

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

The European Standard EN 60909-3:2003 has the status of a
British Standard

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee PEL/73, Short circuit currents, which has the responsibility to:

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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 60909-3:2003)

Courants de court-circuit dans les réseaux triphasés à courant alternatif
Partie 3: Courants durant deux court-circuits monophasés simultanés séparés à la terre et courants de court-circuit partiels s'écoulant à travers la terre
(CEI 60909-3:2003)

Kurzschlussströme in Drehstromnetzen
Teil 3: Ströme bei Doppelerdkurzschluss und Teilkurzschlussströme über Erde
(IEC 60909-3:2003)

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CENELEC

European Committee for Electrotechnical Standardization
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Foreword

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with the EN have to be withdrawn (dow) 2006-11-01

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 annexes A and B are informative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60909-3:2003 was approved by CENELEC as a European Standard without any modification.

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SHORT-CIRCUIT CURRENTS IN THREE-PHASE AC SYSTEMS –

Part 3: Currents during two separate simultaneous line-to-earth short circuits and partial short-circuit currents flowing through earth

1 Scope

This part of IEC 60909 specifies procedures for calculation of the prospective short-circuit currents with an unbalanced short circuit in high-voltage three-phase AC systems operating at nominal frequency 50 Hz or 60 Hz, i.e.

- a) currents during two separate simultaneous line-to-earth short circuits in isolated neutral or resonant earthed neutral systems;
- b) partial short-circuit currents flowing through earth in case of single line-to-earth short circuit in solidly earthed or low-impedance earthed neutral systems.

The currents calculated by these procedures are used when determining induced voltages or touch or step voltages and rise of earth potential at a station (power station or substation).

This standard does not cover:

- a) short-circuit currents deliberately created under controlled conditions as in short-circuit testing stations, or
- b) short-circuit currents in the electrical installations on board ships or aeroplanes, or
- c) single line-to-earth faults in isolated or resonant earthed systems.

The object of this standard is to establish practical and concise procedures for the calculation of line-to-earth short-circuit currents during two separate simultaneous line-to-earth short circuits and partial short-circuit currents through earth from electrical installations, leading to conservative results with sufficient accuracy. For this purpose, the current is determined by considering an equivalent voltage source applied at the short-circuit location with all other sources set to zero. The procedure is suitable for determination by manual methods or digital computation.

This standard is an addition to IEC 60909-0. General definitions, symbols and calculation assumptions refer to that publication. Special items only are defined or specified in this document. 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.

As stated in IEC 60909-0, short-circuit currents and their parameters may also be determined by system tests.

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

2 Normative reference

The following referenced documents are indispensable for the application 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 60909-0:2001, *Short-circuit currents in three-phase a.c. systems – Part 0: Calculation of currents*

3 Terms and definitions

For the purposes of this standard, the following definitions apply.

3.1

two separate simultaneous line-to-earth short circuits

line-to-earth short circuits at different locations at the same time on different conductors of a three-phase AC system having a resonant earthed or an isolated neutral.

3.2

initial short-circuit currents during two separate simultaneous

line-to-earth short circuits I''_{KEE}

r.m.s. value of the initial short-circuit currents flowing with the same magnitude at both locations at the instant of the two separate simultaneous line-to-earth short circuits.

3.3

total earth current I_{Etot} at the short-circuit location

r.m.s. value of the earth current at the short-circuit location flowing through the earthing system of a station (power station or substation) or the footing resistance of an overhead line tower far away from a station and through earthed conductors to earth (Figures 4 and 5). Such conductors may be earth wires of over-head lines or sheaths, shielding or armouring of cables.

3.4

earth current I_{ETn}

r.m.s. value of the earth current causing the potential to rise above earth at an overhead line tower n in the vicinity of a station

3.5

earth current I_{EBn}

r.m.s. value of the earth current causing the potential to rise above earth U_{EBn} of station B, in case of a line-to-earth short circuit at an overhead line tower n in the vicinity of the station B

3.6

partial short-circuit current through earth $\underline{\epsilon} \cdot 3I_{(0)}$

part of the total current flowing through earth remote from the short-circuit location and the earthing system of a station, where the distribution of the total current between earthed conductors and earth is nearly constant. Its magnitude depends on the reduction factor $\underline{\epsilon}$.

3.7

reduction factor r

factor which determines the part of the zero-sequence current flowing through earth remote from the short-circuit location and the earthing system of a station.

3.8

driving point impedance Z_P of an infinite chain

in the case of an overhead line, the driving point impedance, according to Figure 1, is composed of the earth-wire impedance $Z_W = Z'_W \cdot d_T$ between two towers with earth return and the footing resistance R_T of the overhead line towers:

$$Z_P = 0,5 \cdot Z_W + \sqrt{(0,5 \cdot Z_W)^2 + Z_W R_T} \quad (1)$$

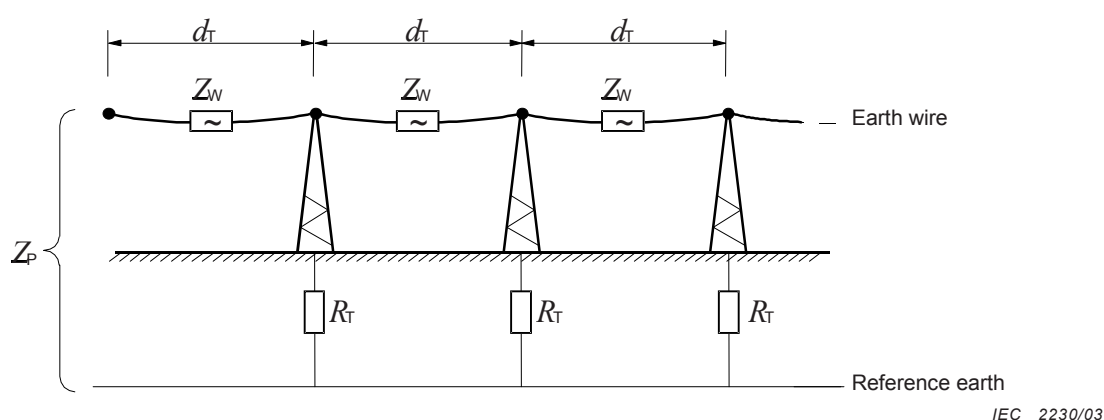


Figure 1 – Driving point impedance Z_P of an infinite chain, composed of the earth-wire impedance $Z_W = Z'_W \cdot d_T$ and the footing resistance R_T of the towers, with equal distances d_T between towers

The driving point impedance Z_P can be assumed constant at a distance from the short-circuit location F longer than the far-from-station distance D_F defined by Equation (18).

In the case of power cables, a similar approach may be used, but special considerations are necessary.

3.9

driving point impedance Z_{Pn} of a finite chain

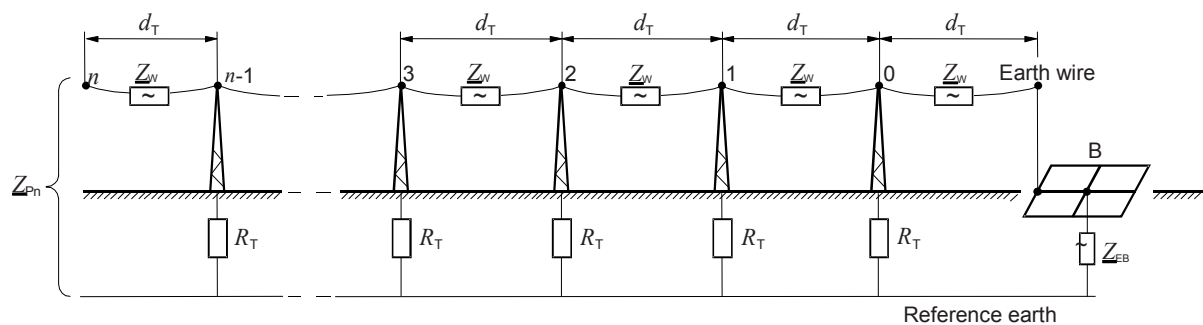
driving point impedance Z_{Pn} of an overhead line, with n towers as given in Figure 2 and with the earth impedance Z_{EB} of a station B at the end, can be calculated according to Equation (2):

$$Z_{Pn} = \frac{Z_P \left(\frac{Z_{EB} + Z_P}{Z_P} \right) \cdot k^n + \left[Z_P \left(\frac{Z_{EB} - Z_P + 2 \cdot Z_W}{Z_P} \right) - Z_W \left(\frac{Z_{EB} + Z_W}{Z_P} \right) \right] \cdot k^{-n}}{\left(\frac{Z_{EB} + Z_P}{Z_P} \right) \cdot k^n - \left(\frac{Z_{EB} - Z_P + Z_W}{Z_P} \right) \cdot k^{-n}} \quad (2)$$

with

$$k = 1 + Z_W \left(\frac{1}{R_T} + \frac{1}{Z_P} \right) \quad (3)$$

NOTE For $n \rightarrow \infty$, Equation (2) is leading to Equation (1). In practical cases, this is already true for $n \approx 10 \dots 15$.



IEC 2231/03

Figure 2 – Driving point impedance $\underline{Z}_{Pn}$ of a finite chain with n towers, composed of the earth-wire impedance $\underline{Z}_W = \underline{Z}'_W \cdot d_T$, the footing resistance R_T of the towers with equal distances d_T between towers and the earthing impedance $\underline{Z}_{EB}$ (Equation (28)) of a station B

4 Symbols

All equations are written as quantity equations, in which the symbols represent physical quantities possessing both numerical values and dimensions. Symbols of complex quantities are underlined, e.g. $\underline{Z} = R + jX$.

c	Voltage factor according to Table 1 of IEC 60909-0
$cU_n/\sqrt{3}$	Equivalent voltage source, see IEC 60909-0
D_F	Far-from-station distance
d_T	Distance between towers
I_{bEE}	Short-circuit breaking current in the case of two separate simultaneous line-to-earth short circuits
I_{Etot}	Total earth current at the short-circuit location
I_{ETn}	Earth current at the short-circuited tower in the vicinity of a station
I''_{k1}	Initial line-to-earth short-circuit current
I''_{KEE}	Initial short-circuit current in the case of two separate simultaneous line-to-earth short circuits
I''_{KE2E}	Initial short-circuit current flowing to earth in the case of a line-to-line short circuit with earth connection, see IEC 60909-0
I_W	Earth wire current
i_{pEE}	Peak short-circuit current in the case of two separate simultaneous line-to-earth short circuits
I_T	Short-circuit current through the tower
$\underline{M}_{(1)}, \underline{M}_{(2)}$	Coupling impedance, in the positive- and negative-sequence system
R_E	Resistance of earth grid
R_T	Footing resistance of an overhead line tower
$\mathcal{L}$	Reduction factor
$\mathcal{L}^3 \underline{I}_{(0)}$	Partial short-circuit current through earth at a distance longer than D_F
$\underline{Z}_{(1)A}, \underline{Z}_{(1)B}$	Positive-sequence short-circuit impedance of the three-phase AC system at the short-circuit locations A and B

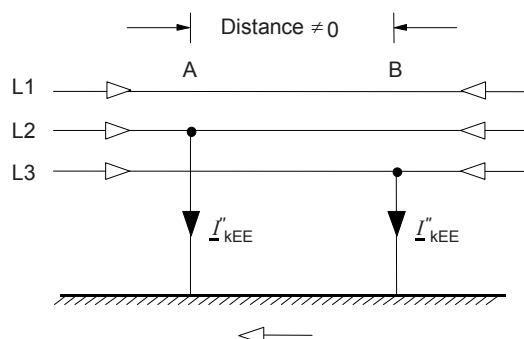
$Z_{(2)A}, Z_{(2)B}$	Negative-sequence short-circuit impedance of the three-phase AC system at the short-circuit locations A and B
$Z_{(0)}$	Zero-sequence short-circuit impedance of the entire network between the short-circuit locations A and B (admittances between line conductors and earth are disregarded)
Z_E	Earthing impedance of a station according to Equation (28)
Z_{ET}	Earthing impedance of the short circuited tower according to Equation (27)
Z_{Etot}	Total earthing impedance of a station according to Equation (16)
Z_{ETtot}	Total earthing impedance of the short circuited tower according to Equation (21)
Z_P	Driving point impedance of an infinite chain (Equation (1) and Figure 1)
Z_{Pn}	Driving point impedance of a finite chain (Equation (2) and Figure 2)
Z_U	Input impedance of sheaths, shielding or armouring of cables
$Z_W = Z'_W \cdot d_T$	Earth-wire impedance between two towers
Z'_W	Per unit length earth-wire impedance with earth return
Z'_{WL}	Per unit length mutual impedance between earth wires and the line conductors with common earth return
δ	Equivalent earth penetration depth
ρ	Soil resistivity

5 Currents during two separate simultaneous line-to-earth short circuits

5.1 Calculation method

5.1.1 Initial symmetrical short-circuit current

Figure 3 shows the short-circuit current I''_{KEE} during two separate simultaneous line-to-earth short circuits on different line conductors at the locations A and B with finite distance between them, i.e. distance $\neq 0$. It is assumed that the locations A and B are far from stations.



NOTE The direction of current is chosen arbitrarily.

IEC 2232/03

Figure 3 – Characterization of two separate simultaneous line-to-earth short circuits and the current I''_{KEE}