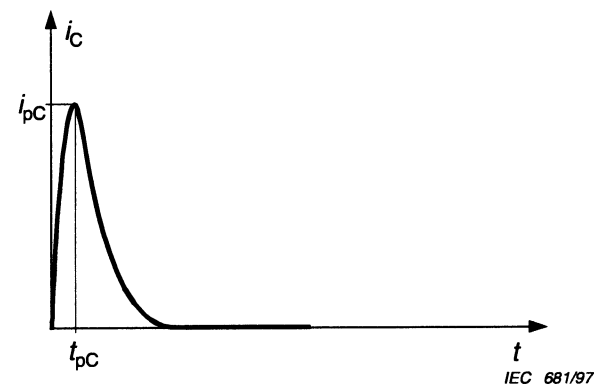
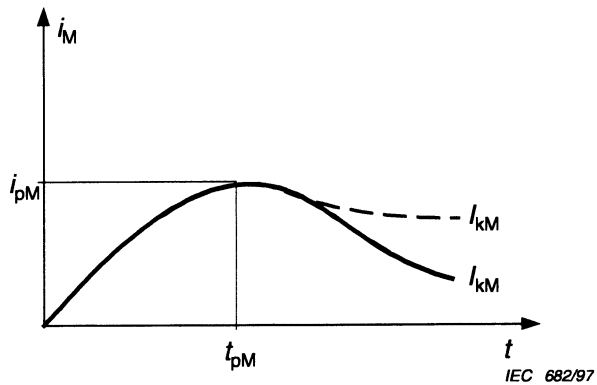


Figure 1c — Capacitor



- Motor without additional inertia mass
- Motor with additional inertia mass

Figure 1d

Figure 1 — Diagrams of typical short-circuit currents