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Short-circuit currents in three-phase a.c. systems –

Part 0: Calculation of currents

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SHORT-CIRCUIT CURRENTS IN THREE-PHASE AC SYSTEMS –

Part 0: Calculation of currents

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. 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. The 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 the 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 National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.
6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

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

This first edition cancels and replaces IEC 60909 published in 1988 and constitutes a technical revision.

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

FDIS	Report on voting
73/119/FDIS	73/121/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

Annex A forms an integral part of this standard.

This part of IEC 60909 shall be read in conjunction with the International Standards, Technical Reports and Technical Specifications mentioned below:

- IEC TR 60909-1,— *Short-circuit current calculation in three-phase a.c. systems – Part 1: Factors for the calculation of short-circuit currents in three-phase a.c. systems according to IEC 60909-0* [1]
- IEC TR3 60909-2:1992, *Electrical equipment – Data for short-circuit current calculations in accordance with IEC 60909*
- IEC 60909-3:1995, *Short-circuit current calculation in three-phase a.c. systems – Part 3: Currents during two separate simultaneous single-phase line-to-earth short circuits and partial short-circuit currents following through earth*
- IEC TR 60909-4:2000, *Short-circuit current calculation 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 2007. At this date, the publication will be

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

The contents of the corrigendum of February 2002 have been included in this copy.

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[1] To be published.

SHORT-CIRCUIT CURRENTS IN THREE-PHASE AC SYSTEMS –

Part 0: Calculation of currents

1 General

1.1 Scope

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

- in low-voltage three-phase a.c. systems
- in high-voltage three-phase a.c. 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.

In case of an accidental or intentional conductive path between one line conductor and local earth, the following two cases must be clearly distinguished with regard to their different physical properties and effects (resulting in different requirements for their calculation):

- line-to-earth short circuit, occurring in a solidly earthed neutral system or an impedance earthed neutral system;
- a single line-to-earth fault, occurring in an isolated neutral earthed system or a resonance earthed neutral system. This fault is beyond the scope of, and is therefore not dealt with in, this standard.

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 analyzer, 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 short-circuit currents, which differ in their magnitude, are to be calculated:

- 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 standard.

This standard 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.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60909. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 60909 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60038:1983, *IEC standard voltages*

IEC 60050(131):1978, *International Electrotechnical Vocabulary – Chapter 131: Electric and magnetic circuits*

IEC 60050(151):1978, *International Electrotechnical Vocabulary – Chapter 151: Electric and magnetic devices*

IEC 60050-195:1998, *International Electrotechnical Vocabulary – Part 195: Earthing and protection against electric shock*

IEC 60056:1987, *High-voltage alternating-current circuit-breakers*

IEC 60071-1:1993, *Insulation coordination – Part 1: Definitions, principles and rules*

IEC 60781:1989, *Application guide for calculation of short-circuit currents in low-voltage radial systems*

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

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

IEC TR3 60909-2:1992, *Electrical equipment – Data for short-circuit current calculations in accordance with IEC 60909*

IEC 60909-3:1995, *Short-circuit current calculation in three-phase a.c. systems – Part 3: Currents during two separate simultaneous single phase line-to-earth short circuits and partial short-circuit currents flowing through earth*

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

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 electrical cables with a rated voltage from 1,8/3 (3,6) kV to 18/30 (36) kV*

1.3 Definitions

For the purposes of this part of IEC 60909, the definitions given in IEC 60050(131) and the following definitions apply.

1.3.1
short circuit
accidental or intentional conductive path between two or more conductive parts forcing the electric potential differences between these conductive parts to be equal or close to zero

1.3.1.1
line-to-line short circuit
accidental or intentional conductive path between two or more line conductors with or without earth connection

1.3.1.2
line-to-earth 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

1.3.2
short-circuit current
over-current resulting from a short circuit in an electric system

NOTE 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.

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[1] To be published.

1.3.3

prospective (available) 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 (see note of 1.1)

1.3.4

symmetrical short-circuit current

r.m.s. value of the a.c. symmetrical component of a prospective (available) short-circuit current (see 1.3.3), the aperiodic component of current, if any, being neglected

1.3.5

initial symmetrical short-circuit current I''_k

r.m.s. value of the a.c. symmetrical component of a prospective (available) short-circuit current (see 1.3.3), applicable at the instant of short circuit if the impedance remains at zero-time value (see figures 1 and 2)

1.3.6

initial symmetrical short-circuit power S''_k

fictitious value determined as a product of the initial symmetrical short-circuit current I''_k (see 1.3.5), the nominal system voltage U_n (see 1.3.13) and the factor $\sqrt{3}$: $S''_k = \sqrt{3}\ U_n\ I''_k$

NOTE The initial symmetrical short-circuit power S''_k is not used for the calculation procedure in this standard. If S''_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: $S''_{kQ} = \sqrt{3}\,U_{nQ}\ I''_{kQ}$ or $Z_Q = cU^2_{nQ} / S''_{kQ}$.

1.3.7

decaying (aperiodic) component $i_{d.c.}$ of short-circuit current

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

1.3.8

peak short-circuit current i_p

maximum possible instantaneous value of the prospective (available) short-circuit current (see figures 1 and 2)

NOTE The magnitude of the peak short-circuit current varies in accordance with the moment at which the short circuit occurs. The calculation of the three-phase peak short-circuit current i_p applies to the line conductor and to the instant at which the greatest possible short-circuit current exists. Sequential short circuits are not considered.

1.3.9

symmetrical short-circuit breaking current I_b

r.m.s. value of an integral cycle of the symmetrical a.c. component of the prospective short-circuit current at the instant of contact separation of the first pole to open of a switching device

1.3.10

steady-state short-circuit current I_k

r.m.s. value of the short-circuit current which remains after the decay of the transient phenomena (see figures 1 and 2)

1.3.11

symmetrical locked-rotor current I_{LR}

highest symmetrical r.m.s. current of an asynchronous motor with locked rotor fed with rated voltage U_{rM} at rated frequency

1.3.12

equivalent electric circuit

model to describe the behaviour of a circuit by means of a network of ideal elements [IEV 131-01-33]

1.3.13

nominal system voltage U_n

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

NOTE Values are given in IEC 60038.

1.3.14

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

voltage of an ideal source applied at the short-circuit location in the positive-sequence system for calculating the short-circuit current according to 2.3. This is the only active voltage of the network

1.3.15

voltage factor c

ratio between the equivalent voltage source and the nominal system voltage U_n divided by $\sqrt{3}$. The values are given in table 1

NOTE 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 2.3.1,
- the subtransient behaviour of generators and motors.

1.3.16

subtransient voltage E'' of a synchronous machine

r.m.s. value of the symmetrical internal voltage of a synchronous machine which is active behind the subtransient reactance X''_d at the moment of short circuit

1.3.17

far-from-generator short circuit

short circuit during which the magnitude of the symmetrical a.c. component of the prospective (available) short-circuit current remains essentially constant (see figure 1)

1.3.18

near-to-generator short circuit

short circuit to which 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 I''_k without motors (see figure 2)

1.3.19

short-circuit impedances at the short-circuit location F

1.3.19.1

positive-sequence short-circuit impedance $\underline{Z}_{(1)}$ of a three-phase a.c. system

impedance of the positive-sequence system as viewed from the short-circuit location (see 2.3.2 and figure 5a)

1.3.19.2

negative-sequence short-circuit impedance $\underline{Z}_{(2)}$ of a three-phase a.c. system

impedance of the negative-sequence system as viewed from the short-circuit location (see 2.3.2 and figure 5b)

1.3.19.3

zero-sequence short-circuit impedance $\underline{Z}_{(0)}$ of a three-phase a.c. system

impedance of the zero-sequence system as viewed from the short-circuit location (see 2.3.2 and figure 5c). It includes three times the neutral-to-earth impedance $\underline{Z}_N$

1.3.19.4

short-circuit impedance $\underline{Z}_k$ of a three-phase a.c. system

abbreviated expression for the positive-sequence short-circuit impedance $\underline{Z}_{(1)}$ according to 1.3.19.1 for the calculation of three-phase short-circuit currents

1.3.20

short-circuit impedances of electrical equipment

1.3.20.1

positive-sequence short-circuit impedance $\underline{Z}_{(1)}$ of 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 (see clause 2 and IEC 60909-4)

NOTE 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.

1.3.20.2

negative-sequence short-circuit impedance $\underline{Z}_{(2)}$ of 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 (see clause 2 and IEC 60909-4).

1.3.20.3

zero-sequence short-circuit impedance $\underline{Z}_{(0)}$ of 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 a.c. 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 (see clause 2 and IEC 60909-4)

1.3.21

subtransient reactance X''_d of a synchronous machine

effective reactance at the moment of short circuit. For the calculation of short-circuit currents the saturated value of X''_d is taken

NOTE When the reactance X''_d in ohms is divided by the rated impedance $Z_{rG} = U^2_{rG}/S_{rG}$ of the synchronous machine, the result in per unit is represented by a small letter $x''_d = X''_d/Z_{rG}$.