IEC 60909-0

Edition 2.0 2016-01

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

## Short-circuit currents in three-phase a.c. systems – Part 0: Calculation of currents

## Courants de court-circuit dans les réseaux triphasés à courant alternatif – Partie 0: Calcul des courants



IEC 60909-0:2016-01(en-fr)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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# SHORT-CIRCUIT CURRENTS IN THREE-PHASE AC SYSTEMS –

## Part 0: Calculation of currents

## FOREWORD

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

This second edition cancels and replaces the first edition published in 2001. This edition constitutes a technical revision.

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

a) contribution of windpower station units to the short-circuit current;
b) contribution of power station units with ful size converters to the short-circuit current;
c) new document structure.

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

| CDV | Report on voting |
|---|---|
| 73/172/CDV | 73/175A/RVC |

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 2.

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

This part of IEC 60909 is to be read in conjunction with the following International Standards and Technical Reports:

– IEC TR 60909-1:2002, *Short-circuit currents in three-phase a.c. systems – Part 1: Factors for the calculation of short-circuit currents according to IEC 60909-0*

– IEC TR 60909-2:2008, *Short-circuit currents in three-phase a.c. systems – Part 2: Data of electrical equipment for short-circuit current calculations*

– IEC 60909-3:2009, *Short-circuit currents in three-phase a.c. systems – Part 3: Currents during two separate simultaneous line-to-earth short circuits and partial short-circuit currents flowing through earth*



– IEC TR 60909-4:2000, *Short-circuit currents in three-phase a.c. systems – Part 4: Examples for the calculation of short-circuit currents*



The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be



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

# SHORT-CIRCUIT CURRENTS IN THREE-PHASE AC SYSTEMS –

# Part 0: Calculation of currents

## 1 Scope

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

- in low-voltage three-phase AC systems, and
- in high-voltage three-phase AC systems,

operating at a nominal frequency of 50 Hz or 60 Hz.

Systems at highest voltages of 550 kV and above with long transmission lines need special consideration.

This part of IEC 60909 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 short-circuit current.



This part of IEC 60909 deals with the calculation of short-circuit currents in the case of balanced or unbalanced short circuits.



A single line-to-earth fault is beyond the scope of this part of IEC 60909.

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 may also be determined by system tests, by measurement on a network analyser, or with a digital computer. 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 short-circuit currents, which differ in their magnitude, are considered:

- the maximum short-circuit current which determines the capacity or rating of electrical equipment; and
- the 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 may lead to higher aperiodic components of short-circuit current, are beyond the scope of this part of IEC 60909.

This part of IEC 60909 does not cover short-circuit currents deliberately created under controlled conditions (short-circuit testing stations).

This part of IEC 60909 does not deal with the calculation of short-circuit currents in installations on board ships and aeroplanes.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60038:2009, *IEC standard voltages*

IEC 60050-131, *International Electrotechnical Vocabulary – Part 131: Circuit theory* (available at: www.electropedia.org)

IEC TR 60909-1:2002, *Short-circuit currents in three-phase a.c. systems – Part 1: Factors for the calculation of short-circuit currents according to IEC 60909-0*

IEC TR 60909-2:2008, *Short-circuit currents in three-phase a.c. systems – Data of electrical equipment for short-circuit current calculations*

IEC 60909-3:2009, *Short-circuit currents in three-phase a.c. systems – Part 3: Currents during two separate simultaneous line-to-earth short circuits and partial short-circuit currents flowing through earth*



IEC TR 60909-4:2000, *Short-circuit currents in three-phase a.c. systems – Part 4: Examples for the calculation of short-circuit currents*



## 3 Terms and definitions

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

**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

**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 may lead to higher aperiodic components of short-circuit current, are beyond the scope of this part of IEC 60909.

**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

**3.5**
**initial symmetrical short-circuit current**
$I''_{\mathrm{k}}$
rms value of the AC symmetrical component 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: Figures 1 and 2

**3.6**
**initial symmetrical short-circuit power**
$S''_{\mathrm{k}}$
fictitious value determined as a product of the initial symmetrical short-circuit current $I''_{\mathrm{k}}$ (see 3.5), the nominal system voltage $U_{\mathrm{n}}$ (see 3.13) and the factor $\sqrt{3}$: $S''_{\mathrm{k}} = \sqrt{3} \cdot U_{\mathrm{n}} \cdot I''_{\mathrm{k}}$



Note 1 to entry: The initial symmetrical short-circuit power $S''_{\mathrm{k}}$ is not used for the calculation procedure in this part of IEC 60909. If $S''_{\mathrm{k}}$ is used in spite of this in connection with short-circuit calculations, for instance to calculate the internal impedance of a network feeder at the connection point Q, then the definition given should be used in the following form: $S''_{\mathrm{kQ}} = \sqrt{3} \cdot U_{\mathrm{nQ}} \cdot I''_{\mathrm{kQ}}$ or $Z_{\mathrm{Q}} = c \cdot U^2_{\mathrm{nQ}} / S''_{\mathrm{kQ}}$.

**3.7**
**decaying (aperiodic) component of short-circuit current or DC component**
$i_{\mathrm{DC}}$
mean value between the top and bottom envelope of a short-circuit current decaying from an initial value to zero according to Figures 1 and 2

**3.8**
**peak short-circuit current**
$i_{\mathrm{p}}$
maximum possible instantaneous value of the prospective short-circuit current

SEE: Figures 1 and 2

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

**3.9**
**symmetrical short-circuit breaking current**
$I_{\mathrm{b}}$
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

**3.10**
**steady-state short-circuit current**
$I_k$
rms value of the short-circuit current which remains after the decay of the transient phenomena

SEE: Figures 1 and 2

**3.11**
**symmetrical locked-rotor current**
$I_{LR}$
symmetrical rms current of an asynchronous motor with locked rotor fed with rated voltage $U_{rM}$ at rated frequency

**3.12**
**equivalent electric circuit**
model to describe the behaviour of a circuit by means of a network of ideal elements

**3.13**
**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.



**3.14**
**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 5.3.1

Note 1 to entry: This is the only active voltage of the network.

**3.15**
**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. These are:

– voltage variations depending on time and place,
– changing of transformer taps,
– neglecting loads and capacitances by calculations according to 5.2,
– the subtransient behaviour of generators and motors.

**3.16**
**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

**3.17**
**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 2

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.

**3.18**
**short-circuit impedances at the short-circuit location F**

**3.18.1**
**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 5.3.2.

**3.18.2**
**short-circuit impedance**

$\underline{Z}_{k}$

<three-phase AC system> abbreviated expression for the positive-sequence short-circuit impedance $\underline{Z}_{(1)}$ according to 3.18.1 for the calculation of three-phase short-circuit currents

**3.18.3**
**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 5.3.2.



**3.18.4**
**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 (see 5.3.2)

Note 1 to entry: It includes three times the neutral-to-earth impedance $\underline{Z}_{N}$.

**3.19**
**short-circuit impedances of electrical equipment**

**3.19.1**
**positive-sequence short-circuit 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 Clause 6 and IEC TR 60909-4.

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

**3.19.2**
**negative-sequence short-circuit 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 Clause 6 and IEC TR 60909-4.

**3.19.3**
**zero-sequence short-circuit 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 a fourth line and/or earth as a joint return

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

**3.20**
**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.

**3.21**
**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.



**3.22**
**thermal equivalent short-circuit current**
$I_{th}$
the rms value of a current having the same thermal effect and the same duration as the actual short-circuit current, which may contain a DC component and may subside in time



**3.23**
**maximum short-circuit current**
$i_{kWDmax}$
<doubly fed asynchronous generator> instantaneous maximum short-circuit current of a wind power station unit with doubly fed asynchronous generator in case of a three-phase short-circuit at the high-voltage side of the unit transformer

**3.24**
**maximum short-circuit current**
$I_{kPFmax}$
<full size converter> maximum steady state current of a power station unit with full size converter in case of a three-phase short-circuit at the high-voltage side of the unit transformer

**3.25**
**maximum source current**
$I_{skPF}$
<full size converter, three phase> rms value of the maximum 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 unit transformer

**3.26**
**maximum source current**
$I_{(1)sk2PF}$
<full size converter, two phase> rms value of the maximum source current (positive-sequence system) of a power station unit 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 unit transformer

**3.27**
**maximum source current**
$I_{(1)\mathrm{sk1PF}}$
<full size converter, single phase> rms value of the maximum source current (positive-sequence system) of a power station unit with full size converter and current regulation in case of a line-to-earth short-circuit at the high-voltage side of the unit transformer

**3.28**
**impedance of the nodal impedances matrix**
$\underline{Z}_{(1)ii}$, $\underline{Z}_{(2)ii}$, $\underline{Z}_{(0)ii}$
<self-admittance> diagonal elements of the positive-sequence, or negative-sequence or zero-sequence nodal impedance matrix for the short-circuit location $i$

Note 1 to entry: See Annex B.

**3.29**
**impedance of the nodal impedances matrix**
$\underline{Z}_{(1)ij}$
<mutual admittance> elements of the positive-sequence nodal impedance matrix, where $i$ is the node of the short circuit and $j$ the node where the high-voltage side of a power station unit with full size converter is connected

Note 1 to entry: See Annex B.

# 4 Symbols, subscripts and superscripts



## 4.1 General

The formulas given in this standard are written without specifying units. The symbols represent physical quantities possessing both numerical values and dimensions that are independent of units, provided a consistent unit system is chosen, for example the international system of units (SI). Symbols of complex quantities are underlined, for example $\underline{Z} = R + \mathrm{j}X$.



## 4.2 Symbols

| | |
|---|---|
| $A$ | Initial value of the DC component $i_{\mathrm{DC}}$ |
| $\underline{a}$ | Complex operator |
| $a$ | Ratio between unbalanced short-circuit current and three-phase short-circuit current |
| $c$ | Voltage factor |
| $U_{\mathrm{n}}/\sqrt{3}$ | Equivalent voltage source (rms) |
| $f$ | Frequency (50 Hz or 60 Hz) |
| $I_{\mathrm{b}}$ | Symmetrical short-circuit breaking current (rms) |
| $I_{\mathrm{k}}$ | Steady-state short-circuit current (rms) |
| $I_{\mathrm{kP}}$ | Steady-state short-circuit current at the terminals (poles) of a generator with compound excitation |
| $I_{\mathrm{k}}''$ | Initial symmetrical short-circuit current (rms) |
| $I_{\mathrm{LR}}$ | Symmetrical locked-rotor current of an asynchronous generator or motor |
| $I_{\mathrm{r}}$ | Rated current of electrical equipment |
| $I_{\mathrm{th}}$ | Thermal equivalent short-circuit current |
| $i_{\mathrm{DC}}$ | DC component of short-circuit current |
| $i_{\mathrm{p}}$ | Peak short-circuit current |