

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Low-voltage switchgear and controlgear –
Part 2: Circuit-breakers**

**Appareillage à basse tension –
Partie 2: Disjoncteurs**



THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2016 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 It also gives information on projects, replaced and withdrawn publications.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 15 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 15 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



**Low-voltage switchgear and controlgear –
Part 2: Circuit-breakers**

**Appareillage à basse tension –
Partie 2: Disjoncteurs**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.130.20

ISBN 978-2-8322-3355-9

**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 | 14 |
| 1 General | 16 |
| 1.1 Scope and object | 16 |
| 1.2 Normative references | 17 |
| 2 Terms and definitions | 18 |
| 3 Classification | 22 |
| 4 Characteristics of circuit-breakers | 23 |
| 4.1 Summary of characteristics | 23 |
| 4.2 Type of circuit-breaker | 23 |
| 4.3 Rated and limiting values of the main circuit | 23 |
| 4.3.1 General | 23 |
| 4.3.2 Rated voltages | 23 |
| 4.3.3 Currents | 24 |
| 4.3.4 Rated frequency | 24 |
| 4.3.5 Rated duty | 24 |
| 4.3.6 Short-circuit characteristics | 24 |
| 4.4 Selectivity categories | 27 |
| 4.5 Control circuits | 27 |
| 4.5.1 Electrical control circuits | 27 |
| 4.5.2 Air-supply control circuits (pneumatic or electro-pneumatic) | 27 |
| 4.6 Auxiliary circuits | 27 |
| 4.7 Releases | 28 |
| 4.7.1 Types | 28 |
| 4.7.2 Characteristics | 28 |
| 4.7.3 Current setting of over-current releases | 28 |
| 4.7.4 Tripping time setting of over-current releases | 29 |
| 4.8 Integral fuses (integrally fused circuit-breakers) | 29 |
| 5 Product information | 29 |
| 5.1 Nature of the information | 29 |
| 5.2 Marking | 29 |
| 5.3 Instructions for installation, operation and maintenance | 31 |
| 6 Normal service, mounting and transport conditions | 31 |
| 7 Constructional and performance requirements | 31 |
| 7.1 Constructional requirements | 31 |
| 7.1.1 General | 31 |
| 7.1.2 Withdrawable circuit-breakers | 31 |
| 7.1.3 Additional requirements for circuit-breakers suitable for isolation | 32 |
| 7.1.4 Clearances and creepage distances | 32 |
| 7.1.5 Requirements for the safety of the operator | 32 |
| 7.1.6 List of construction breaks | 32 |
| 7.1.7 Additional requirements for circuit-breakers provided with a neutral pole | 33 |
| 7.1.8 Digital inputs and outputs for use with programmable logic controllers (PLCs) | 33 |
| 7.2 Performance requirements | 33 |
| 7.2.1 Operating conditions | 33 |

| | | |
|---|---|----|
| 7.2.2 | Temperature-rise | 36 |
| 7.2.3 | Dielectric properties | 37 |
| 7.2.4 | Ability to make and break under no load, normal load and overload conditions | 37 |
| 7.2.5 | Ability to make and break under short-circuit conditions | 38 |
| 7.2.6 | Vacant | 39 |
| 7.2.7 | Additional requirements for circuit-breakers suitable for isolation | 39 |
| 7.2.8 | Specific requirements for integrally fused circuit-breakers..... | 39 |
| 7.2.9 | Co-ordination between a circuit-breaker and another short-circuit protective device..... | 39 |
| 7.3 | Electromagnetic compatibility (EMC) | 39 |
| 8 | Tests..... | 39 |
| 8.1 | Kind of tests..... | 39 |
| 8.1.1 | General..... | 39 |
| 8.1.2 | Type tests..... | 39 |
| 8.1.3 | Routine tests..... | 40 |
| 8.2 | Compliance with constructional requirements | 40 |
| 8.3 | Type tests..... | 40 |
| 8.3.1 | Test sequences..... | 40 |
| 8.3.2 | General test conditions | 48 |
| 8.3.3 | Test sequence I: General performance characteristics | 56 |
| 8.3.4 | Test sequence II: Rated service short-circuit breaking capacity | 65 |
| 8.3.5 | Test sequence III: Rated ultimate short-circuit breaking capacity | 66 |
| 8.3.6 | Test sequence IV: Rated short-time withstand current | 68 |
| 8.3.7 | Test sequence V: Performance of integrally fused circuit-breakers..... | 69 |
| 8.3.8 | Test sequence VI: combined test sequence | 71 |
| 8.3.9 | Critical d.c. load current test | 73 |
| 8.4 | Routine tests | 74 |
| 8.4.1 | General..... | 74 |
| 8.4.2 | Mechanical operation tests..... | 74 |
| 8.4.3 | Verification of the calibration of overcurrent releases..... | 75 |
| 8.4.4 | Verification of the operation of undervoltage and shunt releases..... | 75 |
| 8.4.5 | Additional tests for CBRs | 75 |
| 8.4.6 | Dielectric tests | 76 |
| 8.4.7 | Test for the verification of clearances less than those corresponding to the case 1 of Table 13 of IEC 60947-1:2007 | 77 |
| 8.5 | Special tests – Damp heat, salt mist, vibration and shock | 77 |
| Annex A (normative) Co-ordination between a circuit-breaker and another short-circuit protective device associated in the same circuit..... | | 79 |
| A.1 | General | 79 |
| A.2 | Scope and object | 79 |
| A.3 | General requirements for the co-ordination of a circuit-breaker with another SCPD | 80 |
| A.3.1 | General considerations | 80 |
| A.3.2 | Take-over current..... | 80 |
| A.3.3 | Behaviour of C_1 in association with another SCPD | 80 |
| A.4 | Type and characteristics of the associated SCPD | 80 |
| A.5 | Verification of selectivity | 81 |
| A.5.1 | General..... | 81 |
| A.5.2 | Consideration of selectivity by desk study..... | 81 |

| | | |
|---------------------|---|-----|
| A.5.3 | Selectivity determined by test..... | 82 |
| A.6 | Verification of back-up protection | 83 |
| A.6.1 | Determination of the take-over current..... | 83 |
| A.6.2 | Verification of back-up protection | 83 |
| A.6.3 | Tests for verification of back-up protection | 83 |
| A.6.4 | Results to be obtained | 84 |
| Annex B (normative) | Circuit-breakers incorporating residual current protection..... | 90 |
| B.1 | General | 90 |
| B.1.1 | Preamble | 90 |
| B.1.2 | Scope and object | 90 |
| B.2 | Terms and definitions..... | 91 |
| B.2.1 | Terms and definitions relating to currents flowing from live parts to earth..... | 91 |
| B.2.2 | Terms and definitions relating to the energization of a CBR..... | 91 |
| B.2.3 | Terms and definitions relating to the operation and the functions of a CBR | 92 |
| B.2.4 | Terms and definitions relating to values and ranges of energizing quantities..... | 93 |
| B.3 | Classification | 94 |
| B.3.1 | Classification according to the method of operation of the residual current function..... | 94 |
| B.3.2 | Classification according to the possibility of adjusting the residual operating current | 94 |
| B.3.3 | Classification according to time-delay of the residual current function | 94 |
| B.3.4 | Classification according to behaviour in presence of a d.c. component..... | 94 |
| B.4 | Characteristics of CBRs concerning their residual current function..... | 94 |
| B.4.1 | Rated values..... | 94 |
| B.4.2 | Preferred and limiting values | 95 |
| B.4.3 | Value of the rated residual short-circuit making and breaking capacity ($I_{\Delta m}$) | 96 |
| B.4.4 | Operating characteristics in case of an earth fault current in the presence or absence of a d.c. component | 96 |
| B.5 | Marking | 96 |
| B.6 | Normal service mounting and transport conditions | 97 |
| B.7 | Design and operating requirements | 98 |
| B.7.1 | Design requirements | 98 |
| B.7.2 | Operating requirements..... | 98 |
| B.7.3 | Electromagnetic compatibility | 100 |
| B.8 | Tests | 100 |
| B.8.1 | General..... | 100 |
| B.8.2 | Verification of the operating characteristic | 103 |
| B.8.3 | Verification of dielectric properties..... | 105 |
| B.8.4 | Verification of the operation of the test device at the limits of rated voltage | 105 |
| B.8.5 | Verification of the limiting value of the non-operating current under over-current conditions | 105 |
| B.8.6 | Verification of the resistance against unwanted tripping due to surge currents resulting from impulse voltages | 106 |
| B.8.7 | Verification of the behaviour of CBRs of type A in the case of an earth fault current comprising a d.c. component | 107 |

| | | |
|-----------------------|---|-----|
| B.8.8 | Verification of the behaviour of CBRs functionally dependent on line voltage classified under B.3.1.2.1..... | 108 |
| B.8.9 | Verification of the behaviour of CBRs functionally dependent on line voltage as classified under B.3.1.2.2 in the case of failure of line voltage | 109 |
| B.8.10 | Verification of the residual short-circuit making and breaking capacity | 110 |
| B.8.11 | Verification of the effects of environmental conditions..... | 111 |
| B.8.12 | Verification of electromagnetic compatibility | 111 |
| B.8.13 | Test for variations or interruptions of voltage and for voltage dips | 113 |
| Annex C (normative) | Individual pole short-circuit test sequence | 121 |
| C.1 | General | 121 |
| C.2 | Test of individual pole short-circuit breaking capacity | 121 |
| C.3 | Verification of dielectric withstand | 121 |
| C.4 | Verification of overload releases | 121 |
| Annex D | Vacant..... | 122 |
| Annex E (informative) | Items subject to agreement between manufacturer and user | 123 |
| Annex F (normative) | Additional tests for circuit-breakers with electronic over-current protection | 124 |
| F.1 | General | 124 |
| F.2 | List of tests | 124 |
| F.2.1 | General..... | 124 |
| F.2.2 | Electromagnetic compatibility (EMC) tests | 124 |
| F.2.3 | Suitability for multiple frequencies | 125 |
| F.2.4 | Dry heat test | 125 |
| F.2.5 | Damp heat test | 125 |
| F.2.6 | Temperature variation cycles at a specified rate of change | 125 |
| F.3 | General test conditions | 125 |
| F.3.1 | General..... | 125 |
| F.3.2 | Electromagnetic compatibility tests..... | 125 |
| F.4 | Immunity tests | 126 |
| F.4.1 | Harmonic currents | 126 |
| F.4.2 | Electrostatic discharges | 127 |
| F.4.3 | Radiated RF electromagnetic fields | 127 |
| F.4.4 | Electrical fast transient/burst (EFT/B) | 127 |
| F.4.5 | Surge | 128 |
| F.4.6 | Conducted disturbances induced by RF fields (common mode) | 128 |
| F.4.7 | Current dips | 128 |
| F.5 | Emission tests | 129 |
| F.5.1 | Harmonics | 129 |
| F.5.2 | Voltage fluctuations..... | 129 |
| F.5.3 | Conducted RF disturbances (150 kHz to 30 MHz)..... | 129 |
| F.5.4 | Radiated RF disturbances (30 MHz to 1 GHz)..... | 129 |
| F.6 | Suitability for multiple frequencies | 130 |
| F.6.1 | General..... | 130 |
| F.6.2 | Test conditions..... | 130 |
| F.6.3 | Test procedure..... | 130 |
| F.6.4 | Test results..... | 130 |
| F.7 | Dry heat test | 131 |
| F.7.1 | Test procedure..... | 131 |

| | | |
|-----------------------|--|-----|
| F.7.2 | Test results | 131 |
| F.7.3 | Verification of overload releases | 131 |
| F.8 | Damp heat test | 131 |
| F.8.1 | Test procedure..... | 131 |
| F.8.2 | Verification of overload releases | 131 |
| F.9 | Temperature variation cycles at a specified rate of change | 131 |
| F.9.1 | Test conditions..... | 131 |
| F.9.2 | Test procedure..... | 132 |
| F.9.3 | Test results..... | 132 |
| F.9.4 | Verification of overload releases | 132 |
| Annex G (normative) | Power loss | 145 |
| G.1 | General | 145 |
| G.2 | Test methods | 145 |
| G.2.1 | General case | 145 |
| G.2.2 | AC circuit-breakers of rated current not exceeding 400 A..... | 145 |
| G.2.3 | DC circuit-breakers | 146 |
| G.3 | Test procedure..... | 146 |
| Annex H (normative) | Test sequence for circuit-breakers for IT systems | 148 |
| H.1 | General | 148 |
| H.2 | Individual pole short-circuit | 148 |
| H.3 | Verification of dielectric withstand | 149 |
| H.4 | Verification of overload releases | 149 |
| H.5 | Marking | 149 |
| Annex J (normative) | Electromagnetic compatibility (EMC) – Requirements and test methods for circuit-breakers | 150 |
| J.1 | General | 150 |
| J.2 | Immunity..... | 151 |
| J.2.1 | General..... | 151 |
| J.2.2 | Electrostatic discharge | 153 |
| J.2.3 | Radiated RF electromagnetic fields | 154 |
| J.2.4 | Electrical fast transients/bursts (EFT/B)..... | 154 |
| J.2.5 | Surges..... | 154 |
| J.2.6 | Conducted disturbances induced by RF fields (common mode)..... | 155 |
| J.3 | Emission | 155 |
| J.3.1 | General | 155 |
| J.3.2 | Conducted RF disturbances (150 kHz to 30 MHz)..... | 156 |
| J.3.3 | Radiated RF disturbances (30 MHz to 1 000 MHz)..... | 156 |
| Annex K (informative) | Glossary of symbols and graphical representation of characteristics | 161 |
| Annex L (normative) | Circuit-breakers not fulfilling the requirements for overcurrent protection | 170 |
| L.1 | General | 170 |
| L.2 | Terms and definitions..... | 170 |
| L.3 | Classification | 170 |
| L.4 | Rated values..... | 170 |
| L.4.1 | Rated current (I_n)..... | 170 |
| L.4.2 | Rated conditional short-circuit current (I_{cc}) | 171 |
| L.5 | Product information..... | 171 |
| L.6 | Constructional and performance requirements..... | 171 |

| | | |
|---|---|-----|
| L.7 | Tests | 171 |
| L.7.1 | General..... | 171 |
| L.7.2 | Rated conditional short-circuit tests..... | 172 |
| Annex M (normative) Modular residual current devices (without integral current breaking device) | | 175 |
| M.1 | General | 175 |
| M.1.1 | Field of application..... | 175 |
| M.1.2 | Field of application..... | 175 |
| M.2 | Terms and definitions..... | 175 |
| M.2.1 | Terms and definitions relating to the energization of an MRCD | 175 |
| M.2.2 | Terms and definitions relating to the operation and the functions of an MRCD | 176 |
| M.3 | Classification | 176 |
| M.3.1 | Classification according to the configuration of the primary conductors..... | 176 |
| M.3.2 | Classification according to the method of operation | 177 |
| M.3.3 | Classification according to the possibility of adjusting the residual operating current | 177 |
| M.3.4 | Classification according to time-delay of the residual current function..... | 177 |
| M.3.5 | Classification according to behaviour in presence of a d.c. component..... | 177 |
| M.4 | Characteristics of MRCDs | 177 |
| M.4.1 | General characteristics | 177 |
| M.4.2 | Characteristics of MRCDs concerning the residual current function..... | 178 |
| M.4.3 | Behaviour under short-circuit conditions | 179 |
| M.4.4 | Preferred and limiting values | 179 |
| M.5 | Product information..... | 180 |
| M.6 | Normal service, mounting and transport conditions..... | 182 |
| M.7 | Design and operating requirements..... | 182 |
| M.7.1 | Design requirements..... | 182 |
| M.7.2 | Operating requirements..... | 182 |
| M.8 | Tests | 184 |
| M.8.1 | General..... | 184 |
| M.8.2 | Compliance with constructional requirements | 185 |
| M.8.3 | Verification of the operating characteristics | 186 |
| M.8.4 | Verification of dielectric properties..... | 188 |
| M.8.5 | Verification of the operation of the test device at the limits of the rated voltage | 189 |
| M.8.6 | Verification of the limiting value of non-operating current under overcurrent conditions, in case of a single phase load | 189 |
| M.8.7 | Resistance against unwanted tripping due to surge currents resulting from impulse voltages | 189 |
| M.8.8 | Verification of the behaviour in case of an earth fault current comprising a d.c. component..... | 189 |
| M.8.9 | Verification of the behaviour of MRCDs with separate sensing means in case of a failure of the sensing means connection | 192 |
| M.8.10 | Verification of temperature-rise of terminal type MRCDs | 192 |
| M.8.11 | Verification of mechanical and electrical endurance | 193 |
| M.8.12 | Verification of the behaviour of MRCDs in case of failure of the voltage source for MRCDs classified under M.3.2.2.1 | 193 |
| M.8.13 | Verification of the behaviour of MRCDs with voltage source as classified under M.3.2.2.2 in case of failure of the voltage source | 194 |

| | | |
|---------------------|--|-----|
| M.8.14 | Verification of the behaviour of the MRCD under short-circuit conditions | 194 |
| M.8.15 | Verification of effects of environmental conditions..... | 196 |
| M.8.16 | Verification of electromagnetic compatibility | 197 |
| Annex N (normative) | Electromagnetic compatibility (EMC) – Additional requirements and test methods for devices not covered by Annex B, Annex F and Annex M | 219 |
| N.1 | General | 219 |
| N.1.1 | General..... | 219 |
| N.1.2 | General test conditions | 219 |
| N.2 | Immunity..... | 219 |
| N.2.1 | General..... | 219 |
| N.2.2 | Electrostatic discharges | 220 |
| N.2.3 | Radiated RF electromagnetic fields | 220 |
| N.2.4 | Electrical fast transients/bursts (EFT/B)..... | 220 |
| N.2.5 | Surges | 221 |
| N.2.6 | Conducted disturbances induced by RF fields (common mode) | 221 |
| N.2.7 | Voltage dips and interruptions | 221 |
| N.3 | Emission..... | 221 |
| N.3.1 | General..... | 221 |
| N.3.2 | Conducted RF disturbances (150 kHz to 30 MHz)..... | 222 |
| N.3.3 | Radiated RF disturbances (30 MHz to 1 000 MHz)..... | 222 |
| Annex O (normative) | Instantaneous trip circuit-breakers (ICB) | 223 |
| O.1 | General | 223 |
| O.2 | Terms and definitions..... | 223 |
| O.3 | Rated values..... | 223 |
| O.3.1 | General..... | 223 |
| O.3.2 | Rated current (I_n)..... | 223 |
| O.3.3 | Rated short-circuit making capacity | 223 |
| O.3.4 | Rated short-circuit breaking capacities | 223 |
| O.4 | Product information..... | 224 |
| O.5 | Constructional and performance requirements..... | 224 |
| O.6 | Tests | 224 |
| O.6.1 | Test sequence of the ICB alone..... | 224 |
| O.6.2 | ICB associated with a specified protected device (i.e. motor-starter or overload relay)..... | 225 |
| Annex P (normative) | DC circuit-breakers for use in photovoltaic (PV) applications..... | 226 |
| P.1 | Field of application..... | 226 |
| P.2 | Terms and definitions..... | 226 |
| P.3 | Classification | 226 |
| P.4 | Characteristics of PV circuit-breakers..... | 226 |
| P.5 | Product information..... | 227 |
| P.6 | Normal service, mounting and transport conditions | 227 |
| P.7 | Constructional and performance requirements..... | 227 |
| P.7.1 | Constructional requirements..... | 227 |
| P.7.2 | Performance requirements | 227 |
| P.7.3 | Electromagnetic compatibility (EMC) | 228 |
| P.8 | Tests | 228 |
| P.8.1 | Kind of tests..... | 228 |
| P.8.2 | Compliance with constructional requirements | 228 |

| | | |
|---------------------|--|-----|
| P.8.3 | Type tests | 228 |
| P.8.4 | Routine tests | 230 |
| P.8.5 | Special tests | 230 |
| Annex Q | Vacant | 231 |
| Annex R (normative) | Circuit-breakers incorporating residual current protection with automatic re-closing functions | 232 |
| R.1 | General | 232 |
| R.1.1 | Preamble | 232 |
| R.1.2 | Field of application | 232 |
| R.2 | Terms and definitions | 233 |
| R.3 | Classification | 234 |
| R.3.1 | According to the method of construction | 234 |
| R.3.2 | According to the method of automatic reclosing | 234 |
| R.4 | Characteristics | 234 |
| R.4.1 | Rated automatic reclosing operating residual current ($I_{\Delta ar}$) | 234 |
| R.4.2 | Maximum number of consecutive reclosing operations | 234 |
| R.5 | Marking and instructions | 235 |
| R.6 | Normal service, mounting and transport conditions | 235 |
| R.7 | Design and operating requirements | 235 |
| R.7.1 | Design requirements | 235 |
| R.7.2 | Operating requirements | 236 |
| R.8 | Tests | 237 |
| R.8.1 | General conditions | 237 |
| R.8.2 | Verification of the non-reclosing after tripping under over-current conditions | 237 |
| R.8.3 | Verification of the non-reclosing after intentional opening | 238 |
| R.8.4 | Verification of the automatic reclosing function after tripping on earth fault | 238 |
| R.8.5 | Verification of mechanical endurance | 239 |
| R.8.6 | Verification of the isolation function | 240 |
| R.8.7 | Verification of residual short-circuit making and breaking capacity | 240 |
| R.8.8 | Verification of the automatic reclosing function after the test sequences of Clause B.8 | 240 |
| R.8.9 | Test items for external type automatic reclosing devices | 241 |
| Bibliography | | 243 |
| Figure 1 | – Test arrangement (connecting cables not shown) for short-circuit tests | 78 |
| Figure A.1 | – Over-current co-ordination between a circuit-breaker and a fuse or back-up protection by a fuse: operating characteristics | 85 |
| Figure A.2 | – Total selectivity between two circuit-breakers | 86 |
| Figure A.3 | – Back-up protection by a circuit-breaker – Operating characteristics | 87 |
| Figure A.4 | – Example of test circuit for conditional short-circuit breaking capacity tests showing cable connections for a 3-pole circuit-breaker (C_1) | 88 |
| Figure A.5 | – Example of test circuit for the verification of selectivity | 89 |
| Figure B.1 | – Test circuit for the verification of the operating characteristic (see B.8.2) | 114 |
| Figure B.2 | – Test circuit for the verification of the limiting value of the non-operating current under over-current conditions (see B.8.5) | 115 |
| Figure B.3 | – Test circuit for the verification of the behaviour of CBRs classified under B.3.1.2.2 (see B.8.9) | 116 |

| | |
|--|-----|
| Figure B.4 – Current ring wave 0,5 μ s/100 kHz | 117 |
| Figure B.5 – Example of test circuit for the verification of resistance to unwanted tripping..... | 117 |
| Figure B.6 – Surge current wave 8/20 μ s | 118 |
| Figure B.7 – Test circuit for the verification of resistance to unwanted tripping in case of flashover without follow-on current (B.8.6.3)..... | 118 |
| Figure B.8 – Test circuit for the verification of the correct operation of CBRs, in the case of residual pulsating direct currents (see B.8.7.2.1, B.8.7.2.2 and B.8.7.2.3) | 119 |
| Figure B.9 – Test circuit for the verification of the correct operation of CBRs, in the case of a residual pulsating direct current superimposed by a smooth direct residual current (see B.8.7.2.4) | 120 |
| Figure F.1 – Representation of test current produced by back-to-back thyristors in accordance with F.4.1..... | 133 |
| Figure F.2 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Two phase poles in series | 133 |
| Figure F.3 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Three phase poles in series | 134 |
| Figure F.4 – Test circuit for immunity and emission tests in accordance with F.4.1.3, F.4.2, F.4.3, F.4.6, F.4.7.1, F.5.4 and F.6.3 – Three-phase connection..... | 134 |
| Figure F.5 – Test current for the verification of the influence of the current dips and interruptions in accordance with F.4.7.1 | 135 |
| Figure F.6 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Two phase poles in series | 135 |
| Figure F.7 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three phase poles in series | 136 |
| Figure F.8 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in accordance with F.4.4 – Three-phase connection..... | 136 |
| Figure F.9 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Two phase poles in series | 137 |
| Figure F.10 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Three phase poles in series..... | 137 |
| Figure F.11 – Test circuit for the verification of the influence of surges in the main circuit (line-to-earth) in accordance with F.4.5 – Three-phase connection | 138 |
| Figure F.12 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Two phase poles in series..... | 138 |
| Figure F.13 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Three phase poles in series | 139 |
| Figure F.14 – Test circuit for the verification of the influence of current surges in the main circuit in accordance with F.4.5 – Three-phase connection..... | 139 |
| Figure F.15 – Temperature variation cycles at a specified rate of change in accordance with F.9.1..... | 140 |
| Figure F.16 – General test set-up for immunity tests | 141 |
| Figure F.17 – Test set-up for the verification of immunity to radiated RF electromagnetic fields | 141 |
| Figure F.18 – Test set-up for the verification of immunity to electrical fast transients/bursts (EFT/B) on power lines..... | 142 |
| Figure F.19 – Test set-up for verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines | 142 |
| Figure F.20 – General test set-up for the verification of immunity to conducted disturbances induced by RF fields (common mode)..... | 142 |

| | |
|--|-----|
| Figure F.21 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Two phase poles in series configuration | 143 |
| Figure F.22 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Three phase poles in series configuration | 143 |
| Figure F.23 – Arrangement of connections for the verification of immunity to conducted disturbances induced by RF fields – Three-phase configuration..... | 144 |
| Figure G.1 – Example of power loss measurement according to G.2.1..... | 146 |
| Figure G.2 – Example of power loss measurement according to G.2.2 and G.2.3..... | 147 |
| Figure J.1 – EUT mounted in a metallic enclosure | 157 |
| Figure J.2 – Test set up for the measurement of radiated RF emissions | 158 |
| Figure J.3 – Test set up for the verification of immunity to electrostatic discharges | 159 |
| Figure J.4 – Test set up for the verification of immunity to radiated RF electromagnetic fields | 159 |
| Figure J.5 – Test set up for the verification of immunity to electrical fast transients/bursts (EFT/B) on power lines..... | 160 |
| Figure J.6 – Test set up for the verification of immunity to electrical fast transients/bursts (EFT/B) on signal lines | 160 |
| Figure K.1 – Relationship between symbols and tripping characteristics | 163 |
| Figure K.2 – Template for characteristics of cut-off current versus prospective current from 1 kA to 200 kA | 164 |
| Figure K.3 – Template for characteristics of cut-off current versus prospective current from 0,01 kA to 200 kA | 165 |
| Figure K.4 – Template for characteristics of let-through energy versus prospective current from 1 kA to 200 kA | 166 |
| Figure K.5 – Template for characteristics of let-through energy versus prospective current from 0,01 kA to 200 kA..... | 167 |
| Figure K.6 – Example of the use of template to Figure K.2 | 168 |
| Figure K.7 – Example of the use of template to Figure K.4 | 169 |
| Figure M.1 – Test circuits for the verification of operation in the case of a steady increase of residual current | 198 |
| Figure M.2 – Test circuits for the verification of operation in the case of a sudden appearance of residual current (with breaking device) | 199 |
| Figure M.3 – Test circuits for the verification of operation in the case of a sudden appearance of residual current (without breaking device) | 200 |
| Figure M.4 – Test circuits for the verification of the limiting value of non-operating current under overcurrent conditions..... | 201 |
| Figure M.5 – Test circuits for the verification of the resistance to unwanted tripping in the case of loading of the network capacitance | 202 |
| Figure M.6 – Test circuit for the verification of the resistance to unwanted tripping in the case of flashover without follow-on current..... | 203 |
| Figure M.7 – Test circuits for the verification of operation in the case of a continuous rise of a residual pulsating direct current..... | 204 |
| Figure M.8 – Test circuits for the verification of operation in the case of a sudden appearance of residual pulsating direct current (without breaking device)..... | 205 |
| Figure M.9 – Test circuits for the verification of operation in the case of a sudden appearance of residual pulsating direct current (with breaking device)..... | 206 |
| Figure M.10 – Test circuits for the verification of operation in the case of a residual pulsating direct current superimposed by smooth direct current of 6 mA | 207 |

| | |
|--|-----|
| Figure M.11 – Test circuits for the verification of operation in the case of a slowly rising residual smooth direct current | 208 |
| Figure M.12 – Test circuits for the verification of operation in the case of a sudden appearance of residual smooth direct current (without breaking device) | 209 |
| Figure M.13 – Test circuits for the verification of operation in the case of a sudden appearance of residual smooth direct current (with breaking device) | 210 |
| Figure M.14 – Test circuits for the verification of operation in the case of a slowly rising residual current resulting from a fault in a circuit fed by a three-pulse star or a six-pulse bridge connection | 211 |
| Figure M.15 – Test circuits for the verification of operation in the case of a slowly rising residual current resulting from a fault in a circuit fed by a two-pulse bridge connection line-to-line..... | 212 |
| Figure M.16 – Test circuit for the verification of the behaviour of MRCDs with separate sensing means in the case of a failure of the sensor means connection..... | 213 |
| Figure M.17 – Test circuit for the verification of the behaviour of MRCD with separate sensing means under short-circuit conditions | 214 |
| Figure M.18 – Test circuit for the verification of the behaviour of MRCD with integral sensing means under short-circuit conditions | 215 |
| Figure M.19 – Test circuit for the verification of the behaviour of terminal type MRCD under short-circuit conditions | 216 |
| Figure M.20 – Verification of immunity to radiated RF electromagnetic fields – Test set-up for MRCD with separate sensing means (additional to the test of Annex B) | 217 |
| Figure M.21 – Verification of immunity to electrical fast transients/bursts (EFT/B) on the sensing means connection of an MRCD with separate sensing means (additional to the test of Annex B) | 218 |
| Figure M.22 – Verification of immunity to conducted disturbances induced by RF fields – Test set up for MRCD with separate sensing means (additional to the test of Annex B) | 218 |
| Figure R.1 – Test circuit for the verification of the automatic reclosing functions | 242 |
| Table 1 (void) | 26 |
| Table 2 – Ratio n between short-circuit making capacity and short-circuit breaking capacity and related power factor (for a.c. circuit-breakers)..... | 26 |
| Table 3 – Minimum values of rated short-time withstand current | 27 |
| Table 4 (void) | 27 |
| Table 5 – Preferred values of the rated control supply voltage, if different from that of the main circuit..... | 27 |
| Table 6 – Characteristics of the opening operation of inverse time-delay over-current opening releases at the reference temperature | 35 |
| Table 7 – Temperature-rise limits for terminals and accessible parts | 36 |
| Table 8 – Number of operating cycles | 38 |
| Table 9 – Overall schema of test sequences ^a | 43 |
| Table 9a – Applicability of test sequences according to the relationship between I_{CS} , I_{CU} and I_{CW} ^a | 44 |
| Table 9b – Applicability of tests or test sequences to 1, 2 and 4-pole circuit-breakers according to the alternative programme 1 of 8.3.1.4 | 46 |
| Table 9c – Applicability of tests or test sequences to 1, 2 and 3-pole circuit-breakers according to the alternative programme 2 of 8.3.1.4 | 47 |
| Table 10 – Number of samples for test (1 of 2)..... | 50 |
| Table 11 – Values of power factors and time constants corresponding to test currents..... | 52 |

| | |
|--|-----|
| Table 12 – Test circuit characteristics for overload performance..... | 64 |
| Table B.1 – Operating characteristic for non-time-delay type | 95 |
| Table B.2 – Operating characteristic for time-delay type having a limiting non-actuating time of 0,06 s..... | 96 |
| Table B.3 – Requirements for CBRs functionally dependent on line voltage | 100 |
| Table B.4 – Additional test sequences | 102 |
| Table B.5 – Tripping current range for CBRs in case of an earth fault comprising a d.c. component..... | 107 |
| Table F.1 – Test parameters for current dips and interruptions | 129 |
| Table J.1 – EMC – Immunity tests..... | 152 |
| Table J.2 – Reference data for immunity test specifications..... | 153 |
| Table J.3 – EMC – Emission tests..... | 156 |
| Table J.4 – Reference data for emission test specifications..... | 156 |
| Table M.1 – Product information | 181 |
| Table M.2 – Requirements for MRCDs with voltage source..... | 183 |
| Table M.3 – Test sequences | 185 |
| Table P.1 – Rated impulse withstand levels for PV circuit-breakers | 226 |
| Table P.2 – Number of operating cycles | 228 |
| Table R.1 – Test sequences for external type automatic re-closing devices | 241 |

INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

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 nearly 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 60947-2 has been prepared by subcommittee 121A: Low-voltage switchgear and controlgear, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low-voltage.

This fifth edition cancels and replaces the fourth edition published in 2006, Amendment 1:2009 and Amendment 2:2013. This edition constitutes a technical revision.

This edition includes the following significant additions with respect to the previous edition:

- tests for verification of selectivity in Annex A (see A.5.3);
- critical load current tests for d.c. circuit-breakers (see 8.3.9);
- new Annex P for circuit-breakers for use in photovoltaic applications;
- new Annex R for residual-current circuit-breakers with automatic reclosing functions.

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

| FDIS | Report on voting |
|--------------|------------------|
| 121A/71/FDIS | 121A/83/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.

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

A list of all parts in the IEC 60947 series, published under the general title *Low-voltage switchgear and controlgear*, can be found on the IEC website.

This International Standard is to be used in conjunction with IEC 60947-1:2007 and its Amendment 1:2010 and Amendment 2:2014.

The provisions of the general rules dealt with in IEC 60947-1 are applicable to this standard, where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to IEC 60947-1 and its amendments when applicable, for example, 1.2.3 of IEC 60947-1:2007, Table 4 of IEC 60947-1:2007/AMD1:2010, or Annex A of IEC 60947-1:2007/AMD1:2010/AMD2:2014.

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.

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 publication using a colour printer.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 2: Circuit-breakers

1 General

1.1 Scope and object

This part of IEC 60947 series applies to circuit-breakers, the main contacts of which are intended to be connected to circuits, the rated voltage of which does not exceed 1 000 V a.c. or 1 500 V d.c.; it also contains additional requirements for integrally fused circuit-breakers.

Circuit-breakers rated above 1 000 V a.c. but not exceeding 1 500 V a.c. may also be tested to this standard.

It applies whatever the rated currents, the method of construction or the proposed applications of the circuit-breakers may be.

The requirements for circuit-breakers which are also intended to provide earth leakage protection are contained in Annex B.

The additional requirements for circuit-breakers with electronic over-current protection are contained in Annex F.

The additional requirements for circuit-breakers for IT systems are contained in Annex H.

The requirements and test methods for electromagnetic compatibility of circuit-breakers are contained in Annex J.

The requirements for circuit-breakers not fulfilling the requirements for over-current protection are contained in Annex L.

The requirements for modular residual current devices (without integral current breaking device) are contained in Annex M.

The requirements and test methods for electromagnetic compatibility of circuit-breaker auxiliaries are contained in Annex N.

The requirements and test methods for d.c. circuit-breakers for use in photovoltaic (PV) applications are contained in Annex P.

The requirements and test methods for circuit-breakers incorporating residual current protection with automatic reclosing functions are contained in Annex R.

Supplementary requirements for circuit-breakers used as direct-on-line starters are given in IEC 60947-4-1, applicable to low-voltage contactors and starters.

The requirements for circuit-breakers for the protection of wiring installations in buildings and similar applications, and designed for use by uninstructed persons, are contained in IEC 60898.

The requirements for circuit-breakers for equipment (for example electrical appliances) are contained in IEC 60934.