

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Surge arresters –
Part 5: Selection and application recommendations**

**Parafoudres –
Partie 5: Recommandations pour le choix et l'utilisation**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2013 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue

The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue

Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org

Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary

65 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Surge arresters –
Part 5: Selection and application recommendations**

**Parafoudres –
Partie 5: Recommandations pour le choix et l'utilisation**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.120.50; 29.240.10

ISBN 978-2-8322-4488-3

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

CONTENTS

FOREWORD.....	6
1 Scope.....	8
2 Normative references	8
3 Terms and definitions	9
4 General principles for the application of surge arresters	18
5 Surge arrester fundamentals and applications issues	19
5.1 Evolution of surge protection equipment.....	19
5.2 Different types and designs and their electrical and mechanical characteristics	20
5.2.1 General	20
5.2.2 Metal-oxide arresters without gaps according to IEC 60099-4.....	20
5.2.3 Metal-oxide surge arresters with internal series gaps according to IEC 60099-6	30
5.2.4 Externally gapped line arresters (EGLA) according to IEC 60099-8:2011	32
5.3 Installation considerations for arresters	35
5.3.1 High-voltage station arresters	35
5.3.2 Distribution arresters	43
5.3.3 Line surge arresters (LSA).....	46
6 Insulation coordination and surge arrester applications	47
6.1 General.....	47
6.2 Insulation coordination overview.....	47
6.2.1 General	47
6.2.2 IEC insulation coordination procedure	48
6.2.3 Overvoltages	48
6.2.4 Line insulation coordination: Arrester Application Practices	53
6.2.5 Substation insulation coordination: Arrester application practices	58
6.2.6 Insulation coordination studies	62
6.3 Selection of arresters	63
6.3.1 General	63
6.3.2 General procedure for the selection of surge arresters	65
6.3.3 Selection of line surge arresters, LSA.....	75
6.3.4 Selection of arresters for cable protection.....	84
6.3.5 Selection of arresters for distribution systems – special attention	86
6.3.6 Selection of UHV arresters	88
6.4 Normal and abnormal service conditions	89
6.4.1 Normal service condition	89
6.4.2 Abnormal service conditions	89
7 Surge arresters for special applications	92
7.1 Surge arresters for transformer neutrals	92
7.1.1 General	92
7.1.2 Surge arresters for fully insulated transformer neutrals.....	92
7.1.3 Surge arresters for neutrals of transformers with non-uniform insulation.....	93
7.2 Surge arresters between phases	93
7.3 Surge arresters for rotating machines.....	94
7.4 Surge arresters in parallel	95

7.4.1	General	95
7.4.2	Combining different designs of arresters.....	96
7.5	Surge arresters for capacitor switching.....	96
7.6	Surge arresters for series capacitor banks	98
8	Asset management of surge arresters	98
8.1	General	98
8.2	Managing surge arresters in a power grid.....	98
8.2.1	Asset database.....	98
8.2.2	Technical specifications.....	98
8.2.3	Strategic spares	99
8.2.4	Transportation and storage.....	99
8.2.5	Commissioning	99
8.3	Maintenance.....	99
8.3.1	General	99
8.3.2	Polluted arrester housing.....	100
8.3.3	Coating of arrester housings.....	100
8.3.4	Inspection of disconnectors on surge arresters.....	101
8.3.5	Line surge arresters	101
8.4	Performance and diagnostic tools.....	101
8.5	End of life.....	101
8.5.1	General	101
8.5.2	GIS arresters.....	101
8.6	Disposal and recycling	102
Annex A (informative)	Determination of temporary overvoltages due to earth faults	103
Annex B (informative)	Current practice	107
Annex C (informative)	Arrester modelling techniques for studies involving insulation coordination and energy requirements	108
Annex D (informative)	Diagnostic indicators of metal-oxide surge arresters in service.....	111
Annex E (informative)	Typical data needed from arrester manufacturers for proper selection of surge arresters.....	125
Annex F (informative)	Typical maximum residual voltages for metal-oxide arresters without gaps according to IEC 60099-4.....	126
Annex G (informative)	Steepness reduction of incoming surge with additional line terminal surge capacitance	127
Annex H (informative)	End of life and replacement of old gapped SiC-arresters.....	136
Bibliography.....	141
Figure 1	– GIS arresters of three mechanical/one electrical column (middle) and one column (left) design and current path of the three mechanical/one electrical column design (right)	25
Figure 2	– Typical deadfront arrester	26
Figure 3	– Internally gapped metal-oxide surge arrester designs.....	30
Figure 4	– Components of an EGLA acc. to IEC 60099-8	32
Figure 5	– Examples of UHV and HV arresters with grading and corona rings.....	36
Figure 6	– Same type of arrester mounted on a pedestal (left), suspended from an earthed steel structure (middle) or suspended from a line conductor (right).....	37
Figure 7	– Typical arrangement of a 420-kV arrester.....	39
Figure 8	– Installations without earth-mat (distribution systems)	40

Figure 9 – Installations with earth-mat (high-voltage substations)	40
Figure 10 – Definition of mechanical loads according to IEC 60099-4	42
Figure 11 – Distribution arrester with disconnecter and insulating bracket.....	44
Figure 12 – Examples of good and poor earthing principles for distribution arresters	45
Figure 13 – Typical voltages and duration example for an efficiently earthed system	49
Figure 14 – Typical phase-to-earth overvoltages encountered in power systems.....	50
Figure 15 – Arrester Voltage-Current Characteristics	51
Figure 16 – Direct strike to a phase conductor with LSA	55
Figure 17 – Strike to a shield wire or tower with LSA	56
Figure 18 – Typical procedure for a surge arrester insulation coordination study	61
Figure 19 – Flow diagrams for standard selection of surge arrester	67
Figure 20 – Examples of arrester TOV capability	68
Figure 21 – Flow diagram for the selection of NGLA	77
Figure 22 – Flow diagram for the selection of EGLA.....	81
Figure 23 – Common neutral configurations	87
Figure 24 – Typical configurations for arresters connected phase-to-phase and phase-to-ground.....	94
Figure A.1 – Earth fault factor k on a base of X_0/X_1 , for $R_1/X_1 = R_1 = 0$	104
Figure A.2 – Relationship between R_0/X_1 and X_0/X_1 for constant values of earth fault factor k where $R_1 = 0$	104
Figure A.3 – Relationship between R_0/X_1 and X_0/X_1 for constant values of earth fault factor k where $R_1 = 0,5 X_1$	105
Figure A.4 – Relationship between R_0/X_1 and X_0/X_1 for constant values of earth fault factor k where $R_1 = X_1$	105
Figure A.5 – Relationship between R_0/X_1 and X_0/X_1 for constant values of earth fault factor k where $R_1 = 2X_1$	106
Figure C.1 – Schematic sketch of a typical arrester installation.....	108
Figure C.2 – Increase in residual voltage as function of virtual current front time	109
Figure C.3 – Arrester model for insulation coordination studies – fast-front overvoltages and preliminary calculation (Option 1)	110
Figure C.4 – Arrester model for insulation coordination studies – fast-front overvoltages and preliminary calculation (Option 2)	110
Figure C.5 – Arrester model for insulation coordination studies – slow-front overvoltages	110
Figure D.1 – Typical leakage current of a non-linear metal-oxide resistor in laboratory conditions	113
Figure D.2 – Typical leakage currents of arresters in service conditions	114
Figure D.3 – Typical voltage-current characteristics for non-linear metal-oxide resistors.....	115
Figure D.4 – Typical normalized voltage dependence at +20 °C	115
Figure D.5 – Typical normalized temperature dependence at U_c	116
Figure D.6 – Influence on total leakage current by increase in resistive leakage current	117
Figure D.7 – Measured voltage and leakage current and calculated resistive and capacitive currents ($V = 6,3$ kV r.m.s)	119
Figure D.8 – Remaining current after compensation by capacitive current at U_c	120

Figure D.9 – Error in the evaluation of the leakage current third harmonic for different phase angles of system voltage third harmonic, considering various capacitances and voltage-current characteristics of non-linear metal-oxide resistors	121
Figure D.10 – Typical information for conversion to "standard" operating voltage conditions	123
Figure D.11 – Typical information for conversion to "standard" ambient temperature conditions	123
Figure G.1 – Surge voltage waveforms at various distances from strike location (0,0 km) due to corona	128
Figure G.2 – Case 1: EMTP Model: Thevenin equivalent source, line (Z,c) & station bus (Z,c) & Cap(C _S)	131
Figure G.3 – Case 2: Capacitor Voltage charge via line Z: $u(t) = 2 \times U_S \times (1 - \exp[-t/(Z \times C)])$	132
Figure G.4 – EMTP model	133
Figure G.5 – Simulated surge voltages at the line-station bus interface	133
Figure G.6 – Simulated Surge Voltages at the Transformer	134
Figure G.7 – EMTP Model	134
Figure G.8 – Simulated surge voltages at the line-station bus interface	135
Figure G.9 – Simulated surge voltages at the transformer	135
Figure H.1 – Internal SiC-arrester stack	137
Table 1 – Minimum mechanical requirements (for porcelain-housed arresters)	42
Table 2 – Arrester classification for surge arresters	69
Table 3 – Definition of factor A in formulas (15) to (17) for various overhead lines	74
Table 4 – Examples for protective zones calculated by formula (10) for open-air substations	74
Table 5 – Example of the condition for calculating lightning current duty of EGLA in 77 kV transmission lines	83
Table 6 – Probability of insulator flashover in Formula (19)	84
Table D.1 – Summary of diagnostic methods	124
Table D.2 – Properties of on-site leakage current measurement methods	124
Table E.1 – Arrester data needed for the selection of surge arresters	125
Table F.1 – Residual voltages for 20 000 A and 10 000 A arresters in per unit of rated voltage	126
Table F.2 – Residual voltages for 5 000 A, 2 500 A and 1 500 A arresters in per unit of rated voltage	126
Table G.1 – C _S impact on steepness ratio f_S and steepness S_n	130
Table G.2 – Change in coordination withstand voltage, U_{CW} ,	130

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SURGE ARRESTERS –**Part 5: Selection and application recommendations**

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of 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, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). 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. 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 IEC on technical matters express, as far as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 60099-5 has been prepared by committee 37: Surge arresters.

This second edition cancels and replaces the first edition published in 1996 and its amendment 1 published in 1999. This edition constitutes a technical revision.

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

- a) Expanded discussion of different types of arresters and their application, including additions of discussion on:
 - transmission of line arresters
 - arresters for shunt capacitor switching
 - arresters for series capacitor protection
 - application of arresters between phases
 - connecting arresters in parallel

- b) Addition of section on asset management, including:
- managing surge arresters in the power grid
 - arrester maintenance
 - significantly expanded discussion of performance diagnostic tools
 - end-of-life considerations
- c) New annexes dealing with:
- arrester modelling for system studies
 - example of data needed for specifying arresters

This bilingual version (2017-06) corresponds to the English version, published in 2013-05.

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

FDIS	Report on voting
37/405/FDIS	37/408/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.

The French version of this standard has not been voted upon.

This publication has been drafted in accordance with the IEC/ISO Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site 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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

SURGE ARRESTERS –

Part 5: Selection and application recommendations

1 Scope

This part of IEC 60099 is not a mandatory standard but provides information, guidance, and recommendations for the selection and application of surge arresters to be used in three-phase systems with nominal voltages above 1 kV. It applies to gapless metal-oxide surge arresters as defined in IEC 60099-4, to surge arresters containing both series and parallel gapped structure – rated 52 kV and less as defined in IEC 60099-6 and metal-oxide surge arresters with external series gap for overhead transmission and distribution lines (ECLA) as defined in IEC 60099-8. In Annex H, some aspects regarding the old type of S.C. gapped arresters are discussed.

The principle of insulation coordination for an electricity system is given in IEC 60071 and IEC 60071-2 standards. Basically the insulation coordination process is a risk management aiming to ensure the safe, reliable and economic design and operation of high voltage electricity networks and substations. The use of surge arrester helps to achieve a system and equipment insulation level and still maintaining an acceptable risk and the best economic of scale.

The introduction of analytical modelling and simulation of power system transients further optimise the equipment insulation level. The selection of surge arresters has become more and more important in the power system design and operation. It is worthwhile to note that the reliability of the power system and equipment is dependent on the safety margin adopted by the user in the design and selection of the equipments and surge arresters.

Surge arrester residual voltage is a major parameter of which most users have paid a lot of attention to when selecting the type and rating. The typical maximum surge arresters residual voltage are given in Annex F. It is likely, however, that for some systems, or in some countries, the system reliability requirements and design are sufficiently uniform that the recommendations of the present standard may lead to the definition of narrow ranges of arresters. The user of surge arresters will, in that case, not be required to apply the whole process introduced here to a new installation and the selection of characteristics resulting from prior practice may be continued.

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 60071-1:2006, *Insulation coordination – Part 1: Definitions, principles and rules*

IEC 60071-2:1996, *Insulation coordination – Part 2: Application guide*

IEC TR 60071-4, *Insulation coordination – Part 4: Computational guide to insulation coordination and modelling of electrical networks*

IEC 60099-4:2009, *Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems*