IEC 60909-0

Edition 3.0 2026-07

INTERNATIONAL STANDARD

Short-circuit currents in three-phase AC systems -
Part 0: Calculation of currents

IEC 60909-0:2026-07(en)

ICS 17.220.01; 29.240.20 ISBN 978-2-8327-1382-2

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FOREWORD

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IEC 60909-0 has been prepared by IEC technical committee 73: Short-circuit currents. It is an International Standard.

This third edition cancels and replaces the second edition published in 2016. This edition constitutes a technical revision.

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

a) restructuring and complementing of the clauses, especially restructuring and updating of Clause 6.
b) restructuring of subscripts.

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

Draft	Report on voting
73/220/CDV	73/236/RVC

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 International Standard 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/publications.

A list of all parts in the IEC 60909 series, published under the general title *Short-circuit currents in three-phase AC systems*, can be found on the IEC website.

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– withdrawn, or
– revised.

INTRODUCTION

Main aim of IEC 60909-0 is calculation of maximum and minimum short-circuit currents of bolted short circuits (see 5.2.4). Calculation results can serve as input for further evaluations such as calculation of arcing current as described in, for example, IEEE 1584.

1 Scope

This part of IEC 60909 is applicable to the calculation of short-circuit currents

– in low-voltage three-phase AC systems,
– in high-voltage three-phase AC systems, and
– operating at a nominal frequency of 50 Hz or 60 Hz.

Systems at highest voltages of 550 kV and above with long transmission lines are outside the scope of this document.

This document establishes a general, practicable and concise procedure leading to results which are generally of acceptable accuracy. For this calculation method, an equivalent voltage source at the short-circuit location is introduced. This does not exclude the use of special methods, for example the superposition method, adjusted to particular circumstances, if they give at least the same precision. The superposition method gives the short-circuit current related to the one load flow presupposed. This method, therefore, does not necessarily lead to the maximum respective minimum short-circuit current.

This document deals with the calculation of short-circuit currents in the case of balanced or unbalanced short circuits.

A single line-to-earth fault occurring in networks with isolated or resonant earthing of the neutral point is beyond the scope of this document.

For currents during two separate simultaneous single-phase line-to-earth short circuits in an isolated neutral system or a resonance earthed neutral system, see IEC 60909-3.

Short-circuit currents and short-circuit impedances can also be determined by system tests, by measurement on a network analyser, or numerical simulations with electromagnetic programs. In existing low-voltage systems, it is possible to determine the short-circuit impedance on the basis of measurements at the location of the prospective short circuit considered.

The calculation of the short-circuit impedance is in general based on the rated data of the electrical equipment and the topological arrangement of the system and has the advantage of being possible both for existing systems and for systems at the planning stage.

In general, two types of short-circuit currents, which differ in their magnitude, are considered:

– maximum short-circuit current which determines the capacity or rating of electrical equipment;
– minimum short-circuit current which can be a basis, for example, for the selection of fuses, for the setting of protective devices, and for checking the run-up of motors.

NOTE The current in a three-phase short circuit is assumed to be made simultaneously in all poles. Investigations of non-simultaneous short circuits, which can lead to higher aperiodic components of short-circuit currents, are beyond the scope of this document.

This document does not cover short-circuit currents deliberately created under controlled conditions (short-circuit testing stations).

This document does not deal with the calculation of short-circuit currents in installations on board ships and aeroplanes.

This document does not distinguish between grid-forming and grid-following converters for the calculation of short-circuit currents.

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 60050-131, *International Electrotechnical Vocabulary (IEV) - Part 131: Circuit theory*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-131 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

– IEC Electropedia: available at https://www.electropedia.org/

– ISO Online browsing platform: available at https://www.iso.org/obp

3.1
short circuit
accidental or intentional conductive path between two or more conductive parts (e.g. three-phase short circuit) forcing the electric potential differences between these conductive parts to be equal or close to zero

[SOURCE: IEC 60050-151:2001, 151-12-04, modified – The parenthesis "(e.g. three-phase short circuit)" has been added.]

3.1.1
line-to-line short circuit
two-phase short circuit
accidental or intentional conductive path between two line conductors with or without earth connection

3.1.2
line-to-earth short circuit
single-phase short circuit
accidental or intentional conductive path in a solidly earthed neutral system or an impedance earthed neutral system between a line conductor and local earth

3.2
short-circuit current
over-current resulting from a short circuit in an electric system

Note 1 to entry: It is necessary to distinguish between the short-circuit current at the short-circuit location and partial short-circuit currents in the network branches (see Figure 3) at any point of the network.

3.3
prospective short-circuit current
current that would flow if the short circuit were replaced by an ideal connection of negligible impedance without any change of the supply

Note 1 to entry: The current in a three-phase short circuit is assumed to be made simultaneously in all poles. Investigations of non-simultaneous short circuits, which can lead to higher aperiodic components of short-circuit current, are beyond the scope of this document.

3.4
symmetrical short-circuit current
RMS value of the AC symmetrical component of a prospective short-circuit current (see 3.3), the aperiodic component of current, if any, being neglected

3.4.1
initial symmetrical short-circuit current
I_k''
RMS value of the total AC symmetrical components of a prospective short-circuit current (see 3.3), applicable at the instant of short circuit if the impedance remains at zero-time value

SEE: Figure 1.

Note 1 to entry: The total initial short-circuit current is the sum of the short-circuit currents, caused by voltage and current sources (see 3.4.2 and 3.4.3).

3.4.2
initial symmetrical short-circuit current
I_{kVS}''
<voltage source> RMS value of the AC symmetrical components of a prospective short-circuit current (see 3.3), caused by a voltage source, applicable at the instant of short circuit if the impedance remains at zero-time value

3.4.3
initial symmetrical short-circuit current
I_{kCS}''
<current source> RMS value of the AC symmetrical components of a prospective short-circuit current (see 3.3), caused by a current source, applicable at the instant of short circuit if the impedance remains at zero-time value

3.5
initial symmetrical short-circuit power
S_k''
fictitious value determined as a product of the initial symmetrical short-circuit current I_k'' (see 3.4.1), the nominal system voltage U_n (see 3.11) and the factor $\sqrt{3}$:

$$S_k'' = \sqrt{3} \cdot U_n \cdot I_k''$$

Note 1 to entry: The initial symmetrical short-circuit power S_k'' is not used for the calculation procedure in this document.

3.6
decaying aperiodic component of short-circuit current
DC component
i_{DC}
mean value between the top and bottom envelope of a short-circuit current decaying from an initial value to zero according to Figure 1

3.7
peak short-circuit current
i_p
maximum possible instantaneous value of the prospective short-circuit current

SEE: Figure 1.

Note 1 to entry: Sequential short circuits are not considered.

3.8
symmetrical short-circuit breaking current
I_b
RMS value of an integral cycle of the symmetrical AC component of the prospective short-circuit current at the instant of contact separation of the first pole to open of a switching device

3.9
steady-state short-circuit current
I_k
RMS value of the short-circuit current which remains after the decay of the transient phenomena

SEE: Figure 1.

3.10
symmetrical locked-rotor current
I_{LR}
symmetrical RMS current of an asynchronous machine with locked rotor fed with rated voltage U_{rA} at rated frequency

3.11
nominal system voltage
U_n
voltage (line-to-line) by which a system is designated, and to which certain operating characteristics are referred

Note 1 to entry: Values are given in IEC 60038.

3.12
equivalent voltage source
$cU_n / \sqrt{3}$

voltage of an ideal source applied at the short-circuit location for calculating the short-circuit current according to 5.2.2

Note 1 to entry: The equivalent voltage source is the only active voltage of the network.

3.13
voltage factor
c
ratio between the equivalent voltage source and the nominal system voltage U_n divided by $\sqrt{3}$

Note 1 to entry: The values are given in Table 1.

Note 2 to entry: The introduction of a voltage factor c is necessary for various reasons: voltage variations depending on time and place, changing of transformer taps, neglecting loads and capacitances by calculations according to 5.2.4 and the subtransient behaviour of generators and motors.

3.14
far-from-generator short circuit
short circuit during which the magnitude of the symmetrical AC component of the prospective short-circuit current remains essentially constant

SEE: Figure 1 a).

3.15
near-to-generator short circuit
short circuit during which the magnitude of the symmetrical AC component of the prospective short-circuit current decreases

SEE: Figure 1 b).

Note 1 to entry: A near-to-generator short circuit can be assumed if at least one synchronous machine contributes a prospective initial symmetrical short-circuit current which is more than twice the machine's rated current, or a short circuit to which asynchronous motors contribute more than 5 % of the initial symmetrical short-circuit current without motors.

3.16
short-circuit impedances at the short-circuit location F

3.16.1
positive-sequence short-circuit impedance
$\underline{Z}_{(1)}$
<three-phase AC system> impedance of the positive-sequence system as viewed from the short-circuit location

Note 1 to entry: See 5.2.5.

3.16.2
short-circuit impedance
$\underline{Z}_{k}$
<three-phase AC system> abbreviated expression for the positive-sequence short-circuit impedance $\underline{Z}_{(1)}$ according to 3.16.1 for the calculation of three-phase short-circuit currents

3.16.3
negative-sequence short-circuit impedance
$\underline{Z}_{(2)}$
<three-phase AC system> impedance of the negative-sequence system as viewed from the short-circuit location

Note 1 to entry: See 5.2.5.

3.16.4
zero-sequence short-circuit impedance
$\underline{Z}_{(0)}$
<three-phase AC system> impedance of the zero-sequence system as viewed from the short-circuit location

Note 1 to entry: The zero-sequence short-circuit impedance includes three times the neutral-to-earth impedance $\underline{Z}_{E}$.

3.17
impedances of electrical equipment

3.17.1
positive-sequence impedance
$\underline{Z}_{(1)}$
<electrical equipment> ratio of the line-to-neutral voltage to the short-circuit current of the corresponding line conductor of electrical equipment when fed by a symmetrical positive-sequence system of voltages

Note 1 to entry: See IEC TR 60909-4:2021, Clause 6.

Note 2 to entry: The index of symbol $\underline{Z}_{(1)}$ can be omitted if there is no possibility of confusion with the negative-sequence and the zero-sequence impedances.

3.17.2
negative-sequence impedance
$\underline{Z}_{(2)}$
<electrical equipment> ratio of the line-to-neutral voltage to the short-circuit current of the corresponding line conductor of electrical equipment when fed by a symmetrical negative-sequence system of voltages

Note 1 to entry: See IEC TR 60909-4:2021, Clause 6.

3.17.3
zero-sequence impedance
$\underline{Z}_{(0)}$
<electrical equipment> ratio of the line-to-earth voltage to the short-circuit current of one line conductor of electrical equipment when fed by an AC voltage source, if the three paralleled line conductors are used for the outgoing current and either a fourth line or earth as a joint return, or both

Note 1 to entry: See IEC TR 60909-4:2021, Clause 6.

3.18
subtransient reactance
X_d''
effective reactance of a synchronous machine at the moment of short circuit

Note 1 to entry: For the calculation of short-circuit currents, the saturated value of X_d'' is taken.

3.19
minimum time delay
t_{min}
shortest time between the beginning of the short-circuit current and the contact separation of the first pole to open of the switching device

Note 1 to entry: The time t_{min} is the sum of the shortest possible operating time of a protective relay and the shortest opening time of a circuit-breaker. It does not take into account adjustable time delays of tripping devices.

3.20
thermal equivalent short-circuit current
I_{th}
RMS value of a current having the same thermal effect and the same duration as the actual short-circuit current, which can contain a DC component and can subside in time

3.21
short-circuit current of full-size converters
current source of full-size converters

3.21.1
source current for three phase short circuits
I_{kPC}
<source current, three phase> RMS value of the source current of a power station unit with full-size converter and current regulation in case of three-phase short circuit at the high-voltage side of the step-up transformer

3.21.2
source current for line-to-line short circuits
$I_{(1)k2PC}$
<source current, two phase> RMS value of the source current (positive-sequence system) of a power station with full-size converter and current regulation in case of a line-to-line short circuit or a line-to-line short circuit with earth connection at the high-voltage side of the step-up transformer