This document is a preview generated by EVS

LÜHISVOOLUD KOLMEFAASILISTES VAHELDUVVOOLUSÜSTEEMIDES. OSA 0: VOOLUDE ARVUTAMINE

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

EESTI STANDARDIKESKUS
ESTONIAN CENTRE FOR STANDARDISATION

EESTI STANDARDI EESSÕNA

NATIONAL FOREWORD

See Eesti standard EVS-EN 60909-0:2016 sisaldab Euroopa standardi EN 60909-0:2016 ingliskeelset teksti.	This Estonian standard EVS-EN 60909-0:2016 consists of the English text of the European standard EN 60909-0:2016.
Standard on jõustunud sellekohase teate avaldamisega EVS Teatajas	This standard has been endorsed with a notification published in the official bulletin of the Estonian Centre for Standardisation.
Euroopa standardimisorganisatsioonid on teinud Euroopa standardi rahvuslikele liikmetele kättesaadavaks 10.06.2016.	Date of Availability of the European standard is 10.06.2016.
Standard on kättesaadav Eesti Standardikeskusest.	The standard is available from the Estonian Centre for Standardisation.

This document is a preview generated by EVS

Tagasisidet standardi sisu kohta on võimalik edastada, kasutades EVS-i veebilehel asuvat tagasiside vormi või saates e-kirja meiliaadressile standardiosakond@evs.ee.

ICS 17.220.01, 29.240.20

Standardite reprodutseerimise ja levitamise õigus kuulub Eesti Standardikeskusele

Andmete paljundamine, taastekitamine, kopeerimine, salvestamine elektroonsesse süsteemi või edastamine ükskõik millises vormis või millisel teel ilma Eesti Standardikeskuse kirjaliku loata on keelatud.

Kui Teil on küsimusi standardite autorikaitse kohta, võtke palun ühendust Eesti Standardikeskusega: Koduleht www.evs.ee; telefon 605 5050; e-post info@evs.ee

The right to reproduce and distribute standards belongs to the Estonian Centre for Standardisation

No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, without a written permission from the Estonian Centre for Standardisation.

If you have any questions about copyright, please contact Estonian Centre for Standardisation:

Homepage www.evs.ee; phone +372 605 5050; e-mail info@evs.ee

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 60909-0

June 2016

ICS 17.220.01; 29.240.20

Supersedes EN 60909-0:2001

English Version

Short-circuit currents in three-phase a.c. systems - Part 0: Calculation of currents (IEC 60909-0:2016)

Courants de court-circuit dans les réseaux triphasés à courant alternatif - Partie 0: Calcul des courants (IEC 60909-0:2016)

Kurzschlussströme in Drehstromnetzen - Teil 0: Berechnung der Ströme (IEC 60909-0:2016)

This European Standard was approved by CENELEC on 2016-03-03. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

© 2016 CENELEC All rights of exploitation in any form and by any means reserved worldwide for CENELEC Members.

Ref. No. EN 60909-0:2016 E

This document is a preview generated by EVS

European foreword

The text of document 73/172/CDV, future edition 2 of IEC 60909-0, prepared by IEC/TC 73 "Shortcircuit currents" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60909-0:2016.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2016-12-10
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2019-06-10

This document supersedes EN 60909-0:2001.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 60909-0:2016 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60865-1	NOTE	Harmonized as EN 60865-1.
IEC 62428	NOTE	Harmonized as EN 62428.

This document is a preview generated by EVS

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60038 (mod)	2009	IEC standard voltages	EN 60038	2011
IEC 60050-131	-	International Electrotechnical Vocabulary (IEV) - Part 131: Circuit theory	-	-
IEC/TR 60909-1	2002	Short-circuit currents in three-phase e.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	EN 60909-3	2010
IEC/TR 60909-4	2000	Short-circuit currents in three-phase a.c. systems - Part 4: Examples for the calculation of short-circuit currents	-	-

This document is a preview generated by EVS

CONTENTS

FOREWORD....5
1 Scope....7
2 Normative references....8
3 Terms and definitions....8
4 Symbols, subscripts and superscripts....13
4.1 General....13
4.2 Symbols....13
4.3 Subscripts....15
4.4 Superscripts....16
5 Characteristics of short-circuit currents: calculating method....16
5.1 General....16
5.2 Calculation assumptions....19
5.3 Method of calculation....20
5.3.1 Equivalent voltage source at the short-circuit location....20
5.3.2 Symmetrical components....22
6 Short-circuit impedances of electrical equipment....23
6.1 General....23
6.2 Network feeders....23
6.3 Transformers....25
6.3.1 Two-winding transformers....25
6.3.2 Three-winding transformers....25
6.3.3 Impedance correction factors for two- and three-winding network transformers....27
6.4 Overhead lines and cables....28
6.5 Short-circuit current-limiting reactors....29
6.6 Synchronous machines....29
6.6.1 Synchronous generators....29
6.6.2 Synchronous compensators and motors....31
6.7 Power station units....31
6.7.1 Power station units with on-load tap-changer....31
6.7.2 Power station units without on-load tap-changer....32
6.8 Wind power station units....33
6.8.1 General....33
6.8.2 Wind power station units with asynchronous generator....33
6.8.3 Wind power station units with doubly fed asynchronous generator....34
6.9 Power station units with full size converter....35
6.10 Asynchronous motors....35
6.11 Static converter fed drives....36
6.12 Capacitors and non-rotating loads....36
7 Calculation of initial short-circuit current....36
7.1 General....36
7.1.1 Overview....36
7.1.2 Maximum and minimum short-circuit currents....41
7.1.3 Contribution of asynchronous motors to the short-circuit current....42
7.2 Three-phase initial short-circuit current....43
7.2.1 General....43

This document is a preview generated by EVS

7.2.2 Short-circuit currents inside a power station unit with on-load tap-changer 44
7.2.3 Short-circuit currents inside a power station unit without on-load tap-changer 46
7.3 Line-to-line short circuit 47
7.4 Line-to-line short circuit with earth connection 47
7.5 Line-to-earth short circuit 49
8 Calculation of peak short-circuit current 49
8.1 Three-phase short circuit 49
8.1.1 Single-fed and multiple single-fed short circuits 49
8.1.2 Multiple-fed short circuit 51
8.2 Line-to-line short circuit 52
8.3 Line-to-line short circuit with earth connection 52
8.4 Line-to-earth short circuit 52
9 Calculation of symmetrical breaking current 53
9.1 Three-phase short circuit 53
9.1.1 Symmetrical breaking current of synchronous machines 53
9.1.2 Symmetrical breaking current of asynchronous machines 54
9.1.3 Symmetrical breaking current of power station units with doubly fed asynchronous generator 55
9.1.4 Symmetrical breaking current of power station units with full size converter 55
9.1.5 Symmetrical breaking current of network feeder 56
9.1.6 Symmetrical breaking current in case of multiple single-fed short-circuits 56
9.1.7 Symmetrical breaking current in case of multiple-fed short circuits 56
9.2 Unbalanced short-circuits 57
10 DC component of the short-circuit current 57
11 Calculation of steady-state short-circuit current 58
11.1 General 58
11.2 Three-phase short circuit 58
11.2.1 Steady-state short-circuit current of one synchronous generator or one power station unit 58
11.2.2 Steady-state short-circuit current of asynchronous motor or generator 61
11.2.3 Steady-state short-circuit current of wind power station unit with doubly fed asynchronous generator 61
11.2.4 Steady-state short-circuit current of wind power station unit with full size converter 61
11.2.5 Steady-state short-circuit current of network feeder 61
11.2.6 Steady-state short-circuit current in case of multiple single-fed short circuits 61
11.2.7 Steady-state short-circuit current in case of multiple-fed short circuits 62
11.3 Unbalanced short circuits 62
12 Short circuits at the low-voltage side of transformers, if one line conductor is interrupted at the high-voltage side 62
13 Terminal short circuit of asynchronous motors 64
14 Joule integral and thermal equivalent short-circuit current 65
Annex A (normative) Formulas for the calculation of the factors m and n 68
Annex B (informative) Nodal admittance and nodal impedance matrices 69
Bibliography 73

This document is preview generated by EVS

Figure 1 – Short-circuit current of a far-from-generator short circuit with constant AC component (schematic diagram) 17
Figure 2 – Short-circuit current of a near-to-generator short-circuit with decaying AC component (schematic diagram) 18
Figure 3 – Characterization of short-circuits and their currents 19
Figure 4 – Illustration for calculating the initial symmetrical short-circuit current I_k'' in compliance with the procedure for the equivalent voltage source 21
Figure 5 – System diagram and equivalent circuit diagram for network feeders 24
Figure 6 – Three-winding transformer (example) 27
Figure 7 – Diagram to determine the short-circuit type (Figure 3) for the highest initial short-circuit current referred to the initial three-phase short-circuit current when the impedance angles of the sequence impedances $Z_{(1)}$, $Z_{(2)}$, $Z_{(0)}$ are identical 38
Figure 8 – Examples of single-fed short-circuits 40
Figure 9 – Example of a multiple single-fed short circuit 40
Figure 10 – Example of multiple-fed short circuit 41
Figure 11 – Short-circuit currents and partial short-circuit currents for three-phase short circuits between generator and unit transformer with or without on-load tap-changer, or at the connection to the auxiliary transformer of a power station unit and at the auxiliary busbar A 45
Figure 12 – Factor κ for series circuit as a function of ratio R/X or X/R 50
Figure 13 – Factor μ for calculation of short-circuit breaking current I_b 54
Figure 14 – Factor q for the calculation of the symmetrical short-circuit breaking current of asynchronous motors 55
Figure 15 – Factors λ_{min} and λ_{max} factors for cylindrical rotor generators 60
Figure 16 – Factors λ_{min} and λ_{max} for salient-pole generators 60
Figure 17 – Transformer secondary short-circuits, if one line (fuse) is opened on the high-voltage side of a transformer Dyn5 63
Figure 18 – Factor m for the heat effect of the DC component of the short-circuit current (for programming, the formula to calculate m is given in Annex A) 66
Figure 19 – Factor n for the heat effect of the AC component of the short-circuit current (for programming, the formula to calculate n is given in Annex A) 67
Figure B.1 – Formulation of the nodal admittance matrix 70
Figure B.2 – Example 71

Table 1 – Voltage factor c 22
Table 2 – Importance of short-circuit currents 37
Table 3 – Factors α and β for the calculation of short-circuit currents with Formula (96), rated transformation ratio $t_r = U_{rTHV}/U_{rTLV}$ 64
Table 4 – Calculation of short-circuit currents of asynchronous motors in the case of a short circuit at the terminals 65
Table B.1 – Impedances of electrical equipment referred to the 110 kV side 71

This document is a preview generated by EVS

SHORT-CIRCUIT CURRENTS IN THREE-PHASE AC SYSTEMS –

Part 0: Calculation of currents

This document is a preview generated by EVS

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).