

INTERNATIONAL STANDARD



**Low-voltage switchgear and controlgear –
Part 4-1: Contactors and motor-starters – Electromechanical contactors and
motor-starters**

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2018 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.

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

Tel.: +41 22 919 02 11
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 - webstore.iec.ch/advsearchform

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 It also gives information on projects, replaced and withdrawn publications.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 21 000 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

67 000 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: sales@iec.ch.

IECNORM.COM : Click to view the full PDF IEC 60947-4-1:2018 PLV

INTERNATIONAL STANDARD



**Low-voltage switchgear and controlgear –
Part 4-1: Contactors and motor-starters – Electromechanical contactors and
motor-starters**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.120.99, 29.130.20

ISBN 978-2-8322-6208-5

Warning! Make sure that you obtained this publication from an authorized distributor.

INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 60947-4-1
Edition 4.0 2018-10

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

**Part 4-1: Contactors and motor-starters –
Electromechanical contactors and motor-starters**

INTERPRETATION SHEET 1

This interpretation sheet 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.

The text of this interpretation sheet is based on the following documents:

DISH	Report on voting
121A/336/DISH	121A/342/RVDISH

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

Interpretation of the first paragraph of 6.2

The reference to 5.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 is intended to cover the whole subclause where its first paragraph can be discarded.

In particular, the third paragraph of this Subclause 5.2 requiring the marking on the equipment of manufacturer's name or trademark and type designation or serial number is covering items a) and b) of 6.1.1 of IEC 60947-4-1:2018.

Interpretation of footnotes ⁿ and ^o of Table 7

The standard making conditions for the utilization category AC-3e are defined by the ratio I / I_e equal to 12 with the corresponding value of $\cos \phi$ in footnote ^o.

Footnote ⁿ provides the possibility to select an alternate value of the ratio I / I_e between 12 and 13, and gives the corresponding equations to determine the value of $\cos \phi$.

Interpretation of the rated operational current of Table 13 and Table 14

Tables 13 and 14 are intended to be used for contactors and starters specified for motor loads. If the contactor or starter is specified with more than one motor load utilization category (AC-2, AC-3, AC-3e or AC-4), the rated operational current I_e corresponding to the utilization category AC-3 is preferred for determining the prospective current “ r ” for the test.

The utilization category AC-3 is considered as the most representative use case and is deemed to cover the other motor utilization categories.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

CONTENTS

FOREWORD.....	10
INTRODUCTION.....	13
1 Scope ~~and object~~	14
2 Normative references	17
3 Terms, definitions, symbols and abbreviated terms.....	20
3.1 General.....	20
3.2 Alphabetical index of terms	20
3.3 Terms and definitions concerning contactors	22
3.4 Terms and definitions concerning starters	24
3.5 Terms and definitions concerning characteristic quantities	29
3.6 Terms and definitions concerning safety aspects	30
3.7 Symbols and abbreviated terms	31
4 Classification	32
5 Characteristics of contactors and starters	32
5.1 Summary of characteristics	32
5.2 Type of equipment	33
5.2.1 Kind of equipment.....	33
5.2.2 Number of poles	33
5.2.3 Kind of current (AC or DC).....	33
5.2.4 Interrupting medium (air, oil, gas, vacuum, etc.)	33
5.2.5 Operating conditions of the equipment.....	33
5.3 Rated and limiting values for main circuits	33
5.3.1 Rated voltages	33
5.3.2 Currents or powers	35
5.3.3 Rated frequency	37
5.3.4 Rated duties	37
5.3.5 Normal load and overload characteristics	38
5.3.6 Short-circuit characteristics	40
5.3.7 Pole impedance of a contactor (Z)	40
5.4 Utilization category	40
5.4.1 General	40
5.4.2 Assignment of utilization categories based on the results of tests	41
5.5 Control circuits.....	43
5.6 Auxiliary circuits.....	44
5.7 Characteristics of relay and release of overload relays and motor protective switching device (MPSD)	44
5.7.1 Summary of characteristics.....	44
5.7.2 Types of relay or release	45
5.7.3 Characteristic values	45
5.7.4 Designation and current settings of overload relays	47
5.7.5 Time-current characteristics of overload relays	47
5.7.6 Influence of ambient air temperature.....	48
5.8 Co-ordination with short-circuit protective devices.....	48
5.9 Void	48
5.10 Types and characteristics of automatic change-over devices and automatic acceleration control devices	48

5.10.1	Types	48
5.10.2	Characteristics.....	48
5.11	Types and characteristics of auto-transformers for two-step auto-transformer starters	49
5.12	Types and characteristics of starting resistors for rheostatic rotor starters	49
6	Product information	49
6.1	Nature of information	49
6.1.1	Identification.....	49
6.1.2	Characteristics, basic rated values and utilization.....	50
6.2	Marking.....	51
6.3	Instructions for installation, operation, maintenance, decommissioning and dismantling.....	52
6.4	Environmental information	53
7	Normal service, mounting and transport conditions.....	53
8	Constructional and performance requirements	53
8.1	Constructional requirements	53
8.1.1	General	53
8.1.2	Materials	54
8.1.3	Current-carrying parts and their connections	54
8.1.4	Clearances and creepage distances	54
8.1.5	Actuator.....	55
8.1.6	Indication of the contact position	55
8.1.7	Additional requirements for equipment suitable for isolation.....	55
8.1.8	Terminals	55
8.1.9	Additional requirements for equipment provided with a neutral pole	56
8.1.10	Provisions for protective earthing.....	56
8.1.11	Enclosures for equipment	56
8.1.12	Degrees of protection of enclosed equipment	56
8.1.13	Conduit pull-out torque and bending with metallic conduits	56
8.1.14	Limited energy source	56
8.1.15	Stored charge energy circuit.....	58
8.1.16	Fault and abnormal conditions.....	59
8.1.17	Short-circuit and overload protection of ports.....	59
8.2	Performance requirements	59
8.2.1	Operating conditions.....	59
8.2.2	Temperature-rise	67
8.2.3	Dielectric properties.....	69
8.2.4	Normal load and overload performance requirements	70
8.2.5	Co-ordination with short-circuit protective devices	80
	~~Void.....~~	
	~~Additional requirements for combination starters and combination switching devices suitable for isolation~~	
8.3	Electromagnetic compatibility (EMC).....	82
8.3.1	General	82
8.3.2	Immunity.....	83
8.3.3	Emission.....	83
9	Tests	84
9.1	Kinds of test.....	84
9.1.1	General	84

9.1.2	Type tests.....	84
9.1.3	Routine tests	84
9.1.4	Sampling tests	85
9.1.5	Special tests	85
9.2	Compliance with constructional requirements.....	86
9.2.1	General	86
9.2.2	Electrical performance of screwless-type clamping units	86
9.2.3	Ageing test for screwless-type clamping units	87
9.2.4	Limited energy source test.....	87
9.2.5	Breakdown of components.....	88
9.3	Compliance with performance requirements.....	88
9.3.1	Test sequences	88
9.3.2	General test conditions	89
9.3.3	Performance under no load, normal load and overload conditions.....	90
9.3.4	Performance under short-circuit conditions	101
9.3.5	Overload current withstand capability of contactors	106
9.3.6	Routine tests and sampling tests	107
9.4	EMC tests	108
9.4.1	General	108
9.4.2	Immunity.....	109
9.4.3	Emission.....	111
Annex A (normative)	Marking and identification of terminals of contactors, starters and associated overload relays.....	113
A.1	General.....	113
A.2	Marking and identification of terminals of main circuits.....	113
A.3	Marking and identification of terminals of overload relays	113
Annex B (normative)	Special tests	115
B.1	General.....	115
B.2	Mechanical durability.....	115
B.2.1	General	115
B.2.2	Verification of mechanical durability.....	115
B.3	Electrical durability	117
B.3.1	General	117
B.3.2	Results to be obtained	118
B.3.3	Statistical analysis of test results for contactors or starters.....	119
B.4	Coordination at the crossover current between the starter and associated SCPD	119
B.4.1	General and definitions.....	119
B.4.2	Condition for the test for the verification of co-ordination at the crossover current by a direct method	120
B.4.3	Test currents and test circuits.....	120
B.4.4	Test procedure and results to be obtained	120
B.4.5	Verification of co-ordination at the crossover current by an indirect method	121
Annex C	~~(Void)~~ (informative) Typical characteristics of starters.....	124
Annex D (informative)	Items subject to agreement between manufacturer and user	131
Annex E	~~(informative)~~ Examples of control circuit configurations (Void)	131
Annex F (normative)	Requirements for auxiliary contact linked with power contact (mirror contact)	133

F.1	Application and object.....	133
F.1.1	Application.....	133
F.1.2	Object.....	133
F.2	Terms and definitions.....	133
F.3	Characteristics.....	133
F.4	Product information.....	133
F.5	Normal service, mounting and transport conditions	134
F.6	Constructional and performance requirements	134
F.7	Tests	134
F.7.1	General	134
F.7.2	Tests on products in a new condition	134
F.7.3	Test after conventional operational performance (defined under Table 10).....	135
Annex G (informative)	Rated operational currents and rated operational powers of switching devices for electrical motors	136
G.1	General.....	136
G.2	Rated operational powers and rated operational currents.....	136
Annex H (normative)	Extended functions ~~within~~ to electronic overload relays.....	140
H.1	General.....	140
H.2	Terms and definitions.....	140
H.3	Limits of operation of control functions.....	140
H.3.1	General	140
H.3.2	Limits of electronic overload relay with main circuit under-voltage restarting function.....	140
H.4	Test of the control functions.....	141
Annex I (informative)	AC-1 contactors for use with semiconductor controlled motor load	142
Annex J (Void)		143
Annex K (normative)	Procedure to determine data for electromechanical contactors used in functional safety applications.....	144
K.1	General.....	145
K.2	Test requirements.....	145
K.3	Characterization of a failure mode	145
K.4	Failure ratios of a contactor	146
Annex L (normative)	Assessment procedure for electromechanical overload protection used in safety applications and especially in explosive atmospheres	147
L.1	Application and object.....	147
L.1.1	Application.....	147
L.1.2	Object.....	147
L.2	Terms, definitions and symbols	147
L.2.1	Terms and definitions	147
L.2.2	Symbols and abbreviations	148
L.3	Procedure	149
L.3.1	General	149
L.3.2	Safety design process	149
L.4	Requirements	150
L.4.1	General	150
L.4.2	Safety plan	150
L.4.3	Design.....	151

L.4.4	Failure mode and effects analysis of the safety function	151
L.4.5	Design plan	152
L.4.6	Verification	152
L.4.7	Function assessed	152
L.5	Documentation	152
L.5.1	Technical safety documentation	152
L.5.2	Safety instructions	152
L.6	Example	153
L.6.1	architecture description	153
L.6.2	FMEA	154
Annex M (normative)	DC contactors for use in photovoltaic (PV) applications	162
M.1	Application	162
M.2	Object	162
M.3	Terms and definitions	162
M.4	Classification	163
M.5	Characteristics	163
M.5.1	General	163
M.5.2	Rated impulse withstand voltage	163
M.5.3	Utilization category	163
M.6	Product information	164
M.7	Normal service, mounting and transport conditions	164
M.7.1	General	164
M.7.2	Ambient air temperature	164
M.7.3	Altitude	164
M.8	Constructional and performance requirements	165
M.8.1	Constructional requirements	165
M.8.2	Performance requirements	165
M.8.3	Electromagnetic compatibility (EMC)	166
M.9	Tests	166
M.9.1	General	166
M.9.2	Type tests	166
M.9.3	Making and breaking capacities and conventional operational performance	167
M.9.4	Thermal cycling test	167
M.9.5	Climatic test	167
M.9.6	Dielectric test	167
M.9.7	Critical load current test	168
M.9.8	Mechanical properties	169
M.9.9	Degree of protection of enclosed contactors	170
M.9.10	EMC	170
M.9.11	Clearance and creepage distances	170
Annex N (normative)	Additional requirements and tests for equipment with protective separation	171
N.1	General	171
N.2	Definitions	171
N.3	Requirements	171
N.3.1	Test method for implementing protective impedance	171
N.3.2	Touch current measurement	172
Annex O (informative)	Load monitoring indicators	174

O.1	General.....	174
O.2	Indicators list	174
O.3	Uncertainty	176
O.4	Tests	177
O.4.1	Routine tests	177
O.4.2	Type tests.....	177
Annex P (normative)	Short-circuit breaking tests of MPSD	179
P.1	General test conditions	179
P.2	Rated service short-circuit breaking capacity	179
P.2.1	General	179
P.2.2	Test of rated service short-circuit breaking capacity.....	180
P.2.3	Verification of operational performance capability	180
P.2.4	Verification of dielectric withstand.....	180
P.2.5	Verification of temperature-rise.....	181
P.2.6	Verification of overload releases	181
P.3	Rated ultimate short-circuit breaking capacity	181
P.3.1	General	181
P.3.2	Verification of overload releases	181
P.3.3	Test of rated ultimate short-circuit breaking capacity	182
P.3.4	Verification of dielectric withstand.....	182
P.3.5	Verification of overload releases	182
P.4	Test of MPSD for IT system	182
P.4.1	General	182
P.4.2	Individual pole short-circuit.....	182
P.4.3	Verification of dielectric withstand.....	183
P.4.4	Verification of overload releases	183
P.4.5	Marking	183
Annex Q (normative)	Co-ordination under short-circuit conditions between a MPSD and another short-circuit protective device associated in the same circuit.....	184
Q.1	Application	184
Q.2	Object.....	184
Q.3	General requirements for the co-ordination of a MPSD with another SCPD	185
Q.3.1	General considerations	185
Q.3.2	Behaviour of C_1 in association with another SCPD	185
Q.4	Type and characteristics of the associated SCPD	185
Q.5	Verification of selectivity	186
Q.5.1	General	186
Q.5.2	Consideration of selectivity by desk study.....	186
Q.5.3	Selectivity determined by test	187
Bibliography.....		192
Figure 1 – Multiple of current setting limits for ambient air temperature compensated time-delay overload relays		64
Figure 2 – Thermal memory test		65
Figure 3 – Examples of co-ordination characteristics of a starter.....		81
Figure 4 – Voltage drop measurement at contact point of the clamping terminal		87
Figure 5 – Example of a pole impedance measurement for a 3 pole contactor		92
Figure A.1 – Main circuit		113

Figure A.2 – Overload relays	114
Figure B.1 – Examples of time-current withstand characteristic.....	123
Figure C.1 – Typical curves of currents and torques during a star-delta start (see 3.4.4.1)	124
Figure C.2 – Typical curves of currents and torques during an auto-transformer start (see 3.4.4.2)	125
Figure C.3 – Typical variants of protected starters, combination starters, protected switching devices and combination switching devices	126
Figure C.4 – Example of three-phase diagram of a rheostatic rotor starter with three starting steps and one direction of rotation (in the case when all the mechanical switching devices are contactors)	127
Figure C.5 – Typical methods and diagrams of starting alternating-current induction motors by means of auto-transformers	129
Figure C.6 – Examples of speed/time curves corresponding to cases a), b), c), d), e) and f) of 5.3.5.6.1	130
Figure F.1 – Mirror contact.....	134
Figure L.1 – Safety design process	150
Figure L.2 – Typical structure of a thermal overload relay	153
Figure L.3 – typical structure of MPSD	154
Figure M.1 – Critical current.....	168
Figure N.1 – Protection by means of protective impedance	172
Figure N.2 – Measuring instrument	173
Figure O.1 – Example of quantification of a process change	176
Figure Q.1 – Over-current co-ordination between a MPSD and a fuse or back-up protection by a fuse: operating characteristics	189
Figure Q.2 – Total selectivity between MPSD and circuit-breakers – Case 1	190
Figure Q.3 – Total selectivity between MPSD and circuit-breakers – Case 2	190
Figure Q.4 – Back-up protection by a circuit-breaker – Operating characteristics – Case 1	191
Figure Q.5 – Back-up protection by a circuit-breaker – Operating characteristics – Case 2	191
Table 1 – Utilization categories	42
Table 2 – Trip classes of overload relays	46
Table 3 – Limits of operation of time-delay overload relays when energized on all poles	63
Table 4 – Limits of operation of three-pole time-delay overload relays when energized on two poles only	66
Table 5 – Temperature-rise limits for insulated coils in air and in oil	68
Table 6 – Intermittent duty test cycle data.....	69
Table 7 – Making and breaking capacities – Making and breaking conditions according to utilization category	71
Table 8 – Relationship between the test current ~~broken~~ I_e and off-time for the verification of rated making and breaking capacities	75
Table 9 – Operational current determination for utilization categories AC-6a and AC-6b when derived from AC-3 ratings	76
Table 10 – Conventional operational performance – Making and breaking conditions according to utilization category.....	77

Table 11 – Overload current withstand requirements	79
Table 12 – Specific acceptance criteria for immunity tests	83
Table 13 – Value of the prospective test current according to the rated operational current	103
Table 14 – Value of the prospective test current according to the rated operational current (harmonized table)	104
Table 15 – Test conditions for I_{cd}	82
Table 16 – EMC immunity tests	109
Table 17 – Terminal disturbance voltage limits for conducted radio-frequency emission test limits (for mains ports)	111
Table 18 – Radiated emission test limits	112
Table 19 – Limits for limited energy sources without an over-current protective device	57
Table 20 – Limits for limited energy sources with an over-current protective device	57
Table 21 – Limits for limited energy source with current limiting impedance	58
Table B.1 – Verification of the number of on-load operating cycles – Conditions for making and breaking corresponding to the several utilization categories	118
Table B.2 – Test conditions	121
Table F.1 – Test voltage according to altitude	135
Table G.1 – Rated operational powers and rated operational currents of motors	137
Table K.1 – Failure mode of contactors	146
Table K.2 – Typical failure ratios for normally open contactors	146
Table L.1 – Severity	154
Table L.2 – Occurrence	155
Table L.3 – Detection levels	155
Table L.4 – Conclusion	156
Table L.5 – Example of failure mode and effects analysis for thermal overload relay	157
Table M.1 – Rated impulse voltage levels for PV contactors	163
Table M.2 – Utilization categories	163
Table M.3 – Ambient air temperature conditions	164
Table M.4 – Verification of rated making and breaking capacities – Conditions for making and breaking corresponding to the DC-PV category	165
Table M.5 – Conventional operational performance – Making and breaking condition corresponding to the DC-PV category	166
Table M.6 – Overall scheme of test sequences	167
Table M.7 – Number of operating cycles corresponding to the critical load current	169
Table M.8 – Critical load current performance	169
Table O.1 – AC monitoring indicators list	175
Table O.2 – Different possibilities authorized for verification of indicators	177
Table O.3 – Reference for verification conditions	178
Table O.4 – Harmonic levels	178

INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters

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.

This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 60947-4-1 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 fourth edition cancels and replaces the third edition published in 2009 and its Amendment 1:2012. This edition constitutes a technical revision.

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

- Scope structure and exclusions
- Editorial correction of notes and hanging paragraphs
- Reference to IEC 62683-1
- Motor protective switching device (MPSD) with its requirements
- Safety aspects related to:
 - General aspects;
 - Limited energy circuits;
 - Electronic circuits;
 - Assessment procedure for electromechanical overload protection used in safety - applications (new Annex L)
- Introduction of provisions covering the impact of higher locked rotor current to achieve high efficiency class
- Mention of dedicated wiring accessories
- Pickup power measurement
- Alignment to IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, and IEC 60947-1:2007/AMD2:2014
- Direct current requirements for covering photovoltaic application (new Annex M)
- Load monitoring indicators (new Annex O)
- Short-circuit breaking tests of MPSD (new Annex P)
- Co-ordination under short-circuit conditions between a MPSD and another short-circuit protective device associated in the same circuit (new Annex Q)

The text of this International Standard is based on the following documents:

FDIS	Report on voting
121A/224/FDIS	121A/233/RVD

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

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

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

This document shall be read in conjunction with IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014, *Low voltage switchgear and controlgear – Part 1: General rules*. The provisions of the general rules are applicable to this document, where specifically called for.

The provisions of the general rules dealt with IEC 60947-1 are applicable to this part of IEC 60947 series where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, and IEC 60947-1:2007/AMD2:2014. For example, 4.3.4.1 of IEC 60947-1:2007, Table 4 of IEC 60947-1:2007, or Annex A of IEC 60947-1:2007.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

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

The contents of the interpretation sheet of March 2020 have been included in this copy.

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.

The contents of the corrigenda 1 (2020-04) and 2 (2021-04) have been included in this copy.

INTRODUCTION

This document introduces the requirements for motor protection switching devices (MPSD).

MPSDs have been available on the market for many years. They are introduced in this document for covering the minimum safety and performance requirements of a manual motor starter with integral electromechanical or electronic short-circuit protection. This device fulfils all requirements of a starter and specific requirements of a circuit-breaker according to IEC 60947-2, mainly I_{cu} and I_{cs} , for protecting the motor and its circuit with control devices e.g. a contactor. An MPSD is not intended to support neutral pole, DC ratings, rated uninterrupted current I_u , backup protection, short-circuit tripping time-delay, selectivity category, withdrawable capability, RCD, recloser, EMC requirements of IEC 60947-2, etc.

Circuit-breakers according to Annex O of IEC 60947-2:2016 with motor overload protection characteristic according to this document but without starter ratings e.g. AC-3 are also available on the market. These devices are not covered by this document.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters

1 ~~Scope and object~~

1.1 ~~Scope~~

~~This part of IEC 60947 applies to the types of equipment listed in 1.1.1 and 1.1.2 whose main contacts 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.~~

~~Starters and/or contactors dealt with in this standard are not normally designed to interrupt short-circuit currents. Therefore, suitable short-circuit protection (see 9.3.4) forms part of the installation but not necessarily of the contactor or the starter.~~

~~In this context, this standard gives requirements for:~~

- ~~— contactors associated with overload and/or short-circuit protective devices;~~
- ~~— starters associated with separate short-circuit protective devices and/or with separate short-circuit and integrated overload protective devices;~~
- ~~— contactors or starters combined, under specified conditions, with their own short-circuit protective devices. Such combinations, e.g. combination starters or protected starters are rated as units.~~

~~For circuit-breakers and fuse-combination units used as short-circuit protective devices in combination starters and in protected starters, the requirements of IEC 60947-2 and IEC 60947-3 respectively apply.~~

~~Equipment covered by this standard is as follows.~~

1.1.1 ~~AC and DC contactors~~

~~AC and DC contactors intended for closing and opening electric circuits and, if combined with suitable relays (see 1.1.2), for protecting these circuits against operating overloads which may occur therein.~~

~~NOTE For contactors combined with suitable relays and which are intended to provide short-circuit protection, the relevant conditions specified for circuit-breakers (IEC 60947-2) additionally apply.~~

~~This standard applies also to the actuators of contactor relays and to the contacts dedicated exclusively to the coil circuit of a contactor.~~

~~Contactors or starters with an electronically controlled electromagnet are also covered by this standard.~~

1.1.2 ~~AC motor-starters~~

~~AC motor-starters intended to start and accelerate motors to normal speed, to ensure continuous operation of motors, to switch off the supply from the motor and to provide means for the protection of motors and associated circuits against operating overloads.~~

~~For overload relays for starters, including those based on electronic technology with or without extended functions according to Annex H, the requirements of this standard apply.~~

~~1.1.2.1 — Direct-on-line (full voltage) a.c. starters~~

~~Direct-on-line starters intended to start and accelerate a motor to normal speed, to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.~~

~~This standard applies also to reversing starters.~~

~~1.1.2.2 — Reduced voltage a.c. starters~~

~~Reduced voltage a.c. starters intended to start and accelerate a motor to normal speed by connecting the line voltage across the motor terminals in more than one step or by gradually increasing the voltage applied to the terminals, to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.~~

~~Automatic change-over devices may be used to control the successive switching operations from one step to the others. Such automatic change-over devices are, for example, time-delay contactor relays or specified time all-or-nothing relays, under current devices and automatic acceleration control devices (see 5.10).~~

~~1.1.2.2.1 — Star-delta starters~~

~~Star-delta starters intended to start a three-phase motor in the star connection, to ensure continuous operation in the delta connection, to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.~~

~~The star-delta starters dealt with in this standard are not intended for reversing motors rapidly and, therefore, utilization category AC-4 does not apply.~~

~~NOTE In the star connection, the current in the line and the torque of the motor are about one-third of the corresponding values for delta connection. Therefore, star-delta starters are used when the inrush current due to the starting is to be limited, or when the driven machine requires a limited torque for starting. Figure 1 indicates typical curves of starting current, of starting torque of the motor and of torque of the driven machine.~~

~~1.1.2.2.2 — Two-step auto-transformer starters~~

~~Two-step auto-transformer starters, intended to start and accelerate an a.c. induction motor from rest with reduced torque to normal speed and to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.~~

~~This standard applies to auto-transformers which are part of the starter or which constitute a unit specially designed to be associated with the starter.~~

~~Auto-transformer starters with more than two steps are not covered by this standard.~~

~~The auto-transformer starters dealt with in this standard are not intended for inching duty or reversing motors rapidly and, therefore, utilization category AC-4 does not apply.~~

~~NOTE In the starting position, the current in the line and the torque of the motor related to the motor starting with rated voltage are reduced approximately as the square of the ratio (starting voltage):(rated voltage). Therefore, auto-transformer starters are used when the inrush current due to the starting is to be limited or when the driven machine requires a limited torque for starting. Figure 2 indicates typical curves of starting current, of starting torque of the motor and of torque of the driven machine.~~

1.1.2.3 — Rheostatic rotor starters

Starters intended to start an a.c. induction motor having a wound rotor by cutting out resistors previously inserted in the rotor circuit, to provide means for the protection of the motor against operating overloads and to switch off the supply from the motor.

In the case of asynchronous slip-ring motors (wound rotors), the highest voltage between open slip-rings is not greater than twice the rated insulation voltage of the switching devices inserted in the rotor circuit (see 5.3.1.1.2).

NOTE This requirement is based on the fact that the electric stresses are less severe in the rotor than in the stator and are of short duration.

This standard applies also to starters for two directions of rotation when reversal of connections is made with the motor stopped (see 5.3.5.5). Operations including inching and plugging necessitate additional requirements and are subject to agreement between manufacturer and user.

This standard applies to resistors which are part of the starter or constitute a unit specially designed to be associated with the starter.

1.2 — Exclusions

This standard does not apply to:

- d.c. starters;
- star-delta starters, rheostatic rotor starters, two-step auto-transformer starters intended for special applications and designed for continuous operation in the starting position;
- unbalanced rheostatic rotor starters, i.e. where the resistances do not have the same value in all phases;
- equipment designed not only for starting, but also for adjustment of speed;
- liquid starters and those of the "liquid-vapour" type;
- semiconductor contactors and starters making use of semiconductor contactors in the main circuit;
- rheostatic stator starters;
- contactors or starters designed for special applications;
- auxiliary contacts of contactors and contacts of contactor relays. These are dealt with in IEC 60947-5-1.

1.3 — Object

The object of this standard is to state:

- a) the characteristics of contactors and starters and associated equipment;
- b) the conditions applicable to contactors and starters with reference to:
 - 1) their operation and behaviour;
 - 2) their dielectric properties;
 - 3) the degrees of protection provided by their enclosures, where applicable;
 - 4) their construction;
- c) the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests;
- d) the information to be given with the equipment or in the manufacturer's literature.

This part of IEC 60947 is applicable to the following equipment:

- electromechanical contactors and starters including motor protective switching device (MPSD);
- actuators of contactor relays;
- contacts dedicated exclusively to the coil circuit of this contactor or this contactor relay;
- dedicated accessories (e.g. dedicated wiring, dedicated latch accessory);

intended to be connected to distribution circuits, motors circuits and other load circuits, the rated voltage of which does not exceed 1 000 V AC or 1 500 V DC.

This document covers also the assessment procedure for electromechanical overload protection used in safety applications such as protecting a motor located in explosive atmosphere from the outside atmosphere: See Annex L.

This document does not apply to:

- starters for DC motors¹;
NOTE 1 The requirements for DC motor starters are under consideration for the next maintenance cycle.
- auxiliary contacts of contactors and contacts of contactor relays. These are covered by IEC 60947-5-1;
- starter used downstream to frequency drive¹;
NOTE 2 Additional requirements for starter used downstream to frequency drive are under consideration for the next maintenance cycle.
- short-circuit protective device integrated within starters other than MPSDs. This is covered by IEC 60947-2 and IEC 60947-3;
- the use of the product with additional measure within explosive atmospheres. These are given in IEC 60079 series;
- embedded software design rules¹;
- cyber security aspects. These are covered by IEC 62443 series.

The objective of this document is to state:

- a) the characteristics of the equipment;
- b) the conditions applicable to the equipment with reference to:
 - 1) its operation and behaviour,
 - 2) its dielectric properties,
 - 3) its degree of protection,
 - 4) its construction including safety measures against electric shock, fire hazard and mechanical hazard;
- c) the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests;
- d) the information to be given with the equipment or in the manufacturer's literature.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition

¹ For this subject the manufacturer is responsible for taking additional safety measures.

cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034-1:2004 2017, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-12:2016, *Rotating electrical machines – Part 12: Starting performance of single-speed three-phase cage induction motors*

IEC 60034-30-1, *Rotating electrical machines – Part 30-1: Efficiency classes of line operated AC motors (IE code)*

IEC 60038, *IEC standard voltages*

IEC 60068-2-14:2009, *Environmental testing – Part 2-14: Tests – Test M: Change of temperature*

IEC 60079-14, *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*

IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*

~~IEC 60300-3-5:2001, Dependability management – Part 3-5: Application guide – Reliability test conditions and statistical test principles~~

IEC 60364-1:2005, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC 60364-7-712, *Low voltage electrical installations – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*

~~IEC 60410:1973, Sampling plans and procedures for inspection by attributes~~

IEC 60715:2017, *Dimensions of low-voltage switchgear and controlgear – Standardized mounting on rails for mechanical support of switchgear, controlgear and accessories*

IEC 60730-1, *Automatic electrical controls – Part 1: General requirements*

IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 60947-1:2007/AMD1:2010

IEC 60947-1:2007/AMD2:2014

IEC 60947-2:2006 2016, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*

~~IEC 60947-3:2008, Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units~~

IEC 60947-5-1:2003 2016, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

~~IEC 61000-4-2:2008, Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test~~

~~IEC 61000-4-3:2006, Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test – Amendment 1 (2007)~~

~~IEC 61000-4-4:2004, Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test~~

~~IEC 61000-4-5:2005, Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test~~

~~IEC 61000-4-6:2008, Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields~~

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

IEC 61051-2, *Varistors for use in electronic equipment – Part 2: Sectional specification for surge suppression varistors*

IEC 61140:2016, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61439 (all parts), *Low-voltage switchgear and controlgear assemblies*

~~IEC 61439-1:2009, Low-voltage switchgear and controlgear assemblies – Part 1: General rules~~

~~IEC 61508 (all parts), Functional safety of electrical/electronic/programmable electronic safety-related systems~~

~~IEC 61511 (all parts), Functional safety – Safety instrumented systems for the process industry sector~~

~~IEC 61513:2001, Nuclear power plants – Instrumentation and control for systems important to safety – General requirements for systems~~

~~IEC 61649:2008, Weibull analysis~~

IEC 61810-1:2008, *Electromechanical elementary relays – Part 1: General and safety requirements (available in English only)*

~~IEC 62061:2005, Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems~~

~~CISPR 11:2003, Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement – Amendment 1 (2004) – Amendment 2 (2006)~~

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*
CISPR 11:2015/AMD1:2016

~~ISO 13849-1:2006, Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design~~

ISO 2859-1:1999, *Sampling procedures for inspection by attributes – Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

ISO 3864-2, *Graphical symbols – Safety colours and safety signs – Part 2: Design principles for product safety labels*

3 Terms, definitions, symbols and abbreviated terms

3.1 General

For the purposes of this document, the terms and definitions of Clause 2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, as well as the following terms, definitions, symbol and abbreviations apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.2 Alphabetical index of terms

	Reference
A	
abnormal operating condition	3.6.1
accessible part	3.6.2
auto-transformer starter	3.4.4.2
auto-transformer	3.4.4.3
C	
closed transition (with an auto-transformer starter or star-delta starter)	3.4.22
combination starter	3.4.7
combination switching device	3.4.26
CO operation	3.5.2
contactor (mechanical)	3.3.1
D	
dedicated wiring accessory	3.4.32
direct-on-line starter	3.4.2
E	
electromagnetic contactor	3.3.2
electromagnetic starter	3.4.9
~~electronic overload relay with current imbalance detection~~	~~H.2.2~~
~~electronic overload relay with ground/earth fault function~~	~~H.2.1~~
~~electronic overload relay with phase reversal function~~	~~H.2.4~~
~~electronic overload relay with under power detection~~	~~H.2.6~~
electronically energized coil of controlled electromagnet	3.3.8
electro-pneumatic contactor	3.3.4
electro-pneumatic starter	3.4.12

G	
galvanic opening (of a circuit)	3.5.9
galvanic separation	3.5.10
H	
hazardous-live-part	3.6.3
holding power (of a contactor)	3.3.9
I	
I^2t characteristic of a circuit-breaker or a MPSD	3.5.6
I_{cd} current	3.5.4
inching (jogging)	3.4.23
~~inhibit current (I_{ic})~~	~~H.2.7~~
inhibit time	3.4.29
J	
jam ~~sensitive (electronic overload)~~ relay (or release)	3.4.28
L	
latch accessory	3.4.33
latched contactor	3.3.5
limited energy source	3.6.4
M	
manual starter	3.4.8
mirror contact	F.2.1
motor management starter	3.4.30
motor-operated starter	3.4.10
motor protective switching device (abbreviation: MPSD)	3.4.31
motor starter	3.4.1
N	
n -step starter	3.4.15
O	
O operation	3.5.3
open transition (with an auto-transformer starter or star-delta starter)	3.4.21
overload current setting (abbreviation: I_r)	3.5.8
P	
phase loss sensitive ~~thermal~~ overload relay or release	3.4.16
pick-up power (of a contactor)	3.3.10
plugging	3.4.24
pneumatic contactor	3.3.3
pneumatic starter	3.4.11
position of rest (of a contactor)	3.3.7
protected starter	3.4.6
protected switching device	3.4.25
protective impedance	3.6.5

R

rated instantaneous short-circuit current setting (abbreviation: I_i)	3.5.7
reasonably foreseeable misuse	3.6.6
reduced voltage starter	3.4.4
resetting time	3.5.5
reversing starter	3.4.3
rheostatic rotor starter	3.4.5.2
rheostatic starter	3.4.5
rheostatic stator starter	3.4.5.1

S

single fault condition	3.6.7
single-step starter	3.4.13
stall-sensitive (electronic overload) relay (or release)	3.4.27
star-delta starter	3.4.4.1
~~starter~~	~~3.4.1~~
starting time (of a rheostatic starter)	3.4.19
starting time (of an auto-transformer starter)	3.4.20

T

transient recovery voltage (abbreviation: TRV)	3.5.1
~~two-direction starter~~	~~3.4.4~~
two-step starter	3.4.14

U

under-current relay or release	3.4.17
under-voltage relay or release	3.4.18

V

vacuum contactor (or starter)	3.3.6

3.3 Terms and definitions concerning contactors

3.3.1

(mechanical) contactor

mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions

Note 1 to entry: Mechanical contactors may be designated according to the method by which the force for closing the main contacts is provided.

Note 2 to entry: The term "operated otherwise than by hand" means that the device is intended to be controlled and kept in working position from one or more external supplies.

Note 3 to entry: In French, a contactor the main contacts of which are closed in the position of rest is usually called a "rupteur". The word "rupteur" has no equivalent in the English language.

Note 4 to entry: A contactor is usually intended to operate frequently.

Note 5 to entry: A mechanical contactor can provide a galvanic opening (3.5.9) but is not suitable for isolation unless the additional requirements defined under 8.1.7 are fulfilled. In this case the equipment can be marked in accordance with IEC 60417-6169-1 "Disconnector; isolator".

[SOURCE: IEC 60050-441:2000, 441-14-33, modified – Term "mechanical" in bracket; "may" replaced by "can" in Note 1 to entry; Notes to entry 2 to 5 have been added]

3.3.2

electromagnetic contactor

contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by an electromagnet

Note 1 to entry: The electromagnet may be electronically controlled.

3.3.3

pneumatic contactor

contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by a device using compressed air, without the use of electrical means

3.3.4

electro-pneumatic contactor

contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by a device using compressed air under the control of electrically operated valves

3.3.5

latched contactor

contactor, the moving elements of which are prevented by means of a latching arrangement from returning to the position of rest when the operating means are de-energized

Note 1 to entry: The latching, and the release of the latching, ~~may~~ can be mechanical, electromagnetic, pneumatic, etc.

Note 2 to entry: Because of the latching, the latched contactor actually acquires a second position of rest and, according to the definition of a contactor, it is not, strictly speaking, a contactor. However, since the latched contactor in both its utilization and its design is more closely related to contactors in general than to any other classification of switching device, it is considered proper to require that it complies with the specifications for contactors wherever they are appropriate.

[SOURCE: IEC 60050-441:2000, 441-14-34, modified – “may” replaced by “can” in Note 1 to entry]

3.3.6

vacuum contactor (or starter)

contactor (or starter) in which the main contacts open and close within a highly evacuated envelope

3.3.7

position of rest (of a contactor)

position which the moving elements of the contactor take up when its electromagnet or its compressed-air device is not energized

[SOURCE: IEC 60050-441:2000, 441-16-24]

3.3.8

electronically ~~energized coil of~~ controlled electromagnet

electromagnet in which the coil is ~~energized~~ controlled by a circuit with active electronic elements

3.3.9

holding power (of a contactor)

power needed to maintain the operation of the electromagnet

3.3.10

pick-up power (of a contactor)

power needed to operate the contactor from the de-energized state to the energized state

3.4 Terms and definitions concerning starters

3.4.1

motor starter

combination of all the switching means necessary to start and stop a motor in combination with suitable overload protection

[SOURCE: IEC 60050-441:2000, 441-14-38, modified – “Motor” added to the term and Note 1 to entry has been deleted]

3.4.2

direct-on-line starter

starter which connects the line voltage across the motor terminals in one step

[SOURCE: IEC 60050-441:2000, 441-14-40]

3.4.3

reversing starter

starter intended to cause the motor to reverse the direction of rotation by reversing the motor primary connections when the motor ~~may be~~ is not running

Note 1 to entry: An application where reversing the motor primary connections while the motor is running is called plugging (see 3.4.24).

~~3.4.4~~

~~two-direction starter~~

~~starter intended to cause the motor to reverse the direction of rotation by reversing the motor primary connections only when the motor is not running~~

3.4.4

reduced voltage starter

starter which connects the line voltage across the motor terminals in more than one step or by gradually increasing the voltage applied to the terminals

3.4.4.1

star-delta starter

starter for a three-phase induction motor such that in the starting position the stator windings are connected in star and in the final running position they are connected in delta

Note 1 to entry: A star-delta starter is not intended for reversing motor running and, therefore, utilization category AC-4 does not apply.

Note 2 to entry: In the star connection, the starting current in the line and the torque of the motor are about one-third of the corresponding values for delta connection. Therefore, star-delta starters are used when the inrush current due to the starting is to be limited, or when the driven machine needs a limited torque for starting. See Figure C.1a) and Figure C.1b)).

[SOURCE: IEC 60050-441:2000, 441-14-44, modified – Notes to entry have been added]

3.4.4.2

auto-transformer starter

starter for an induction motor which uses for starting one or more reduced voltages derived from an auto-transformer

~~NOTE An auto-transformer is defined as follows in 3.1.2 of IEC 60076-1: “A transformer in which at least two windings have a common part.”~~

Note 1 to entry: The auto-transformer starter is not intended for inching duty or reversing running motors and, therefore, utilization category AC-4 does not apply.

Note 2 to entry: In the starting position, the current in the line and the torque of the motor related to the motor starting with rated voltage are reduced approximately as the square of the ratio (starting voltage)/(rated voltage).

Therefore, auto-transformer starters are used when the inrush current due to the starting is to be limited or when the driven machine needs a limited torque for starting. See Figure C.2a) and Figure C.2b).

[SOURCE: IEC 60050-441:2000, 441-14-45, modified – Notes to entry have been added]

3.4.4.3

auto-transformer

transformer in which at least two windings have a common part

[SOURCE: IEC 60050-421:1990, 421-01-11]

3.4.5

rheostatic starter

starter utilizing one or several resistors for obtaining, during starting, stated motor torque characteristics and for limiting the current

Note 1 to entry: A rheostatic starter generally consists of three basic parts which may be supplied either as a composite unit or as separate units to be connected at the place of utilization:

- the mechanical switching devices for supplying the stator (generally associated with an overload protective device);
- the resistor(s) inserted in the stator or rotor circuit;
- the mechanical switching devices for cutting out the resistor(s) successively.

Note 2 to entry: It applies also to starters for two directions of rotation when reversal of connections is made with the motor stopped.

[SOURCE: IEC 60050-441:2000, 441-14-42, modified – Notes to entry have been added]

3.4.5.1

rheostatic stator starter

rheostatic starter for a squirrel cage motor which, during the starting period, cuts out successively one or several resistors previously provided in the stator circuit

3.4.5.2

rheostatic rotor starter

rheostatic starter for an asynchronous wound-rotor motor which, during the starting period, cuts out successively one or several resistors previously provided in the rotor circuit

[SOURCE: IEC 60050-441:2000, 441-14-43]

3.4.6

protected starter

equipment consisting of a starter, a manually-operated switching device and a short-circuit protective device, rated as a unit by the manufacturer

Note 1 to entry: The protected starter may or may not be enclosed.

Note 2 to entry: In the context of this document, the term “manufacturer” means any person, company or organization with ultimate responsibility as follows:

- to verify compliance with the appropriate standard;
- to provide the product information according to Clause 6.

Note 3 to entry: ~~The manually operated switching device and the short-circuit protective device may be just one device and may also incorporate the starter overload protection.~~ A manually protected starter as one unit can be a MPSPD.

3.4.7

combination starter

equipment consisting of a protected starter incorporating an isolating function

Note 1 to entry: Also called "combination motor controller".

Note 2 to entry: See Figure C.3.

3.4.8

manual starter

starter in which the force for closing the main contacts is provided exclusively by manual energy

[SOURCE: IEC 60050-441:2000, 441-14-39]

3.4.9

electromagnetic starter

starter in which the force for closing the main contacts is provided by an electromagnet

3.4.10

motor-operated starter

starter in which the force for closing the main contacts is provided by an electric motor

3.4.11

pneumatic starter

starter in which the force for closing the main contacts is provided by using compressed air, without the use of electrical means

3.4.12

electro-pneumatic starter

starter in which the force for closing the main contacts is provided by using compressed air under the control of electrically operated valves

3.4.13

single-step starter

starter in which there is no intermediate accelerating position between the OFF and ON positions

Note 1 to entry: This starter is a direct-on-line starter.

3.4.14

two-step starter

starter in which there is only one intermediate accelerating position between the OFF and ON positions

EXAMPLE A star-delta starter is a two-step starter.

3.4.15

***n*-step starter**

starter in which there are (*n*-1) intermediate accelerating positions between the OFF and full ON positions

Note 1 to entry: See Figure C.4.

EXAMPLE A three-step rheostatic starter has two sections of resistors used for starting.

[SOURCE: IEC 60050-441:2000, 441-14-41, modified – "OFF" and "ON" in capital; Example and Note 1 to entry are added]

3.4.16

phase loss sensitive-thermal overload relay or release

multipole-thermal overload relay or release which operates in the case of overload and also in case of loss of phase in accordance with specified requirements

3.4.17**under-current relay or release**

measuring relay or release which operates automatically when the current through it is reduced below a predetermined value

3.4.18**under-voltage relay or release**

measuring relay or release which operates automatically when the voltage applied to it is reduced below a predetermined value

3.4.19**starting time (of a rheostatic starter)**

period of time during which the starting resistors or parts of them carry current

Note 1 to entry: The starting time of a starter is shorter than the total starting time of the motor which also takes into account the last period of acceleration following the switching operation to the ON position.

3.4.20**starting time (of an auto-transformer starter)**

period of time during which the auto-transformer carries current

Note 1 to entry: The starting time of a starter is shorter than the total starting time of the motor which also takes into account the last period of acceleration following the switching operation to the ON position.

3.4.21**open transition (with an auto-transformer starter or star-delta starter)**

circuit arrangement such that the supply to the motor is interrupted and reconnected when changing over from one step to another

Note 1 to entry: The transition stage is not considered as an additional step.

3.4.22**closed transition (with an auto-transformer starter or star-delta starter)**

circuit arrangement such that the supply to the motor is not interrupted (even momentarily) when changing over from one step to another

Note 1 to entry: The transition stage is not considered as an additional step.

3.4.23**inching (jogging)**

energizing a motor or solenoid repeatedly for short periods to obtain small movements of the driven mechanism

3.4.24**plugging**

stopping or reversing a motor rapidly by reversing the motor primary connections while the motor is running

3.4.25**protected switching device**

equipment (for non-motor loads) consisting of a contactor or a semiconductor controller, overload protection, a manually operated switching device and a short-circuit protective device, rated as a unit by the manufacturer

Note 1 to entry: The protected switching device may or may not be enclosed.

Note 2 to entry: In the context of this document, the term “manufacturer” means any person, company or organization with ultimate responsibility as follows:

- to verify compliance with the appropriate standard;
- to provide the product information according to Clause 6.

Note 3 to entry: The manually operated switching device and the short-circuit protective device may be just one device and may incorporate the overload protection as well.

3.4.26

combination switching device

equipment consisting of a protected switching device incorporating an isolating function

3.4.27

stall-sensitive (electronic overload) relay (or release)

electronic overload relay or release which operates when the current has not decreased below a predetermined value for a specific period of time during start-up or when the relay or the release receives the input indicating there is no rotation of the motor after a predetermined time in accordance with specified requirements

Note 1 to entry: Explanation of stall: rotor locked during start.

Note 2 to entry: With appropriate adjustment of the current and starting time settings, such relay or release can be used to detect ~~overtime~~ starts requiring longer than specified times.

3.4.28

jam-sensitive (electronic overload) relay (or release)

electronic overload relay or release which operates in the case of overload and also when the current has increased above a predetermined value for a specific period of time during operation, in accordance with specified requirements

Note 1 to entry: A jam is a high overload occurring after the completion of starting which causes the current to reach the locked rotor current value of the motor being controlled.

3.4.29

inhibit time

time-delay period during which the tripping function of the relay is inhibited (may be adjustable)

3.4.30

motor management starter

starter including extended functions with communication ability

Note 1 to entry: Interoperable device profiles for motor management starter are defined by IEC 61915-2:2011.

3.4.31

motor protective switching device

MPSD

manually operated motor starter additionally providing resettable short-circuit protection to the motor and the circuit

Note 1 to entry: A MPSD can also be used as a manual starter, a protected starter or a combination starter.

Note 2 to entry: A MPSD can be used as a SCPD within the motor branch.

Note 3 to entry: In North America, this device is called manual motor controller suitable for tap conductor protection.

3.4.32

dedicated wiring accessory

prefabricated connection wiring system specifically intended for identified switchgear or controlgear

Note 1 to entry: A dedicated wiring accessory can be integrated in the switchgear or controlgear or delivered separately.

Note 2 to entry: A typical dedicated wiring accessory is for example a connection link.

3.4.33**latch accessory**

mechanical device attached to a contactor, the moving elements of which are prevented from returning to the position of rest when the operating means are de-energized

Note 1 to entry: The latching, and the release of the latching, can be mechanical, electromagnetic, pneumatic, etc.

[SOURCE: IEC 60050-441:2000, 441-14-34, modified – Adapted to accessories, and Note 2 to entry deleted]

3.5 Terms and definitions concerning characteristic quantities**3.5.1****transient recovery voltage****TRV**

recovery voltage during the time in which it has a significant transient character

Note 1 to entry: In a vacuum contactor or starter, the highest transient recovery voltage ~~may~~ can occur on another pole than the first pole to clear.

[SOURCE: IEC 60947-1:2007, 2.5.34, modified – Note 1 to entry has been modified]

3.5.2**CO operation**

breaking of the circuit by the SCPD resulting from closing the circuit by the equipment under test

3.5.3**O operation**

breaking of the circuit by the SCPD resulting from closing the circuit on the equipment under test which is in the closed position

Note 1 to entry: The SCPD is normally in the closed position prior closing the circuit; in some cases, the SCPD has to close the circuit (see 9.3.4.2.2, item b).

3.5.4 **I_{cd} current**

current representing a fault current equal to or higher than the current corresponding to the crossover point of the mean value of the published curves representing the time-current characteristics of the overload relay and the SCPD respectively

3.5.5**resetting time**

time elapsed between a circuit-breaker (MPSD) tripping due to an over-current and subsequently reaching a condition where it can be reclosed

[SOURCE: IEC 60947-2:2016, 2.19, modified – Insertion of “(MPSD)” in definition]

3.5.6 **I^2t characteristic of a circuit-breaker or a MPSD**

information (usually a curve) giving the maximum values of I^2t related to break time as a function of prospective current (r.m.s. symmetrical for a.c.) up to the maximum prospective current corresponding to the rated service short-circuit breaking capacity and associated voltage

[SOURCE: IEC 60947-2:2016, 2.18, modified – “or a MPSD” inserted in term]

3.5.7 rated instantaneous short-circuit current setting

I_i
rated value of the current causing the operation of a release without any intentional time-delay

[SOURCE: IEC 60947-2:2016, 2.20]

3.5.8 overload current setting

I_r
current setting of an adjustable overload release

[SOURCE: IEC 60947-2:2016, 2.21, modified – Note 1 to entry has been deleted]

3.5.9 galvanic opening (of a circuit)

prevention of electric conduction within an electric circuit intended to provide power and/or signals

Note 1 to entry: Galvanic opening can be provided e.g. by a switch or a contactor.

3.5.10 galvanic separation

prevention of electric conduction between two electric circuits intended to exchange power and/or signals

Note 1 to entry: Galvanic separation can be provided e.g. by an isolating transformer or an opto-coupler.

[SOURCE: IEC 60050-151:2001, 151-12-26]

3.6 Terms and definitions concerning safety aspects

3.6.1 abnormal operating condition

temporary operating condition that is not a normal operating condition and is not a single fault condition of the equipment itself

Note 1 to entry: An abnormal operating condition is a temporary condition which may be introduced by the equipment or by a person and may result in a failure of a component, a device or a safeguard.

Note 2 to entry: This definition is used in the context of component failure risk analysis.

3.6.2 accessible part

part which can be touched by means of the standard test finger

[SOURCE: IEC 60050-442:1998, 442-01-15]

3.6.3 hazardous-live-part

live part which, under certain conditions, can give a harmful electric shock

[SOURCE: IEC 60050-195:1998, 195-06-05]

3.6.4 limited energy source

source that is designed and protected that, under both normal operating conditions and single fault conditions, the current that can be delivered is not hazardous with respect to fire hazard

3.6.5**protective impedance**

impedance connected between hazardous-live-parts and accessible conductive parts, of such value that the current, in normal use and under likely fault conditions, is limited to a safe value, and which is so constructed that its ability is maintained throughout the life of the equipment

[SOURCE: IEC 62477-1:2012, 3.42]

3.6.6**reasonably foreseeable misuse**

use of a product or system in a way not intended by the supplier, but which can result from readily predictable human behaviour

[SOURCE: ISO/IEC Guide 51:2014, 3.7, modified – Notes to entry have been removed]

3.6.7**single fault condition**

condition in which there is a fault of a single protection (but not a reinforced protection) or of a single component or a device

Note 1 to entry: If a single fault condition results in one or more other fault conditions, all are considered as one single fault condition.

[SOURCE: IEC Guide 104:2010, 3.8]

3.7 Symbols and abbreviated terms

AQL	Acceptable quality level
EMC	Electromagnetic compatibility
SCPD	Short-circuit protective device
$\hat{I}$	Maximum peak value of the pick-up current of an electronically controlled electromagnet
I_C	Current made and broken (Table 7)
I_{CS}	Rated service short-circuit breaking capacity (5.3.6.2)
I_{CU}	Rated ultimate short-circuit breaking capacity (5.3.6.1)
I_e	Rated operational current (5.3.2.5)
I_{er}	Rated rotor operational current (5.3.2.7)
I_{es}	Rated stator operational current (5.3.2.6)
~~I_{ie}~~	~~Inhibit current (H.2.7)~~
I_i	Instantaneous short-circuit current setting
I_{IT}	Short-circuit test current for IT system
I_q	Maximum conditional short-circuit test current
I_{th}	Conventional free air thermal current (5.3.2.1)
I_{the}	Conventional enclosed thermal current (5.3.2.2)
I_{thr}	Conventional rotor thermal current (5.3.2.4)
I_{ths}	Conventional stator thermal current (5.3.2.3)
I_u	Rated uninterrupted current (5.3.2.8)
P_C	Nominal holding/pickup power of a conventional direct current controlled electromagnet, or the holding power for an electronically direct current controlled electromagnet

P_p	Pick-up power of a direct current controlled contactor with separate pick-up and hold-on windings
" r "	Minimum short-circuit test current
S_h	Holding power of an alternating current controlled electromagnet
S_p	Pick-up power of an alternating current controlled electromagnet
T_p	Tripping time (Table 2)
U_c	Rated control circuit voltage (5.5)
U_d	Voltage drop of a contactor pole
U_e	Rated operational voltage (5.3.1.1)
U_{er}	Rated rotor operational voltage (5.3.1.1.3)
U_{es}	Rated stator operational voltage (5.3.1.1.2)
U_i	Rated insulation voltage (5.3.1.2)
U_{imp}	Rated impulse (withstand) voltage (5.3.1.3)
U_{ir}	Rated rotor insulation voltage (5.3.1.2.3)
U_{is}	Rated stator insulation voltage (5.3.1.2.2)
U_r	Power frequency or DC recovery voltage (Table 7)
U_s	Rated control circuit supply voltage (5.5)
Z	Pole impedance of a contactor (5.3.7)

4 Classification

Subclause 5.2 gives all the data which may be used as criteria for classification.

5 Characteristics of contactors and starters

5.1 Summary of characteristics

The characteristics of a contactor or starter shall be stated in the following terms, where such terms are applicable:

- type of equipment (5.2);
- rated and limiting values for main circuits (5.3);

NOTE 1 The rated values established for a rheostatic rotor starter are stated in accordance with 5.3.1.1.2, 5.3.1.1.3, 5.3.1.2.2, 5.3.1.2.3, 5.3.2.3, 5.3.2.4, 5.3.2.6, 5.3.2.7 and 5.3.5.6 but it is not necessary to specify all the values listed.

- utilization category (5.4);
- control circuits (5.5);
- auxiliary circuits (5.6);
- types and characteristics of relays and releases (5.7);
- co-ordination with short-circuit protective devices (5.8);
- types and characteristics of automatic change-over devices and automatic acceleration control devices (5.10);
- types and characteristics of auto-transformers for two-step auto-transformer starters (5.11);
- types and characteristics of starting resistors for rheostatic rotor starters (5.12);
- items subject to agreement between manufacturer and user; see Annex D.

For information exchange in electronic format, e.g. electronic catalogue, IEC 62683-1 gives the data format of the essential characteristics of motor starters, contactors and their accessories.

NOTE 2 In the case of a star-delta starter, the currents relate to the delta connection and, in the case of a two-step auto-transformer or rheostatic rotor starter, to the ON position.

5.2 Type of equipment

~~The following shall be stated (see also Clause 6).~~

5.2.1 Kind of equipment

- contactor;
- direct-on-line AC starter;
- star-delta starter;
- two-step auto-transformer starter;
- rheostatic rotor starter;
- combination or protected starter.

5.2.2 Number of poles

5.2.3 Kind of current (AC or DC)

5.2.4 Interrupting medium (air, oil, gas, vacuum, etc.)

5.2.5 Operating conditions of the equipment

5.2.5.1 Method of operation

For example: manual, electromagnetic, motor-operated, pneumatic, electro-pneumatic.

5.2.5.2 Method of control

For example:

- automatic (by pilot switch or sequence control);
- non-automatic (such as by hand operation or by push-buttons);
- semi-automatic (i.e. partly automatic, partly non-automatic).

5.2.5.3 Method of change-over for particular types of starters

The change-over for star-delta starters, rheostatic rotor starters or auto-transformer starters may be automatic, non-automatic or semi-automatic (see Figure C.4 and Figure C.5).

5.2.5.4 Method of connecting for particular types of starters

For example: open transition starter, closed transition starter (see Figure C.5).

5.3 Rated and limiting values for main circuits

~~The rated values established for a contactor or starter shall be stated in accordance with 5.3.1 to 5.4, and 5.8 and 5.9, but it may not be necessary to specify all the values listed.~~

~~NOTE The rated values established for a rheostatic rotor starter are stated in accordance with 5.3.1.2, 5.3.2.3, 5.3.2.4, 5.3.2.6, 5.3.2.7 and 5.3.5.5 but it is not necessary to specify all the values listed.~~

5.3.1 Rated voltages

~~A contactor or starter is defined by the following rated voltages.~~

5.3.1.1 Rated operational voltage (U_e)

5.3.1.1.1 General

Subclause 4.3.1.1 of IEC 60947-1:2007 applies.

The value of the rated operational voltage shall clearly indicate for which 3 phase system (star or delta) it is valid, according to IEC 60038, e.g. 230/400 V or 400 V (50 Hz), 277/480 V or 480 V (60 Hz). When given in the form X/Y V, the lower value is the voltage RMS to neutral and the higher value is the voltage RMS between phases. When one value only is indicated, it refers to the voltage RMS between phases and to neutral.

5.3.1.1.2 Rated stator operational voltage (U_{es})

For rheostatic rotor starters, a rated stator operational voltage is a value of voltage which, when combined with a rated stator operational current, determines the application of the stator circuit including its mechanical switching devices and to which are referred the making and breaking capacities, the type of duty and the starting characteristics. In no case shall the maximum rated operational voltage exceed the corresponding rated insulation voltage.

NOTE The rated stator operational voltage is expressed as the voltage between phases.

5.3.1.1.3 Rated rotor operational voltage (U_{er})

For rheostatic rotor starters, the value of rated rotor operational voltage is that of the voltage which, when combined with a rated rotor operational current, determines the application of the rotor circuit including its mechanical switching devices and to which are referred the making and breaking capacities, the type of duty and the starting characteristics.

This voltage is taken as equal to the voltage measured between slip-rings, with the motor stopped and the rotor open-circuited, when the stator is supplied at its rated voltage.

The rated insulation voltage of the switching devices inserted in the rotor circuit shall be at least 50 % of the highest voltage between open slip-rings.

NOTE Electrical stresses are lower and shorter in the rotor than in the stator.

The rated rotor operational voltage is only applied for a short duration during the starting period. For this reason, it is permissible that the rated rotor operational voltage exceeds the rated rotor insulation voltage by 100 %.

The maximum voltage between the different live parts (e.g. switching devices, resistors, connecting parts, etc.) of the rotor circuit of the starter will vary and account may be taken of this fact in choosing the equipment and its disposition.

5.3.1.2 Rated insulation voltage (U_i)

5.3.1.2.1 General

Subclause 4.3.1.2 of IEC 60947-1:2007 applies.

5.3.1.2.2 Rated stator insulation voltage (U_{is})

For rheostatic rotor starters, the rated stator insulation voltage is the value of voltage which is designated for the devices inserted in the stator supply, as well as the unit they are part of, and to which dielectric tests and creepage distances are referred.

Unless otherwise stated, the rated stator insulation voltage is the value of the maximum rated stator operational voltage of the starter.

5.3.1.2.3 Rated rotor insulation voltage (U_{ir})

For rheostatic rotor starters, the rated rotor insulation voltage is the value of voltage which is designated to the devices inserted in the rotor circuit, as well as the unit they are part of (connecting links, resistors, enclosure), and to which dielectric tests and creepage distances are referred.

5.3.1.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1:2007 applies.

5.3.1.4 Rated starting voltage of an auto-transformer starter

The rated starting voltage of an auto-transformer starter is the reduced voltage derived from the transformer.

Preferred values of rated starting voltage are 50 %, 65 % or 80 % of the rated operational voltage.

5.3.2 Currents or powers

~~A contactor or a starter is defined by the following currents.~~

~~NOTE—In the case of a star-delta starter, these currents relate to the delta connection and, in the case of a two-step auto-transformer or rheostatic rotor starter, to the ON position.~~

5.3.2.1 Conventional free air thermal current (I_{th})

Subclause 4.3.2.1 of IEC 60947-1:2007 applies.

5.3.2.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of IEC 60947-1:2007 applies.

5.3.2.3 Conventional stator thermal current (I_{ths})

The conventional stator thermal current of a starter may be either free air current I_{ths} or enclosed current I_{thes} , in line with 5.3.2.1 and 5.3.2.2.

For a rheostatic rotor starter, the stator thermal current is the maximum current it can carry on eight-hour duty (see 5.3.4.1) without the temperature-rise of its several parts exceeding the limits specified in 8.2.2 when tested in accordance with 9.3.3.3.

5.3.2.4 Conventional rotor thermal current (I_{thr})

The conventional rotor thermal current of a starter may be either free air current I_{thr} or enclosed current I_{ther} , in line with 5.3.2.1 and 5.3.2.2.

For rheostatic rotor starters, the rotor thermal current is the maximum current that those parts of the starter through which the rotor current flows in the ON position, precisely after cutting out resistors, can carry on eight-hour duty (see 5.3.4.1) without their temperature-rise exceeding the limits specified in 8.2.2 when tested in accordance with 9.3.3.3.

NOTE 1 For those elements (switching devices, connecting links, resistors) through which a current of practically no value flows in the ON position, it ~~should~~ can be verified that, for the rated duties (see 5.3.4) stated by the manufacturer, the value of integral

$$\int_0^t i^2 dt$$

does not lead to temperature-rises higher than those appearing in 8.2.2.

NOTE 2 When resistors are built-in into the starter, the temperature-rise ~~should~~ can be taken into account.

5.3.2.5 Rated operational currents (I_e) or rated operational powers

A rated operational current of a contactor or a starter is stated by the manufacturer and takes into account the rated operational voltage (see 5.3.1.1), the conventional free air or enclosed thermal current, the rated current of the overload relay, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the utilization category (see 5.4) and the type of protective enclosure, if any.

In the case of equipment for direct switching of individual motors, the indication of a rated operational current may be replaced or supplemented by an indication of the maximum rated power output, at the rated operational voltage considered, of the motor for which the equipment is intended. The manufacturer shall be prepared to state the relationship assumed between the current and the power.

NOTE Annex G gives values concerning the relationship between rated operational currents and rated operational powers.

For starters, the rated operational current (I_e) is the current in the ON position of the starter.

5.3.2.6 Rated stator operational current (I_{es}) or rated stator operational power

For rheostatic rotor starters, a rated stator operational current is stated by the manufacturer and takes into account the rated current of the overload relay installed in this starter, the rated stator operational voltage (see 5.3.1.1.1), the conventional free air or enclosed thermal current, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the starting characteristics (see 5.3.5.6) and the type of protective enclosure.

The indication of a rated stator operational current may be replaced by the indication of the maximum rated power output, at the rated stator operational voltage considered, of the motor for which the stator elements of the starter are intended. The manufacturer shall be prepared to state the relationship assumed between the motor power and the stator current.

5.3.2.7 Rated rotor operational current (I_{er})

For rheostatic rotor starters, a rated rotor operational current is stated by the manufacturer and takes into account the rated rotor operational voltage (see 5.3.1.1.2), the conventional free air or enclosed rotor thermal current, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the starting characteristics (see 5.3.5.6) and the type of protective enclosure.

It is taken as equal to the current flowing in the connections to the rotor when the latter is short-circuited and the motor is running at full load and the stator is supplied at its rated voltage and rated frequency.

When the rotor part of a rheostatic rotor starter is rated separately, the indication of a rated rotor operational current may be supplemented by the maximum rated power output, for motors having the rated rotor operational voltage considered, of the motor for which that part of the starter (switching devices, connecting links, relays, resistors) is intended. This power varies in particular with the breakaway torque foreseen and consequently takes into account the starting characteristics (see 5.3.5.6).

5.3.2.8 Rated uninterrupted current (I_u)

Subclause 4.3.2.4 of IEC 60947-1:2007 applies.

5.3.3 Rated frequency

Subclause 4.3.3 of IEC 60947-1:2007 applies.

5.3.4 Rated duties

~~Subclause 4.3.4 of IEC 60947-1 applies.~~

5.3.4.1 Eight-hour duty (continuous duty)

Subclause 4.3.4.1 of IEC 60947-1:2007 applies with the following addition.

For a star-delta starter, a two-step auto-transformer starter or a rheostatic rotor starter, the continuous duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it, which are closed in this position, remain closed while each of them carries a steady current long enough for the starter to reach thermal equilibrium, but not for more than 8 h without interruption.

5.3.4.2 Uninterrupted duty

Subclause 4.3.4.2 of IEC 60947-1:2007 applies with the following addition.

For a star-delta starter, a two-step auto-transformer starter or a rheostatic rotor starter, the uninterrupted duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it, which are closed in this position, remain closed without interruption while each of them carries a steady current for periods of more than 8 h (weeks, months or even years).

5.3.4.3 Intermittent periodic duty or intermittent duty

Subclause 4.3.4.3 of IEC 60947-1:2007 applies with the following addition.

For a reduced voltage starter, the intermittent duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it remain closed for periods bearing a definite relation to the no-load periods, both periods being too short to allow the starter to reach thermal equilibrium.

Preferred classes of intermittent duty are:

- for contactors: 1, 3, 12, 30, 120, 300 and 1 200 (operating cycles per hour);
- for starters: 1, 3, 12 and 30 (operating cycles per hour).

It is recalled that an operating cycle is a complete working cycle comprising one closing operation and one opening operation.

For starters, an operating cycle comprises starting, running to full speed and switching off the supply from the motor.

NOTE In the case of starters for intermittent duty, the difference between the thermal time-constant of the overload relay and that of the motor ~~may~~ can render a thermal relay unsuited for overload protection. ~~It is recommended that,~~ For installations intended for intermittent duty, the question of overload protection ~~be~~ is subject to agreement between manufacturer and user.

5.3.4.4 Temporary duty

Subclause 4.3.4.4 of IEC 60947-1:2007 applies.

5.3.4.5 Periodic duty

Subclause 4.3.4.5 of IEC 60947-1:2007 applies.

5.3.5 Normal load and overload characteristics

5.3.5.1 General

Subclause 4.3.5 of IEC 60947-1:2007 applies with the following additions.

5.3.5.2 Ability to withstand motor switching overload currents

Requirements to meet these conditions are given for contactors in 8.2.4.4.

5.3.5.3 Rated making capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.1. The rated making and breaking capacities are only valid when the contactor or the starter is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.5.4 Rated breaking capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.1. The rated making and breaking capacities are only valid when the contactor or the starter is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.5.5 Conventional operational performance

This performance is specified as a series of making and breaking operations in 8.2.4.2.

5.3.5.6 Starting and stopping characteristics of starters (see Figure C.6)

5.3.5.6.1 General

Typical service conditions for starters are:

- one direction of rotation with the motor being switched off during running in normal service conditions (utilization categories AC-2, AC-3 and AC-3e);
- two directions of rotation, but the running in the second direction is realized after the starter has been switched off and the motor has completely stopped (utilization categories AC-2, AC-3 and AC-3e);
- one direction of rotation, or two directions of rotation as in item b), but with the possibility of infrequent inching (jogging). For this service condition, direct-on-line starters are usually employed (utilization category AC-3 and AC-3e);
- one direction of rotation with frequent inching (jogging). Usually direct-on-line starters (utilization category AC-4) are used for this duty;
- one or two directions of rotation, but with the possibility of infrequent plugging for stopping the motor, plugging being associated, if so provided, with rotor resistor braking (reversing starter with braking). Usually a rheostatic rotor starter is used for this duty condition (utilization category AC-2);
- two directions of rotation, but with the possibility of reversing the supply connections to the motor while it is running in the first direction (plugging), in order to obtain its rotation in the other direction, with switching off the motor running in normal service conditions. Usually a direct-on-line reversing starter while running is used for this duty condition (utilization category AC-4).

Unless otherwise stated, starters are designed on the basis of the starting characteristics of the motors compatible with the making capacities of Table 7. These making capacities cover both the transient and steady-state starting currents of the great majority of standard motors.

However, the starting currents for some large motors may attain peak values corresponding to power factors considerably lower than those specified for the test circuit in Table 7. In these cases, the operational current of the contactor or starter should be decreased to a value lower than its rated value such that the making capacity of the contactor or starter is not exceeded.

5.3.5.6.2 Starting characteristics of rheostatic rotor starters

A distinction shall be drawn between the currents and voltages in the stator and rotor circuits of slip-ring motors. However, the changes of the current values in stator and rotor circuits, caused by the various steps of the starting process, are nearly proportional under normal operating conditions.

The following definitions deal mainly with the characteristics of the rotor circuit:

U_{er} is the rated rotor operational voltage;

I_{er} is the rated rotor operational current;

Z_r is the characteristic impedance of the rotor of an AC slip-ring induction motor;

where

$$Z_r = \frac{U_{er}}{\sqrt{3} \times I_{er}} ;$$

I_1 is the current in the rotor circuit immediately before shorting out a resistor section;

I_2 is the current in the rotor circuit immediately after shorting out a resistor section;

$I_m = 1/2 (I_1 + I_2)$;

T_e is the rated motor operational torque;

t_s is the starting time;

k is the severity of start = $\frac{I_m}{I_{er}}$.

It is recognized that many rheostatic rotor starter applications have very specific starting requirements which may result not only in a different number of starting steps and different values of I_1 and I_2 , but also in the values of I_1 and I_2 being different for individual resistor sections. Therefore, no attempt has been made to lay down standard parameters, but the following factors should be taken into consideration:

- for most applications, between two and six starting steps are adequate depending upon load torque, inertia and the severity of start required;
- the resistor sections should be designed to have adequate thermal ratings bearing in mind the starting time of the drive, which will be dependent upon load torque and load inertia.

5.3.5.6.3 Standard conditions for making and breaking corresponding to the starting characteristics for rheostatic rotor starters

These conditions are given in Table 7 and apply to starting with high torque (for the designation of the mechanical switching devices, see Figure C.4).

~~NOTE—Conditions for starting with full torque and half torque are under consideration.~~

The conditions for making and breaking as given in Table 7 for AC-2 utilization category are considered as standard.

The starter circuit shall be designed to open all rotor resistor switching devices before or approximately simultaneously with the opening of the stator switching device. Otherwise, the stator switching device shall comply with AC-3 and AC-3e requirements.

5.3.5.6.4 Starting characteristics for two-step auto-transformer starters

Unless otherwise stated, the auto-transformer starters and specifically the auto-transformers are designed on the condition that the starting time for all classes of duty (see 5.3.4) shall not exceed 15 s. The number of starting cycles per hour assumes equal periods between starts except that, in the event of two operating cycles being made in rapid succession, the starter and the auto-transformer shall be allowed to cool to ambient air temperature before a further start is made.

When a starting time in excess of 15 s is required, this shall be the subject of agreement between manufacturer and user.

5.3.6 Short-circuit characteristics

5.3.6.1 Rated ultimate short-circuit breaking capacity of a MPSD (I_{cu})

The rated ultimate short-circuit breaking capacity of a MPSD is the value of ultimate short-circuit breaking capacity assigned to that MPSD by the manufacturer for the corresponding rated operational voltage, under the conditions specified in P.3. It is expressed as the value of the prospective breaking current, in kA (RMS value of the AC component in the case of alternating current).

5.3.6.2 Rated service short-circuit breaking capacity of a MPSD (I_{cs})

The rated service short-circuit breaking capacity of a MPSD is the value of service short-circuit breaking capacity assigned to that MPSD by the manufacturer for the corresponding rated operational voltage U_e , under the conditions specified in P.2. It is expressed as a value of prospective breaking current, in kA, or as a % of I_{cu} (for example $I_{cs} = 25 \% I_{cu}$).

I_{cs} shall be at least equal to 25 % of I_{cu} .

5.3.6.3 Rated conditional short-circuit current

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

5.3.7 Pole impedance of a contactor (Z)

The pole impedance may be stated by the manufacturer and is determined by measuring the voltage drop resulting of the current flowing through the pole.

5.4 Utilization category

5.4.1 General

Subclause 4.4 of IEC 60947-1:2007 applies with the following additions.

For contactors and starters, the utilization categories as given in Table 1 are considered standard. Any other type of utilization shall be based on agreement between manufacturer and user, but information given in the manufacturer's catalogue or tender may constitute such an agreement.

Each utilization category is characterized by the values of the currents, voltages, power-factors or time-constants and other data of Table 7 and Table 10, and by the test conditions specified in this document.

For contactors or starters defined by their utilization category, it is therefore unnecessary to specify separately the rated making and breaking capacities as these values depend directly on the utilization category as shown in Table 7.

The voltage for all utilization categories is the rated operational voltage of a contactor or a starter other than a rheostatic rotor starter, and the rated stator operational voltage for a rheostatic rotor starter.

All direct-on-line starters belong to one or more of the following utilization categories: AC-3, AC-3e, AC-4, AC-7b, AC-8a and AC-8b.

All star-delta and two-step auto-transformer starters belong to utilization category AC-3 or AC-3e.

Rheostatic rotor starters belong to utilization category AC-2.

5.4.2 Assignment of utilization categories based on the results of tests

- a) A contactor or starter which has been tested for one utilization category or at any combination of parameters (such as highest operational voltage and current, etc.) can be assigned other utilization categories without testing, provided that the test currents, voltages, power-factors or time-constants, number of operating cycles, on and off times given in Table 7 and Table 10, and the test circuit for the assigned utilization categories are not more severe than those at which the contactor or starter has been tested and the temperature-rise has been verified at a current not less than the highest assigned rated operational current in continuous duty.

For example, when tested for utilization category AC-4, a contactor may be assigned utilization category AC-3 provided I_e for AC-3 is not higher than $1,2 I_e$ for AC-4 at the same rated operational voltage.

- b) DC-3 and DC-5 contactors are assumed to be capable of opening and closing loads other than those on which they have been tested provided that:
- the voltage and current do not exceed the specified values of U_e and I_e ;
 - the energy J stored in the actual load is equal to or less than the energy J_c stored in the load with which they were tested.

The values of the energy stored in the test circuit are as follows:

Utilization category	Stored energy J_c
DC-3	$0,005\ 25 \times U_e \times I_e$
DC-5	$0,031\ 5 \times U_e \times I_e$

The values of the constants 0,005 25 and 0,031 5 are derived from:

$$J_c = 1/2 LI^2$$

where the time-constant has been replaced by:

$2,5 \times 10^{-3}$ s (DC-3) and:

15×10^{-3} s (DC-5)

and where $U = 1,05 U_e$, $I = 4 I_e$ and L is the inductance of the test circuit (see Table 7).

Table 1 – Utilization categories

Kind of current	Utilization categories	Additional category designation	Typical applications
AC	AC-1	General use	Non-inductive or slightly inductive loads, resistance furnaces
	AC-2		Slip-ring motors: starting, switching off
	AC-3		Squirrel-cage motors: starting, switching off motors during running ^a
	AC-4	Ballast Incandescent	Squirrel-cage motors: starting, plugging, inching
	AC-5a		Switching of electric discharge lamp controls
	AC-5b		Switching of incandescent lamps
	AC-6a		Switching of transformers
	AC-6b		Switching of capacitor banks
	AC-7a ^c		Slightly inductive loads in household appliances and similar applications
	AC-7b ^c		Motor loads for household applications
	AC-8a		Hermetic refrigerant compressor motor ^b control with manual resetting of overload releases
	AC-8b		Hermetic refrigerant compressor motor ^b control with automatic resetting of overload releases
DC	DC-1		Non-inductive or slightly inductive loads, resistance furnaces
	DC-3		Shunt-motors: starting, plugging, inching
	DC-5		Dynamic breaking of d.c. motors
			Series-motors: starting, plugging, inching
	DC-6	Incandescent	Dynamic breaking of d.c. motors
			Switching of incandescent lamps
a — AC-3 category may be used for occasional inching (jogging) or plugging for limited time periods such as machine set-up; during such limited time periods, the number of such operations should not exceed five per minute or more than ten in a 10-min period. b — A hermetic refrigerant compressor motor is a combination consisting of a compressor and a motor, both of which are enclosed in the same housing, with no external shaft or shaft seals, the motor operating in the refrigerant. c — For AC-7a and AC-7b, see IEC 61095.			

Kind of current	Utilization categories	Additional category designation	Typical load
AC	AC-1	General use	Non-inductive or slightly inductive loads
	AC-2		Slip-ring motors or mixed resistive and inductive loads, including moderate overloads
	AC-3		Squirrel-cage motors ^d : starting, switching off motors during running, reversing ^a
	AC-3e ^e		Squirrel-cage motors with higher locked rotor current ^e : starting, switching off motors during running, reversing ^a
	AC-4	Ballast Incandescent	Squirrel-cage motors ^d : starting, plugging, inching
	AC-5a		Discharge lamps
	AC-5b		AC incandescent lamps
	AC-6a		Transformers
	AC-6b		Capacitor banks
	AC-7a ^c		Slightly inductive loads for household appliances and similar applications
	AC-7b ^c		Motor-loads for household applications
	AC-8a		Hermetic refrigerant compressor motor ^b control with manual resetting of overload releases
AC-8b	Hermetic refrigerant compressor motor ^b control with automatic resetting of overload releases		
DC	DC-1	Incandescent	Non-inductive or slightly inductive loads
	DC-3		Shunt-motors: starting, plugging, inching, dynamic breaking of DC motors
	DC-5		Series-motors: starting, plugging, inching, dynamic breaking of DC motors
	DC-6		DC incandescent lamps
^a AC-3 category may be used for occasional inching (jogging) or plugging for limited time periods such as machine set-up; during such limited time periods, the number of such operations should not exceed five per minute or more than ten in a 10-min period.			
^b A hermetic refrigerant compressor motor is a combination consisting of a compressor and a motor, both of which are enclosed in the same housing, with no external shaft or shaft seals, the motor operating in the refrigerant.			
^c For AC-7a and AC-7b, see IEC 61095.			
^d Asynchronous motor of design N and H according to IEC 60034-12:2016.			
^e Asynchronous motor of design NE and HE, according to IEC 60034-12:2016, having extended / higher locked rotor apparent power and current than design N and H respectively, to achieve a higher efficiency class according to IEC 60034-30-1.			

5.5 Control circuits

~~Subclause 4.5 of IEC 60947-1 applies; moreover for an electronically controlled electromagnet, 4.5.1 of IEC 60947-1 applies with the following addition.~~

~~The electronic part may form an integral part or a separate part provided it is an intrinsic function of the device. In both cases, the device shall be tested with this electronic part mounted as in normal use.~~

~~The characteristics of electronic control circuits are as follows:~~

- ~~— type of current;~~
- ~~— power consumption;~~

- ~~— rated frequency (or d.c.);~~
- ~~— rated control circuit voltage, U_c (nature: a.c./d.c.);~~
- ~~— rated control supply voltage, U_s (nature: a.c./d.c.);~~
- ~~— nature of external control circuit devices (contacts, sensors, optocouplers, electronic active components, etc).~~

~~Annex E gives examples and illustrations of different circuit configurations.~~

~~NOTE A distinction is made between the control circuit voltage U_c , which is the controlling input signal, and the control supply voltage U_s , which is the voltage applied to energize the power supply terminals of the control circuit equipment and may be different from U_c due to the presence of built-in transformers, rectifiers, resistors, electronic circuitry, etc.~~

Subclause 4.5 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies with the following additions.

The list of characteristics given in 4.5.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 shall be completed by:

- limited energy (if the source is in accordance with 8.1.14);
- SELV (PELV) supply (in accordance with Annex N of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014);
- the power consumption of the electromagnet of a contactor, necessary for determining the characteristics of the power supply of the control circuit, which is given by:
 - holding power,
 - pick-up power.

NOTE In the USA and Canada, control circuits are characterised as Class 2 sources as defined in NFPA 70, National Electrical Code and CSA C22.1, Canadian Electrical Code (CE Code) in lieu of or in addition to SELV (PELV) sources.

5.6 Auxiliary circuits

Subclause 4.6 of IEC 60947-1:2007 applies.

Digital inputs and/or digital outputs contained in contactors and motor-starters, and intended to be compatible with PLCs shall fulfil the requirements of Annex S of IEC 60947-1:2007.

5.7 Characteristics of relay and releases of overload relays and motor protective switching device (MPSD)

NOTE In the remainder of this document, the words "overload relay" will be taken to apply equally to an overload relay or an overload release, as appropriate.

5.7.1 Summary of characteristics

The characteristics of relays and releases shall be stated in the following terms, whenever applicable:

- types of relay or release (see 5.7.2);
- characteristic values (see 5.7.3);
- designation and current settings of overload relays (see 5.7.4);
- time-current characteristics of overload relays (see 5.7.5);
- influence of ambient air temperature (see 5.7.6);
- extended functions as given in Annex H;
- load monitoring indicators as given in Annex O.

5.7.2 Types of relay or release

- a) Release with shunt-coil (shunt trip).
- b) Under-voltage and under-current opening relay or release.
- c) Overload time-delay relay the time-lag of which is:
 - 1) substantially independent of previous load;
 - 2) dependent on previous load;
 - 3) dependent on previous load and also phase loss sensitive overload relay or release.
- d) Instantaneous ~~over-current~~ overload relay or release ~~(e.g. jam sensitive)~~;
- e) Instantaneous short-circuit relays or releases.

NOTE A MPSD has a combination of relays or releases from c) and e) above.

- f) Stall relay or release.
- g) Other relays or releases (e.g. control relay associated with devices for the thermal protection of the motor).

5.7.3 Characteristic values

- a) Release with shunt-coil, under-voltage (under-current), over-voltage (instantaneous over current), current or voltage imbalance and phase reversal opening relay or release:
 - rated voltage (current);
 - rated frequency;
 - operating voltage (current);
 - operating time (when applicable);
 - inhibit time (when applicable).
- b) Overload relay and release (including the overload function of MPSD):
 - designation and current settings (see 5.7.4);
 - rated frequency, when necessary (for example in the case of a current transformer operated overload relay);
 - time-current characteristics (or range of characteristics), when necessary;
 - trip class according to classification in Table 2, or the value of the maximum tripping time, in seconds, under the conditions specified in 8.2.1.5.1, Table 3, column D, when this time exceeds 40 s;
 - nature of the relay: thermal, magnetic, electronic or electronic without thermal memory (electronic relay not fulfilling the thermal memory test verification according 8.2.1.5.1.2 shall be marked ~~Thm~~);
 - nature of the reset: in case of manual ~~and/or~~ /automatic; ~~in case of combination manual or automatic reset~~, the set position shall be indicated;
 - tripping time of overload relays class 10A if longer than 2 min at –5 °C or below (see 8.2.1.5.1.1, item c).
- c) Release with residual current sensing relay:
 - rated current;
 - operating current;
 - operating time or time-current characteristic according to Table ~~H.1~~ T.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010;
 - inhibit time (when applicable);
 - type designation (see Annex ~~H~~ T of IEC 60947-1: 2007, IEC 60947-1:2007/AMD1:2010).
- d) Short-circuit release of an MPSD:

- rated operational currents (I_e) or rated operational powers;
- rated frequency;
- current setting (or range of settings) if applicable.

Table 2 – Trip classes of overload relays

Trip class	Tripping time T_p under the conditions specified in 8.2.1.5.1, Table 3, column D^a	Tripping time T_p under the conditions specified in 8.2.1.5.1, Table 3, column D for tighter tolerances (tolerance band E)^a
	s	s
2	–	$T_p \leq 2$
3	–	$2 < T_p \leq 3$
5	$0,5 < T_p \leq 5$	$3 < T_p \leq 5$
10 A	$2 < T_p \leq 10$	$5 < T_p \leq 10$
10	$4 < T_p \leq 10$	$10 < T_p \leq 20$
20	$6 < T_p \leq 20$	$20 < T_p \leq 30$
30	$9 < T_p \leq 30$	$30 < T_p \leq 40$
40	–	

^a The manufacturer shall add the letter E to trip classes to indicate compliance with the band E.

NOTE 1 Depending on the nature of the relay, the tripping conditions are given in 8.2.1.5.

NOTE 2 In the case of a rheostatic rotor starter, the overload relay is commonly inserted in the stator circuit. As a result, it cannot efficiently protect the rotor circuit and more particularly the resistors (generally more easily damageable than the rotor itself or the switching devices in case of a faulty start); protection of the rotor circuit should be the subject of a specific agreement between manufacturer and user (see, inter alia, 8.2.1.1.3).

NOTE 3 In the case of a two-step auto-transformer starter, the starting auto-transformer is normally designed for use during the starting period only: as a result, it cannot be efficiently protected by the overload relay in the event of faulty starting. Protection of the auto-transformer should be the subject of specific agreement between manufacturer and user (see 8.2.1.1.4).

NOTE 4 The lower limiting values of T_p are selected to allow for differing heater characteristics and manufacturing tolerances.

Trip class	Tripping time T_p under the conditions specified in 8.2.1.5.1, Table 3, column D ^a	Tripping time T_p under the conditions specified in 8.2.1.5.1, Table 3, column D for tighter tolerances (tolerance band E) ^a
	s	S
2	–	$T_p \leq 2$
3	–	$2 < T_p \leq 3$
5	$0,5 < T_p \leq 5$	$3 < T_p \leq 5$
10A	$2 < T_p \leq 10$	–
10	$4 < T_p \leq 10$	$5 < T_p \leq 10$
20	$6 < T_p \leq 20$	$10 < T_p \leq 20$
30	$9 < T_p \leq 30$	$20 < T_p \leq 30$
40	–	$30 < T_p \leq 40$
NOTE 1 Depending on the nature of the relay, the tripping conditions are given in 8.2.1.5. NOTE 2 In the case of a rheostatic rotor starter, the overload relay is commonly inserted in the stator circuit. As a result, it cannot efficiently protect the rotor circuit and more particularly the resistors (generally more easily damageable than the rotor itself or the switching devices in case of a faulty start); protection of the rotor circuit is the subject of a specific agreement between manufacturer and user (see, inter alia, 8.2.1.1.3). NOTE 3 In the case of a two-step auto-transformer starter, the starting auto-transformer is normally designed for use during the starting period only: as a result, it cannot be efficiently protected by the overload relay in the event of faulty starting. Protection of the auto-transformer is the subject of specific agreement between manufacturer and user (see 8.2.1.1.4). NOTE 4 The lower limiting values of T_p are selected to allow for differing heater characteristics and manufacturing tolerances.		
^a The manufacturer shall add the letter E to trip classes to indicate compliance with the band E.		

5.7.4 Designation and current settings of overload relays

Overload relays are designated by their current setting (or the upper and lower limits of the current setting range, if adjustable) and their trip class.

The current setting (or current setting range) shall be marked on the relays.

However, if the current setting is influenced by the conditions of use or other factors which cannot readily be marked on the relay, then the relay or any interchangeable parts thereof (e.g. heaters, operating coils or current transformers) shall carry a number or an identifying mark which makes it possible to obtain the relevant information from the manufacturer or his catalogue or, preferably, from data furnished with the starter.

In the case of current transformer operated overload relays, the marking may refer either to the primary current of the current transformer through which they are supplied or to the current setting of the overload relays. In either case, the ratio of the current transformer shall be stated.

5.7.5 Time-current characteristics of overload relays

Typical time-current characteristics shall be given in the form of curves supplied by the manufacturer. These curves shall indicate how the tripping time, starting from the cold state (see 5.7.6), varies with the current up to a value of at least eight times the full-load current of the motor with which it is intended that the relay be used. The manufacturer shall be prepared to indicate, by suitable means, the general tolerances applicable to these curves and the conductor cross-sections used for establishing these curves (see 9.3.3.2.2, item c)).

NOTE ~~It is recommended that~~ The current ~~be~~ is plotted as abscissa and the time as ordinates, using logarithmic scales. ~~It is recommended that~~ The current ~~be~~ is plotted as multiples of the setting current I_r and the time in seconds on the standard graph sheet detailed in 5.6.1 and Figure 1 of IEC 60269-1:2006 and in Figure 104, Figure 504 and Figure 505 of IEC 60269-2:2013.

5.7.6 Influence of ambient air temperature

The time-current characteristics (see 5.7.5) refer to a stated value of ambient air temperature, and are based on no previous loading of the overload relay (i.e. from an initial cold state). This value of the ambient air temperature shall be clearly given on the time curves; the preferred values are +20 °C or +40 °C.

The overload relays shall be able to operate within the ambient air temperature range of –5 °C to +40 °C, and the manufacturer shall be prepared to state the effect of variation in ambient air temperature on the characteristics of overload relays.

5.8 Co-ordination with short-circuit protective devices

The co-ordination of contactors and starters is characterized by the type, ratings and characteristics of the short-circuit protective devices (SCPD) that provide protection of the contactor and starter against short-circuit currents. Requirements are given in 8.2.5.1 and 8.2.5.2 of this document, and in 4.8 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010.

Requirements for AC-3e rated starters with type 2 coordination are given in 8.2.5.3.

When a MPSD is used as a manual starter without associated contactor, it does not need to be tested according to this subclause.

5.9 Void

5.10 Types and characteristics of automatic change-over devices and automatic acceleration control devices

5.10.1 Types

- a) Time-delay devices, e.g. time-delay contactor relays according to IEC 60947-5-1 applicable to control-circuit devices or specified-time all-or-nothing relays according to IEC 61810-1.
- b) Undercurrent devices (undercurrent relays).
- c) Other devices for automatic acceleration control:
 - devices dependent on voltage;
 - devices dependent on power;
 - devices dependent on speed.

5.10.2 Characteristics

- a) The characteristics of time-delay devices are:
 - the rated time-delay or its range, if adjustable;
 - for time-delay devices fitted with a coil, the rated voltage, when it differs from the starter line voltage.
- b) The characteristics of the undercurrent devices are:
 - the rated current (thermal current and/or rated short-time withstand current, according to the indications given by the manufacturer);
 - the current setting or its range, if adjustable.
- c) The characteristics of the other devices shall be determined by agreement between manufacturer and user.

5.11 Types and characteristics of auto-transformers for two-step auto-transformer starters

Account being taken of the starting characteristics (see 5.3.5.6.3), starting auto-transformers shall be characterized by:

- the rated voltage of the auto-transformer;
- the number of taps available for adjusting the starting torque and current;
- the starting voltage, i.e. the voltage at the tapping terminals, as a percentage of the rated voltage of the auto-transformer;
- the current they can carry for a specified duration;
- the rated duty (see 5.3.4);
- the method of cooling $\left\{ \begin{array}{l} \text{air-cooling;} \\ \text{oil-cooling.} \end{array} \right.$

The auto-transformer can be:

- either built-in into the starter, in which case the resulting temperature-rise has to be taken into account in determining the ratings of the starter;
- or provided separately, in which case the nature and dimensions of the connecting links have to be specified by agreement between the manufacturer of the transformer and the manufacturer of the starter.

5.12 Types and characteristics of starting resistors for rheostatic rotor starters

Account being taken of the starting characteristics (see 5.3.5.6.2), the starting resistors shall be characterized by:

- the rated rotor insulation voltage (U_{ir});
- their resistance value;
- the mean thermal current, defined by the value of steady current they can carry for a specified duration;
- the rated duty (see 5.3.4);
- the method of cooling $\left\{ \begin{array}{l} \text{free air;} \\ \text{forced air;} \\ \text{oil-immersion.} \end{array} \right.$

They can be:

- either built-in into the starter, in which case the resulting temperature-rise has to be limited in order not to cause any damage to the other parts of the starter;
- or provided separately, in which case the nature and dimensions of the connecting links have to be specified by agreement between the manufacturer of the resistors and the manufacturer of the starter.

6 Product information

6.1 Nature of information

~~The following information shall be given by the manufacturer.~~

6.1.1 Identification

- a) manufacturer's name or trade mark;

- b) type designation or serial number;
- c) number of this document, if the manufacturer claims compliance.

6.1.2 Characteristics, basic rated values and utilization

Characteristics:

- d) rated operational voltages (see 5.3.1.1);
- e) polarity of terminals, if applicable;
- f) utilization category and rated operational currents (or rated powers), at the rated operational voltages of the equipment (see 5.3.2.5 and 5.4);
- g) either the value of the rated frequency 50/60 Hz or the symbol $\overline{\overline{\overline{\hspace{0.5cm}}}}$ (IEC 60417-5031), or other rated frequencies e.g. 16 2/3 Hz, 400 Hz;
- h) rated duty with the indication of the class of intermittent duty, if any (see 5.3.4), and the off time as specified in footnote d) of Table 10, if necessary;
- i) pole impedance of the switching device (Z);
- j) material declaration according to Annex W of IEC 60947-1:2007/AMD2:2014;

Associated values:

- k) rated making and breaking capacities. These indications may be replaced, where applicable, by the indication of the utilization category in Table 7 and in Table M.2.

Safety and installation:

- l) rated insulation voltage (see 5.3.1.2);
- m) rated impulse withstand voltage (see 5.3.1.3);
- n1) IP code, ~~in case of an enclosed equipment (see 8.1.11)~~ according to Annex C of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010;
- n2) pollution degree (see Clause 7);
- o) short-circuit rating:
 - for contactor or starter: rated conditional short-circuit current (see 5.3.6) and type of co-ordination (see 8.2.5.1) and type, current rating and characteristics of the associated SCPD;
 - for combination starter, combination switching device, protected starter or protected switching device: rated conditional short-circuit current (see 5.3.6) and type of co-ordination (see 8.2.5.1);
 - for MPD, rated ultimate short-circuit breaking capacity (I_{cu}) and rated service short-circuit breaking capacity (I_{cs}) (see 8.2.4.7).
- ~~n) void.~~
- p1) maximum permissible altitude of the site of installation, if greater than 2 000 m.
- p2) conductor connection on terminal:
 - length of insulation to be removed before insertion of the conductor into the terminal;
 - maximum number of conductors which may be clamped.

For non-universal screwless terminals:

- "s" or "sol" for terminals declared for rigid-solid conductors;
- "r" for terminals declared for rigid (solid and stranded) conductors;
- "f" for terminals declared for flexible conductors.
- q) reference of dedicated wiring accessories which can be used for wiring the starter or the combination of contactors;

Control circuits:

The following information concerning control circuits shall be placed either on the coil or on the equipment:

- r) rated control circuit voltage (U_c), nature of current and rated frequency;

NOTE 1 Other information such as the holding or pick-up power-consumption could be given e.g. in the product literature.

- s) if necessary, nature of current, rated frequency and rated control circuit supply voltage (U_s);

In the case of electronically controlled electromagnets, other information may also be necessary, for example control circuit configuration (see 5.5 of this document and Annex U of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014).

Air supply systems for starters or contactors operated by compressed air:

- t) rated supply pressure of the compressed air and limits of variation of this pressure, if they are different from those specified in 8.2.1.2.

Auxiliary circuits:

- u) ratings of auxiliary circuits (see 5.6).

~~Overload~~ *Over-current relays and releases:*

- v1) characteristics according to 5.7.2, 5.7.5 and 5.7.6;
v2) characteristics according to 5.7.3 and 5.7.4.

Additional information for certain types of contactor and starter:

Rheostatic rotor starters:

- w) circuit diagram;
x) severity of start (see 5.3.5.6.1);
y) starting time (see 5.3.5.6.1).

Auto-transformer starters:

- z) rated starting voltage(s), i.e. voltage(s) at the tapping terminals.

NOTE 2 This value may can be expressed as a percentage of the rated operational voltage of the starter.

~~Vacuum contactors and starters:~~

- ~~x) maximum permissible altitude of the site of installation, if less than 2 000 m.~~

EMC:

- aa) environment A or B: see 7.3.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010;
ab) special requirements, if applicable, for example shielded or twisted conductors.

NOTE 3 Unshielded or untwisted conductors are considered as normal installation conditions.

6.2 Marking

Subclause 5.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies to contactors, starters and overload relays with the following additions.

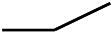
Data under items d) to ab) in 6.1.2 shall be included on the nameplate or on the equipment or in the manufacturer's published literature.

Data under items c) in 6.1.1, e), n) (if the degree of protection is different than IP00) and v2) in 6.1.2 shall be marked on the equipment; time-current characteristics (or range of characteristics) may be provided in the manufacturer's published literature.

~~In the case of electronically controlled electromagnets, information other than that given in o) and p) of 6.1.2 may also be necessary; see also 5.5 and Annex E.~~

NOTE In the USA and Canada, on multiple equipment, the additional category designation given in Table 1 is marked on the product.

MPSD shall be marked in addition, in a place such that they are visible and legible when the MPSD is installed, for the:

- suitability for isolation, if applicable, with the symbol  (IEC 60617- S00287 "Circuit breaker" combined with IEC 60417-6169-1 "Disconnecter; isolator");
- indication of the open and closed positions, with  (IEC 60417-5008 "OFF" (power)) and  (IEC 60417-5007 "ON" (power)) respectively, if symbols are used (see 7.1.6.1 of IEC 60947-1:2007);

The following data shall be marked externally on the MPSD in a place such they may be visible and legible when the MPSD is installed:

- range of the rated instantaneous short-circuit current setting (I_i), for adjustable releases.

For dedicated accessories used for wiring the starter or the combination of contactors, data under 6.1.1 c), 6.1.2 l) and the current I_{th} , if applicable, shall be provided in the manufacturer's published literature.

6.3 Instructions for installation, operation, maintenance, decommissioning and dismantling

Subclause 5.3 of IEC 60947-1:2007 and IEC 60947-1:2007/AMD2:2014 applies with the following addition.

~~Information shall be provided by the manufacturer to advise the user on the measures to be taken with regard to the equipment in the event of a short-circuit and the measures to be taken with regard to the equipment, if any, concerning EMC.~~

The instructions shall also cover the dedicated wiring accessories.

Additional information for the decommissioning and dismantling of the device shall be maintained available to the user in case of foreseeable hazardous condition of the device, for example due to stored energy, instability or falling of objects, etc.

In the case of protected starters, the manufacturer shall also provide the necessary mounting and wiring instructions.

The manufacturer of a starter incorporating an automatic reset overload relay capable of being connected to enable automatic restarting, shall provide, with the starter, that information necessary to alert the user to the possibility of automatic restarting.

If the construction requires energization by an external source that is not a limited energy source as defined in 8.1.14, the manufacturer shall provide the appropriate information for short-circuit and overcurrent protection of the ports.

For each relevant potential hazard, the manufacturer shall provide safety signs, graphical symbols or safety notes of the hazard for example by using e.g. IEC 60417-5036. Signal words shall be defined according to ISO 3864-2.

NOTE ISO/IEC 82079-1 provide guidance for developing safety instructions.

6.4 Environmental information

Subclause 5.4 of IEC 60947-1:2007/AMD2:2014 applies.

NOTE Future publication IEC TS 63058 will give the method for assessing the environmental impact of switchgear and controlgear.

7 Normal service, mounting and transport conditions

Clause 6 of IEC 60947-1:2007 applies with the following addition.

Unless otherwise stated by the manufacturer, a contactor or a starter is for use in pollution degree 3 environmental conditions, as defined in 6.1.3.2 of IEC 60947-1:2007. However, other pollution degrees may be considered to apply, depending upon the micro-environment.

Rail mounting shall be specified according to IEC 60715:2017, when relevant.

Standard conditions of vibration are defined in footnote ^b of Table Q.1 of IEC 60947-1:2007/AMD2:2014.

Altitude above 2 000 m are subjected to agreement between manufacturer and user.

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 General

Subclause 7.1.1 of IEC 60947-1:2007 applies with the following addition.

Measures shall be provided to reduce the likelihood of injury and property damage, under installation, maintenance, normal operation conditions, abnormal operation conditions and reasonably foreseeable misuses. The requirements of this document are generically providing these measures.

Protection against hazards caused by the electronic circuits shall be maintained under normal and single fault conditions, as specified in this document.

The risk assessment method of electromechanical overload protection function used in safety application is given in Annex L.

Components used in the construction of the equipment, compliant with a relevant IEC product standard do not require separate evaluation. Components or assemblies of components, for which no relevant product standard exists, shall be tested according to the requirements of this document.

Where the product is intended to be used together with specific auxiliary equipment and dedicated wiring accessories, the safety evaluation and test shall include this auxiliary equipment and accessories unless it can be shown that it does not affect the safety of any equipment.

The accessible part of the device and especially the operating means shall not present sharp edges and corners which can injure the operator.

Annex O of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 should be considered carefully especially for substitution or reduction in use of hazardous substances or if not possible for providing measures to prevent emission and contact with them.

8.1.2 Materials

8.1.2.1 General materials requirements

Subclause 7.1.2.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies with the following additions.

NOTE Fire hazard aspects are detailed in IEC TR 63054.

Parts of insulating materials located in electrical circuits sourced from limited energy sources according to 8.1.14 are not required to comply with the requirements of this subclause.

8.1.2.2 Glow wire testing

Subclause 7.1.2.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies with the following addition.

When tests on the equipment or on sections taken from the equipment are used, parts of insulating materials necessary to retain current-carrying parts in position shall conform to the glow-wire tests of 8.2.1.1.1 of IEC 60947-1:2007 at a test temperature of 850 °C.

8.1.2.3 Test based on flammability category

Subclause 7.1.2.3 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.

8.1.3 Current-carrying parts and their connections

Subclause 7.1.3 of IEC 60947-1:2007 applies.

8.1.4 Clearances and creepage distances

Subclause 7.1.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies with the following additions.

Clearance and creepage distances within the circuits sourced from limited energy sources as defined in 8.1.14 are not required to comply with the requirements of this subclause.

Clearance and creepage distances on printed wiring boards (PWBs) including components mounted on PWBs, for functional, basic, supplementary and reinforced insulation, designed according to 8.1.14, are considered to meet these requirements and do not need any further investigation.

Where SELV and PELV circuits are accessible, they shall be separated from other hazardous-live-part according to the requirements of Annex N for protective impedance in addition to Annex N of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014.

NOTE If some circuits are only accessible under maintenance or similar conditions, they can, depending on the risk level (severity of harm and the probability of occurrence), be considered under normal service conditions (see 6.1), and use only basic insulation. Accessible parts can be determined using test probes according to IEC 61032.

8.1.5 Actuator

~~Subclause 7.1.5 of IEC 60947-1 applies with the following addition.~~

~~Means for padlocking the operating handle of the manually operated switching device of a combination starter may be provided.~~

8.1.5.1 Insulation

Subclause 7.1.5.1 of IEC 60947-1:2007 applies.

8.1.5.2 Direction of movement

Subclause 7.1.5.2 of IEC 60947-1:2007 applies.

8.1.5.3 Mounting

Actuators mounted on removable panels or opening doors shall be so designed that, when the panels are replaced or the doors closed, the actuator will engage correctly with the associated mechanism.

8.1.5.4 Protection

There shall be no path or opening which allows incandescent particles to be discharged from the area of the manual operating means.

8.1.6 Indication of the contact position

8.1.6.1 Indicating means

Subclause 7.1.6.1 of IEC 60947-1:2007 applies to manually operated starters.

8.1.6.2 Indication by the actuator

Subclause 7.1.6.2 of IEC 60947-1:2007 applies.

8.1.7 Additional requirements for equipment suitable for isolation

Subclause 7.1.7 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with the following additions:

If the tripped position of the MPSD is not the indicated open position, it should be clearly visible that it is not the open position. The verification of the main contact position for a manual starter and a MPSD suitable for isolation shall be tested according to 9.3.3.2.3.

MPSDs and manual motor starter suitable for isolation shall be provided with means for locking in the open position.

8.1.8 Terminals

8.1.8.1 General

Subclause 7.1.8 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with ~~however,~~ the following ~~additional requirements~~ additions.

8.1.8.2 Terminal identification and marking

Subclause 7.1.8.4 of IEC 60947-1:2007 applies with additional requirements as given in Annex A.

8.1.9 Additional requirements for equipment provided with a neutral pole

Subclause 7.1.9 of IEC 60947-1:2007 applies.

8.1.10 Provisions for protective earthing

Subclause 7.1.10 of IEC 60947-1:2007 applies.

8.1.11 Enclosures for equipment

8.1.11.1 Design

Subclause 7.1.11.1 of IEC 60947-1:2007 applies with the following additions.

Starting resistors mounted within an enclosure shall be so located or guarded that issuing heat is not detrimental to other apparatus and materials within the enclosure.

For the specific case of combination starters, the cover or door shall be interlocked so that it cannot be opened without the manually operated switching device being in the open position.

However, provision may be made to open the door or cover with the manually operated switching device in the ON position by the use of a tool.

8.1.11.2 Insulation

Subclause 7.1.11.2 of IEC 60947-1:2007 applies.

8.1.12 Degrees of protection of enclosed equipment

Subclause 7.1.12 of IEC 60947-1:2007 applies.

8.1.13 Conduit pull-out, torque and bending with metallic conduits

Subclause 7.1.13 of IEC 60947-1:2007 applies.

8.1.14 Limited energy source

8.1.14.1 General

A limited energy source can be implemented as a secondary circuit derived from circuits connected to the hazardous-live-part with the following separation means:

- a) galvanic separation;
- b) current limiting impedance.

NOTE Class 2 sources as defined in NFPA 70, National Electrical Code and CSA C22.1 Canadian Electrical Code (CE Code) have the same electrical output characteristics as limited energy sources with galvanic separation.

8.1.14.2 Limited energy source with galvanic separation

A limited energy source with galvanic separation incorporates an isolating component such as a transformer between the primary circuit and the limited energy output. It shall comply with one of the following requirements:

- a) the output is inherently limited in compliance with Table 19; or
- b) a linear or non-linear impedance limits the output in compliance with Table 19. If a positive temperature coefficient device (e.g. PTC) is used, it shall pass the applicable tests specified in IEC 60730-1; or

- c) a regulating network limits the output in compliance with Table 19, both with and without a single fault in the regulating network; or
- d) an over-current protective device is used and the output is limited in compliance with Table 20.

Where an over-current protective device is used, it shall be a fuse or non-adjustable electromechanical device.

Compliance to determine the maximum available power is checked by test of 9.2.4.

In case of external power supply without over-current protective devices, it shall not exceed the values given in Table 19. In case of external power supply with over-current protective devices, it shall not exceed the values given in Table 20.

Table 19 – Limits for limited energy sources without an over-current protective device

Output voltage ^a		Output current ^{b, d} I_{sc} A	Maximum power ^c S VA
V AC	V DC		
≤ 30 RMS	≤ 30 V	≤ 8	100
-	$30 < U_{oc} \leq 60$ ^e	$\leq \frac{150}{U_{oc}}$	100

NOTE This table will be moved into the future revision of IEC 60947-1 and is therefore numbered differently to the other tables in this document.

^a U_{oc} : Output voltage measured in accordance with all load circuits disconnected. Voltages are for substantially sinusoidal alternating current and ripple-free direct current. For non-sinusoidal alternating current and direct current with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V.

^b I_{sc} : Maximum output current with any non-capacitive load, including a short-circuit.

^c S (VA): Maximum output apparent power in VA with any non-capacitive load as determined by 9.2.4.

^d Measurement of I_{sc} is made 5 s after application of the load if protection is by an electronic circuit or a positive temperature coefficient device (e.g. PTC), and 60 s in other cases.

^e In the USA, the limit is 60 V DC continuous or direct current switching outside of 10 Hz to 200 Hz, 24,8 V DC switching at 10 Hz to 200 Hz.

Table 20 – Limits for limited energy sources with an over-current protective device

Output voltage ^a		Output current ^{b, d} I_{sc} A	Maximum power ^{c, d} S VA	Current rating of over-current protective device ^e A
V AC	V DC			
≤ 20	≤ 20	$\leq \frac{1000}{U_{oc}}$	250	$\leq 5,0$
$20 < U_{oc} \leq 30$	$20 < U_{oc} \leq 30$ ^f			$\leq \frac{100}{U_{oc}}$
-	$30 < U_{oc} \leq 60$ ^f			$\leq \frac{100}{U_{oc}}$

NOTE 1 The reason for making measurements with over-current protective devices bypassed is to determine the amount of energy that is available to cause possible overheating during the operating time of the over-current protective devices.

NOTE 2 This table will be moved into the future revision of IEC 60947-1 and is therefore numbered differently to

the other tables in this document.

- ^a U_{oc} : Output voltage measured with all load circuits disconnected. Voltages are for substantially sinusoidal alternating current and ripple free direct current. For non-sinusoidal alternating current and for direct current with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V.
- ^b I_{sc} : Maximum output current with any non-capacitive load, including a short-circuit, measured 60 s after application of the load.
- ^c S (VA): Maximum output VA with any non-capacitive load measured 60 s after application of the load as determined by 9.2.4.
- ^d Current limiting impedances remain in the circuit during measurement, but over-current protective devices are bypassed.
- ^e The current ratings of over-current protective devices that break the circuit within 120 s with a current equal to 210 % of the current rating specified in the table.
- ^f In the USA, the limit is 60 V DC continuous or direct current switching outside of 10 Hz to 200 Hz, 24,8 V DC switching at 10 Hz to 200 Hz.

8.1.14.3 Limited energy source with current limiting impedance

A limited energy source with current limiting impedance has the following characteristics:

- the output voltage is limited in compliance with Table 21 and
- a linear or non-linear impedance limits the output in compliance with Table 21 both with and without a single fault.

A limited energy source with current limiting impedance may be derived from either mains or from a galvanically separated circuit e.g. the secondary of a transformer.

Table 21 – Limits for limited energy source with current limiting impedance

Output voltage ^a		Output current ^{b, d}	Maximum power ^c
U_{oc}			
V AC	V DC	I_{sc} A	S VA
≤ 30 V RMS	≤ 30 V	0,5	15
NOTE This table will be moved into the future revision of IEC 60947-1 and is therefore numbered differently to the other tables in this document. ^a U_{oc}: Output voltage measured in accordance with all load circuits disconnected. Voltages are for substantially sinusoidal alternating current and ripple-free direct current. For non-sinusoidal alternating current and direct current with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V. ^b I_{sc}: Maximum output current measured across the output of the limited energy source. ^c S (VA): Maximum output apparent power in VA as determined by 9.2.4. ^d Measurement of I_{sc} is made 5 s after application of the short-circuit.			

8.1.15 Stored charge energy circuit

Parts including stored charge (capacitors) that are removable for servicing (such as coil replacement), installation, or disconnection shall present no risk of electric energy hazard after disconnection.

Capacitors connected to accessible hazardous live parts shall be discharged to an energy level less than 0,5 mJ within 5 s after the removal of power. Otherwise, a readily visible warning notice shall be provided on the product, indicating the time of discharge to the limit values or a preferable method how to discharge the capacitor before touching the connecting parts.

8.1.16 Fault and abnormal conditions

The product shall be designed to avoid operating modes or sequences that can cause a fault condition or component failure leading to a hazard, unless other measures to prevent the hazard are provided by the installation and are described in the installation information provided with the product. The requirements in this clause also apply to abnormal operating conditions as applicable.

Circuit analysis or testing shall be performed to determine whether or not failure of a particular component (including insulation systems) would result in hazard.

This analysis shall include situations where a failure of the component or the insulation (basic and supplementary) would result in:

- an impact on the risk of electric shock;
- a risk of degradation resulting in emission of flame, burning particles or molten metal.

The analysis or testing shall include the effect of short-circuit and open circuit conditions of the component. Testing is necessary unless analysis can conclusively show that, in short-circuit and open circuit conditions, no shock and fire hazard will result from failure of the component. Compliance shall be checked by test of 9.2.5.

Components evaluated for their reliability according to relevant product standards are considered to meet these requirements and do not need any further investigation, if tested under conditions that fulfil the conditions for which the product is designed.

8.1.17 Short-circuit and overload protection of ports

Where the power source for a signal port or power port that is external to the device does not comply with the requirements for limited energy sources in 8.1.14, the product shall not present a hazard under short-circuit or overload conditions. Instructions for the installation of external overcurrent protection shall be made available in accordance with 6.3.

Compliance shall be checked by inspection and where necessary, by simulation of single fault conditions.

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 General

8.2.1.1.1 General conditions

Subclause 7.2.1.1 of IEC 60947-1:2007 applies with the following additions.

The requirements for the short-circuit protective device of a combination starter or a protected starter are given by IEC 60947-2 for circuit-breaker, by IEC 60947-3 for fuse-combination unit and by this document for MPSD.

Requirements concerning normal load and overload characteristics according to 5.3.5 are given in 8.2.4.1, 8.2.4.2 and 8.2.4.4.

The requirements apply to the product as well as to the dedicated wiring accessories.

If there is no distinction between U_s and U_c , requirements apply with U_c .

8.2.1.1.2 General conditions A

Starters shall be so constructed that they:

- a) are trip free;
- b) can be caused to open their contacts by the means provided when running and at any time during the starting sequence;
- c) will not function in other than the correct starting sequence.

8.2.1.1.3 General conditions B

Starters employing contactors shall not trip due to the shocks caused by operation of the contactors when tested according to 9.3.3.1, after the starter has carried its rated full load current at the reference ambient temperature (i.e. +20 °C) and has reached thermal equilibrium at both minimum and maximum settings of the overload relay, if adjustable.

8.2.1.1.4 General conditions C

For rheostatic starters, the overload relay shall be connected in the stator circuit. Special arrangements may be made to protect the rotor contactors and resistors against overheating, if requested by the user.

8.2.1.1.5 General conditions D

When starters are used in conditions in which the overheating of the starting resistors or transformers would represent an exceptional hazard, it is recommended that a suitable device be fitted to switch off the starter automatically before a dangerous temperature is reached.

8.2.1.1.6 General conditions E

The moving contacts of multipole equipment intended to make and break together shall be so coupled that all poles make and break substantially together, whether operated manually or automatically.

8.2.1.2 Limits of operation of contactors and power-operated starters

~~8.2.1.2.1 Electromagnetic contactors and starters~~

~~Electromagnetic contactors, whether used separately or in starters, shall close satisfactorily at any value between 85 % and 110 % of their rated control supply voltage U_s . Where a range is declared, 85 % shall apply to the lower value and 110 % to the higher.~~

~~The limits between which contactors shall drop out and open fully are 75 % to 20 % for a.c. and 75 % to 10 % for d.c. of their rated control supply voltage U_s . Where a range is declared, 20 % or 10 %, as the case may be, shall apply to the higher value and 75 % to the lower.~~

~~Limits for closing are applicable after the coils have reached a stable temperature corresponding to indefinite application of 100 % U_s in an ambient temperature equivalent to the ambient temperature declared by the manufacturer but not less than +40 °C.~~

~~Limits for drop-out are applicable with the coil circuit resistance at –5 °C. This can be verified by calculation using values obtained at normal ambient air temperature.~~

~~The limits apply to d.c. and a.c. at declared frequency.~~

~~8.2.1.2.2 Contactors and starters with electronically controlled electromagnet~~

~~Subclause 8.2.1.2.1 applies with the following modification.~~

~~Replace the second paragraph as follows:~~

~~The limits between which contactors with an electronically controlled electromagnet shall drop out and open fully are~~

- ~~— for d.c.: 75 % to 10 % of their rated control supply voltage U_s ,~~
- ~~— for a.c.: 75 % to 20 % of their rated control supply voltage U_s ,~~
- ~~— for a.c.: 75 % to 10 % of their rated control supply voltage U_s if specified by the manufacturer,~~
- ~~— for a.c., where the manufacturer specifies limits between 75 % to 10 % of the rated control supply voltage U_s , the contactor shall, in addition, be submitted to the capacitive drop out test of 8.2.1.2.4.~~

~~Where a range is declared, 20 % or 10 % as the case may be, shall apply to the higher value of the range and 75 % to the lower value of the range.~~

~~8.2.1.2.3 Electro-pneumatic contactors and starters~~

~~Electro-pneumatic and pneumatic contactors shall close satisfactorily with the air supply pressure between 85 % and 110 % of the rated pressure and open between 75 % and 10 % of the rated pressure.~~

~~8.2.1.2.4 Capacitive drop out test~~

~~A capacitor C shall be inserted in series in the supply circuit U_s , the total length of the connecting conductors being ≤ 3 m. The capacitor is short circuited by a switch of negligible impedance. The supply voltage shall then be adjusted to 110 % U_s .~~

~~It shall be verified that the contactor drops out when the switch is operated to the open position.~~

~~The value of the capacitor shall be~~

$$C \text{ (nF)} = 30 + 200\,000 / (f \times U_s)$$

~~e.g. for a coil rated 12...24 V 50 Hz, the capacitor value is 196 nF (calculation made with U_s max., see Note 1).~~

~~NOTE 1 The test voltage is the highest value of the declared rated supply voltage range U_s .~~

~~NOTE 2 The value of the capacitor simulates a typical control wiring of 100 m long cable and of $1,5 \text{ mm}^2$ ($0,3 \text{ nF/m}$ that is 30 nF for 100 m) connected to a static output having a $1,3 \text{ mA}$ leakage current ($200\,000$ in the formula $\approx 10 \text{ E}+9 \cdot 1,3 \text{ E}-3/2 \cdot \pi$).~~

~~NOTE 3 The drop out time should be specified for particular uses, e.g. emergency breaking.~~

Subclause 7.2.1.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with following additions:

For latched contactors, the device shall drop out and open fully when a de-latching voltage between 85 % and 110 % of the rated de-latching voltage is applied.

8.2.1.3 Limits of operation of under-voltage relays and releases

Subclause 7.2.1.3 of IEC 60947-1:2007 applies with the following addition: tests are specified in 9.3.3.2.2 of this document.

8.2.1.4 Limits of operation of shunt-coil operated releases (shunt trip)

Subclause 7.2.1.4 of IEC 60947-1, IEC 60947-1:2007/AMD2:2014 applies with the following addition: tests are specified in 9.3.3.2.2 of this document.

8.2.1.5 Limits of operation of current sensing relays and releases

8.2.1.5.1 Limits of operation of time-delay overload relays when all poles are energized

8.2.1.5.1.1 General tripping requirements of overload relays

NOTE 1 The thermal protection of motors in the presence of harmonics in the supply voltage is under consideration.

The relays shall comply with the requirements of Table 3 when tested as follows:

- a) with the overload relay or starter in its enclosure, if normally fitted, and at A times the current setting, tripping shall not occur in less than 2 h starting from the cold state, at the value of reference ambient air temperature stated in Table 3. However, when the overload relay terminals have reached thermal equilibrium at the test current in less than 2 h, the test duration can be the time needed to reach such thermal equilibrium;
- b) when the current is subsequently raised to B times the current setting, tripping shall occur in less than 2 h;
- c) for class 2, 3, 5 and 10A overload relays energized at C times the current setting, tripping shall occur in less than 2 min starting from thermal equilibrium, at the current setting, in accordance with 9.3.3 of IEC 60034-1:2017; for class 10A overload relays, for ambient air temperature -5 °C or below, the manufacturer may declare a longer tripping time but not longer than ~~2 times the values required for 20 °C~~ 4 min;

NOTE 2 Subclause 9.3.3 of IEC 60034-1:2017 states: "Polyphase motors having rated outputs not exceeding 315 kW and rated voltages not exceeding 1 kV shall be capable of withstanding a current equal to 1,5 times the rated current for not less than 2 min".

- d) for class 10, 20, 30 and 40 overload relays energized at C times the current setting, tripping shall occur in less than 4 min, 8 min, 12 min or 16 min respectively, starting from thermal equilibrium, at the current setting;
- e) at D times the current setting, tripping shall occur within the limits given in Table 2 for the appropriate trip class and tolerance band, starting from the cold state.

In the case of overload relays having a current setting range, the limits of operation shall apply when the relay is carrying the current associated with the maximum setting and also when the relay is carrying the current associated with the minimum setting.

For non-compensated overload relays, the current multiple/ambient temperature characteristic shall not be greater than 1,2 %/K.

NOTE 3 1,2 %/K is the derating characteristic of PVC-insulated conductors.

An overload relay is regarded as compensated if it complies with the relevant requirements of Table 3 at $+20\text{ °C}$ and is within the limits shown in Table 3 at other temperatures (see Figure 1).

Table 3 – Limits of operation of time-delay overload relays when energized on all poles

Type of overload relay	Multiples of current setting				Ambient air temperature values
	A	B	C	D	
Thermal type not compensated for ambient air temperature variations	1,0	1,2 ^b	1,5	7,2	+40 °C
Thermal type compensated for ambient air temperature variations	d	d	–	–	less than –5 °C ^e
	1,05	1,3	1,5	–	–5 °C
	1,05	1,2 ^b	1,5	7,2	+20 °C
	1,0	1,2 ^b	1,5	–	+40 °C
	d	d	–	–	more than +40 °C ^e
Electronic type	1,05	1,2 ^b	1,5	7,2 ^a	0 °C, +20 °C and +40 °C
^a — This test shall only be done at 20 °C. ^b — If specified by the manufacturer, the tripping current could be different from 120 % but shall not exceed 125 %. In this case the test current value shall be equal to this tripping current value. In this case, the tripping current value shall be marked on the device. ^c — Test at 20 °C to be done only for A and B multiples of current setting. ^d — Multiples of current setting should be declared by the manufacturer. ^e — See 9.3.3.2.2 for tests outside the –5 °C +40 °C range.					

Type of overload relay	Multiples of current setting				Ambient air temperature values
	A	B	C	D	
Thermal type not compensated for ambient air temperature variations	1,0	1,2 ^b	1,5	7,2	+40 °C
Thermal type compensated for ambient air temperature variations	c	c	–	–	less than -5 °C ^d
	1,05	1,3	1,5	–	-5 °C
	1,05	1,2 ^b	1,5	7,2	+20 °C
	1,0	1,2 ^b	1,5	–	+40 °C
	c	c	–	–	more than +40 °C ^d
Electronic type ^a	1,05	1,2 ^b	1,5	7,2	0 °C, +20 °C and +40 °C
^a This test shall only be done at 20 °C for A, B and D multiples of current setting. ^b If specified by the manufacturer, the tripping current could be different from 120 % but shall not exceed 125 %. In this case the test current value shall be equal to this tripping current value. In this case, the tripping current value shall be marked on the device. ^c Multiples of current setting should be declared by the manufacturer. ^d See 9.3.3.2.2 for tests outside the -5 °C +40 °C range.					

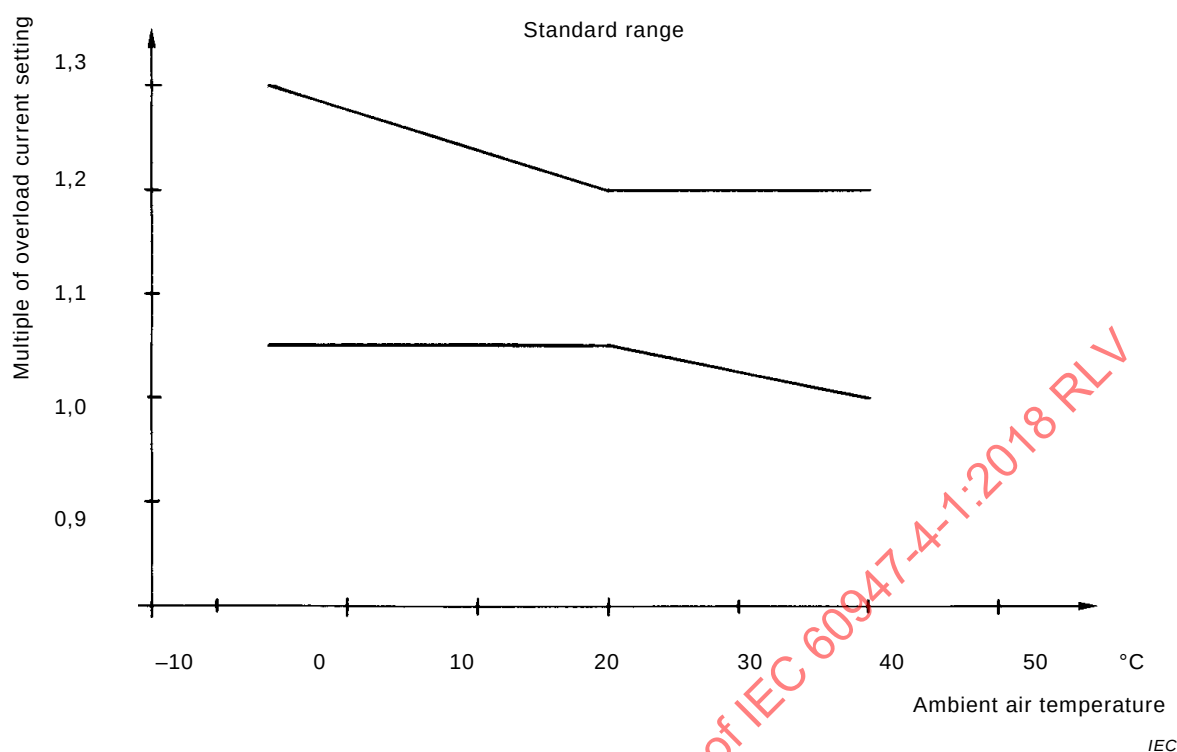


Figure 1 – Multiple of current setting limits for ambient air temperature compensated time-delay overload relays

8.2.1.5.1.2 Thermal memory test verification

Unless the manufacturer has specified that the device does not contain thermal memory, electronic overload relays shall fulfil the following requirements (see Figure 2):

- apply a current equal to I_e until the device has reached the thermal equilibrium;
- interrupt the current for a duration of $2 \times T_p$ (see Table 2) with a relative tolerance of $\pm 10\%$ (where T_p is the time measured at the D current according to Table 3);
- apply a current equal to $7,2 \times I_e$;
- the relay shall trip within 50 % of the time T_p .

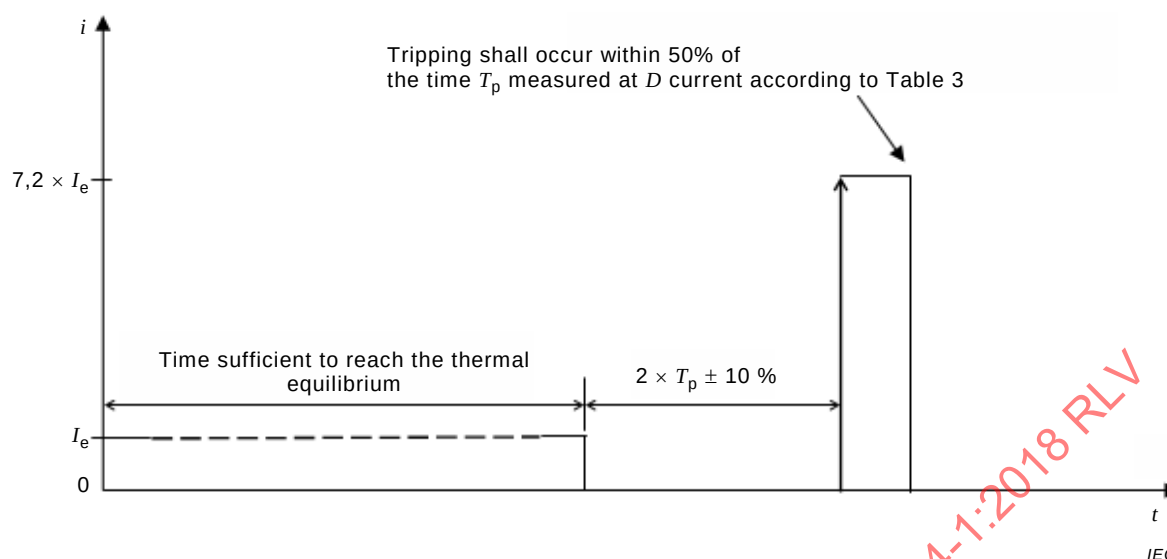


Figure 2 – Thermal memory test

8.2.1.5.2 Limits of operation of three-pole time-delay overload relays energized on two poles

With reference to Table 4:

The overload relay or starter shall be tested in its enclosure if normally fitted. With the relay energized on three poles, at A times the current setting, tripping shall not occur in less than 2 h, starting from the cold state, at the value of the ambient air temperature stated in Table 4.

Moreover, when the value of the current flowing in two poles (in phase loss sensitive **overload** relays **or release**, those carrying the higher current) is increased to B times the current setting, and the third pole de-energized, tripping shall occur in less than 2 h.

The values shall apply to all combinations of poles.

In the case of overload relays having an adjustable current setting, the characteristics shall apply both when the relay is carrying the current associated with the maximum setting and when the relay is carrying the current associated with the minimum setting.

Table 4 – Limits of operation of three-pole time-delay overload relays when energized on two poles only

Type of overload relay	Multiples of current setting		Reference ambient air temperature
	A	B	
Thermal, compensated for ambient air temperature variations or electronic Not phase loss sensitive	3 poles 1,0	2 poles 1,32 1 pole 0	+20 °C
Thermal, not compensated for ambient air temperature variations Not phase loss sensitive	3 poles 1,0	2 poles 1,25 1 pole 0	+40 °C
Thermal, compensated for ambient air temperature variations or electronic Phase loss sensitive	2 poles 1,0 1 pole 0,9	2 poles 1,15 1 pole 0	+20 °C

8.2.1.5.3 Limits of operation of instantaneous magnetic overload relays

For all values of the current setting, instantaneous magnetic overload relays shall trip with an accuracy of $\pm 10\%$ of the value of the published current value corresponding to the current setting.

NOTE Magnetic instantaneous overload relays covered by this document are not intended for short-circuit protection.

8.2.1.5.4 Limits of operation of under-current relays and releases for automatic change over

8.2.1.5.4.1 Limits of operation of under-current relays

An under-current relay or release, when associated with a switching device, shall operate to open the switching device within 80 % to 120 % of the set time, when the current during operation is below 0,9 times the under current setting in all poles. When the operating time is below 1 s, a different tolerance may be given by the manufacturer but the upper limit shall not exceed 1,2 s.

NOTE The tolerance depends on the sensing technology.

8.2.1.5.4.2 Limits of operation of automatic change over by under-current relays

This subclause applies to:

- star-delta starters from star to delta, and
- auto-transformer starters from the starting to the ON position.

The lowest drop-out current of an under-current relay shall be not greater than 1,5 times the actual current setting of the overload relay which is active in the starting or star connection. The under-current relay shall be able to carry any value of current, from its lowest current setting to the stalled current in the starting position or the star connection, for the tripping times determined by the overload relay at its highest current setting.

8.2.1.5.5 Limits of operation of stall relays

A stall relay, when associated with a switching device, shall operate to open the switching device within 80 % to 120 % of the set time (stall inhibit time) or within the accuracy specified by the manufacturer, when:

- a) current sensing relays: the current is 20 % higher than the set stall current value;

EXAMPLE Set current of the stall relay: 100 A; set time: 6 s; accuracy: $\pm 10\%$, the relay shall trip within 5,4 s and 6,6 s when the current is equal to or greater than $100\text{ A} \times 1,2 = 120\text{ A}$.

- b) rotation sensing relays: an input signal indicating no motor rotation exists.

8.2.1.5.6 Limits of operation of jam relays and releases

A jam relay or release, when associated with a switching device, shall operate to open the switching device within 80 % to 120 % of the set time (jam inhibit time) or within the accuracy specified by the manufacturer, when the current is above 1,2 times the set current value of the jam relay, during running after completion of the starting.

8.2.1.5.7 Limits of operation of the short-circuit release of a MPSD

The operation of short-circuit release of a MPSD shall cause its tripping with an accuracy of $\pm 20\%$ of the tripping current value of the current setting for all values of the current setting of the short-circuit release when adjustable.

8.2.2 Temperature-rise

8.2.2.1 General

The requirements of 7.2.2 of IEC 60947-1:2007 apply to contactors and starters in a clean, new condition.

NOTE 1 Contact resistance due to oxidation ~~may~~ can impact the temperature-rise test at test voltages below 100 V. In the case of conducting the test at a voltage below 100 V, such devices ~~may~~ can have the contacts cleaned either by any nonabrasive method or by carrying out 10 operating cycles under the conditions of Table 10 for any applicable utilization category at any voltage.

The temperature-rises of the several parts of the contactor or starter measured during a test carried out under the conditions specified in 9.3.3 shall not exceed the limiting values stated in Table 5 of this document and in 7.2.2.1 and 7.2.2.2 of IEC 60947-1:2007.

In the case of an electronically controlled electromagnet, coil temperature measuring by variation of resistance may be impracticable; in such a case, other methods are permitted, e.g. thermocouples or other suitable methods.

Table 5 – Temperature-rise limits for insulated coils in air and in oil

Class of insulating material (according to IEC 60085:2007)	Temperature-rise limit (measured by resistance variation) K	
	Coils in air	Coils in oil
A	85	60
E	100	60
B	110	60
F	135	–
H	160	–

Because, in an auto-transformer starter, the auto-transformer is energized only intermittently, a maximum temperature-rise of 15 K greater than the figures in Table 5 is permissible for the windings of the transformer when the starter is operated according to the requirements of 5.3.4 and 5.3.5.6.4.

NOTE 2 The temperature-rise limits given in Table 5 of this document and in 7.2.2.2 of IEC 60947-1:2007 are applicable only if the ambient air temperature remains within the limits –5 °C, +40 °C.

8.2.2.2 Terminals

Subclause 7.2.2.1 of IEC 60947-1:2007 applies.

8.2.2.3 Accessible parts

Subclause 7.2.2.2 of IEC 60947-1:2007 applies.

8.2.2.4 Ambient air temperature

Subclause 7.2.2.3 of IEC 60947-1:2007 applies.

8.2.2.5 Main circuit

The main circuit of a contactor or a starter which carries current in the ON position, including the over-current releases which may be associated with it, shall be capable of carrying, without the temperature-rises exceeding the limits specified in 7.2.2.1 of IEC 60947-1:2007 when tested in accordance with 9.3.3.3.4:

- for a contactor or starter intended for continuous duty: its conventional thermal current (see 5.3.2.1 and/or 5.3.2.2);
- for a contactor or starter intended for uninterrupted duty, intermittent duty or temporary duty: its relevant rated operational current (see 5.3.2.5).

8.2.2.6 Control circuits

Subclause 7.2.2.5 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies.

8.2.2.7 Windings of coils and electromagnets

8.2.2.7.1 Uninterrupted and eight-hour duty windings

With the maximum value of current according to 8.2.2.5 flowing through the main circuit, the windings of the coils, including those of electrically operated valves of electro-pneumatic contactors or starters, shall withstand, under continuous load and at the rated frequency, if applicable, their maximum rated control circuit supply voltage without the temperature-rise exceeding the limits specified in Table 5 of this document and in 7.2.2.6 of IEC 60947-1:2007.

NOTE Depending on the technology, e.g. for some kinds of electronically controlled electromagnets, the control supply voltage ~~may not~~ cannot be directly applied on the coil winding when connected as in normal service.

8.2.2.7.2 Intermittent duty windings

With no current flowing through the main circuit, the windings of the coils shall withstand, at the rated frequency, if applicable, their maximum rated control **circuit** supply voltage applied as detailed in Table 6 according to their intermittent duty class, without the temperature-rise exceeding the limits specified in Table 5 of this document and in 7.2.2.2 of IEC 60947-1:2007.

NOTE Depending on the technology, e.g. for some kind of electronically controlled electromagnet, the control supply voltage ~~may not~~ cannot be directly applied on the coil winding when connected as in normal service.

Table 6 – Intermittent duty test cycle data

Intermittent duty class		One close-open operating cycle every	Interval of time during which the supply to the control coil is maintained
Contactors	Starters		
1	1	3 600 s	"ON" time should correspond to the on-load factor specified by the manufacturer
3	3	1 200 s	
12	12	300 s	
30	30	120 s	
120		30 s	
300		12 s	
1 200		3 s	

8.2.2.7.3 Specially rated (temporary or periodic duty) windings

Specially rated windings shall be tested under operating conditions corresponding to the most severe duty for which they are intended and their ratings shall be stated by the manufacturer.

NOTE Specially rated windings ~~may~~ can include coils of starters which are energized during the starting period only, trip coils of latched contactors and certain magnetic valve coils for interlocking pneumatic contactors or starters.

8.2.2.8 Auxiliary circuits

Subclause 7.2.2.7 of IEC 60947-1:2007 applies.

8.2.2.9 Other parts

Subclause 7.2.2.8 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies, replacing words "plastics and insulating materials" with "insulating parts".

8.2.3 Dielectric properties

8.2.3.1 General

Subclause 7.2.3 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with the following additions:

8.2.3.2 Voltage limiting components between circuits

General requirements for device including voltage limiting components inserted between circuits not connected to the ground/earth to be tested according to the dielectric test are described as follows.

These voltage limiting components called varistors used in order to protect electronic parts from surges within the device shall comply with IEC 61051-2. In this clause, the intent is not to reduce the clearances. For the type test of the device the voltage limiting components may be disconnected.

IEC 61051-2 applies as follows:

a) Preferred climatic categories of the varistor:

- maximum lower temperature: -10 °C;
- minimum upper temperature: +85 °C.

The device manufacturer has to verify that the varistor is suitable for use in the extended ambient temperature if any.

b) The minimum rated voltage of the varistor shall be 1,2 times the maximum peak voltage where the varistor is connected.

c) When connected to the mains, varistors shall withstand the surge test according to 9.4.2.5.

NOTE 1 With the verification of the varistors above, it is assumed that a fuse protecting the varistor is not necessary.

NOTE 2 The possibility given in 8.3.3.4.1 item 1) of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 of disconnecting circuits between poles can be not appropriate in the routine test, because the products are completed and it is not appropriate to reopen and manipulate them. The main purpose of this test is to identify the proper operation of the voltage limiting component.

8.2.4 Normal load and overload performance requirements

~~Requirements concerning normal load and overload characteristics according to 5.3.5 are given in 8.2.4.1, 8.2.4.2 and 8.2.4.4.~~

8.2.4.1 Making and breaking capacities

Contactors or starters shall be capable of making and breaking currents without failure under the conditions stated in Table 7 for the required utilization categories and the number of operations indicated, as specified in 9.3.3.5.

The off-time and on-time values given in Table 7 and Table 8 shall not be exceeded.

These capacities correspond to the normal load characteristics given in 5.3.5.3 and 5.3.5.4.

MPSD shall be tested under the conditions stated in Table 7 with following exceptions:

- If the overload release trips during the test, the off-time may be extended up to the point where no tripping occurs.
- If the short-circuit release trips during the test, the instantaneous short-circuit release shall be inhibited. If the instantaneous short-circuit current rating is lower than the test current, the test current may be reduced to the value of the rated instantaneous short-circuit current setting (I_i) plus 20 % if the manufacturer is not giving a lower tolerance. In case of an adjustable instantaneous tripping unit the trip setting has to be set to the maximum value of the setting.

**Table 7 – Making and breaking capacities –
Making and breaking conditions according to utilization category**

Utilization-category	Make-and-break-conditions					
	I_c/I_e	U_i/U_e	$\cos \phi$	On-time ^b s	Off-time s	Number-of operating cycles
AC-1	1,5	1,05	0,8	0,05	f	50
AC-2	4,0 ^h	1,05	0,65 ^h	0,05	f	50
AC-3 ⁱ	8,0	1,05	a	0,05	f	50
AC-4 ⁱ	10,0	1,05	a	0,05	f	50
AC-5a	3,0	1,05	0,45	0,05	f	50
AC-5b	1,5 ^e	1,05	e	0,05	60	50
AC-6a	j					
AC-6b	e					
AC-8a ^k	6,0	1,05	a	0,05	f	50
AC-8b ^k	6,0	1,05	a	0,05	f	50
			— L/R-ms			
DC-1	1,5	1,05	1,0	0,05	f	50 ^d
DC-3	4,0	1,05	2,5	0,05	f	50 ^d
DC-5	4,0	1,05	15,0	0,05	f	50 ^d
DC-6	1,5 ^e	1,05	e	0,05	60	50 ^d
Utilization-category	Make-conditions ⁱ					
	I/I_e	U/U_e	$\cos \phi$	On-time ^b s	Off-time s	Number-of operating cycles
AC-3	10	1,05 ^g	a	0,05	10	50
AC-4	12	1,05 ^g	a	0,05	10	50

~~I — = current made. The making current is expressed in d.c. or a.c. r.m.s. symmetrical values but it is understood that, for a.c., the actual peak value during the making-operation may assume a higher value than the symmetrical peak value.~~
 I_c — = current made and broken, expressed in d.c. or a.c. r.m.s. symmetrical values
 I_e — = rated operational current
 U — = applied voltage
 U_f — = power frequency or d.c. recovery voltage
 U_e — = rated operational voltage
 $\cos \phi$ — = power factor of test circuit
 L/R — = time-constant of test circuit

- ~~a — $\cos \phi = 0,45$ for $I_e \leq 100$ A; $0,35$ for $I_e > 100$ A.~~
- ~~b — The time may be less than $0,05$ s, provided that contacts are allowed to become properly seated before re-opening.~~
- ~~c — Tests to be carried out with an incandescent light load.~~
- ~~d — 25 operating cycles with one polarity and 25 operating cycles with reverse polarity.~~
- ~~e — Capacitive ratings may be derived by capacitor switching tests or assigned on the basis of established practice and experience. As a guide, reference may be made to the formula given in Table 9. This formula takes no account of thermal effects due to harmonic currents, and values derived must consequently be considered taking temperature rise into account.~~
- ~~f — See Table 8.~~
- ~~g — For U/U_e , a tolerance of ± 20 % is accepted.~~
- ~~h — The values shown are for stator contactors. For rotor contactors, the test shall be made with a current of four times the rated rotor operational current and a power factor of $0,95$.~~
- ~~i — The make conditions for utilization categories AC-3 and AC-4 shall also be verified. The verification may be made during the make and break test, but only with the manufacturer's agreement. In this case, the making current multiples shall be as shown for I/I_e and the breaking current as shown for I_c/I_e . 25 operating cycles shall be made at a control supply voltage equal to 110 % of the rated control supply voltage U_s and 25 operating cycles at 85 % of U_s . The off times are to be determined from Table 8.~~
- ~~j — The manufacturer shall verify the AC-6a rating by testing with a transformer or may derive the rating from the values for AC-3 according to Table 9.~~
- ~~k — A lower ratio of locked rotor to full load current may be used if specified by the manufacturer.~~

- a $\cos \phi = 0,45$ for $I_e \leq 100$ A; $0,35$ for $I_e > 100$ A.
- b The time may be less than 0,05 s, provided that contacts are allowed to become properly seated before re-opening. For testing feasibility reason, in agreement with the manufacturer, a longer on-time time may be defined.
- c Tests to be carried out with an incandescent light load.
- d If polarity not marked on the device, 25 operating cycles with one polarity and 25 operating cycles with reverse polarity.
- e The load shall consist of commercially available capacitor combinations to obtain a steady-state reactive current I_e calculated according to 9.3.3.3.4. Alternatively, capacitive ratings may be derived by capacitor switching tests or assigned on the basis of established practice and experience. As a guide, reference may be made to the formula given in Table 9 which does not take into account the thermal effects due to harmonic currents. The available current capacity at the test terminals shall not be less than the prospective current "r". It can be determined by analytical evaluation.
- f Maximum off-time given in Table 8 which can be reduced in agreement with the manufacturer.
- g For U / U_e , a tolerance of ± 20 % is accepted.
- h The values shown are for stator contactors. For rotor contactors, the test shall be made with a current of four times the rated rotor operational current and a power factor of 0,95.
- i The make conditions for utilization categories AC-3, AC-3e and AC-4 shall also be verified. The verification may be made during the make and break test, but only with the manufacturer's agreement. In this case, the making current multiples shall be as shown for I / I_e and the breaking current as shown for I_c / I_e . 25 operating cycles shall be made at a control supply voltage equal to 110 % of the rated control circuit supply voltage U_s and 25 operating cycles at 85 % of U_s .
- j The manufacturer shall verify the AC-6a rating by testing with a transformer or may derive the rating from the values for AC-3 according to Table 9.
- k A lower ratio of I_c / I_e (locked rotor to full load current) may be used if specified by the manufacturer.
- l The on time shall be long enough in order to reach the stabilized current.
- m Off-time according to Table 8. The value of a discharge resistor shall be determined to reach less than 50 V at the end of off-time.
- n As an alternative the factor I / I_e can be selected at the manufacturer discretion between 12 and 13. In this case the power factor is given by the following formulas:

$$I_e \leq 100 \text{ A: } \cos \phi = 0,1 \times I / I_e - 0,85$$

$$I_e > 100 \text{ A: } \cos \phi = 0,1 \times I / I_e - 0,95$$
- o $\cos \phi = 0,35$ for $I_e \leq 100$ A; $\cos \phi = 0,25$ for $I_e > 100$ A

Table 8 – Relationship between the test current ~~broken~~ I_e and off-time for the verification of rated making and breaking capacities

Current broken I_e A	Off-time s
~~$I_e \leq 100$~~	10
~~$100 < I_e \leq 200$~~	20
~~$200 < I_e \leq 300$~~	30
~~$300 < I_e \leq 400$~~	40
~~$400 < I_e \leq 600$~~	60
~~$600 < I_e \leq 800$~~	80
~~$800 < I_e \leq 1\,000$~~	100
~~$1\,000 < I_e \leq 1\,300$~~	140
~~$1\,300 < I_e \leq 1\,600$~~	180
~~$1\,600 < I_e$~~	240

Test current I A	Off-time s
$I \leq 100$	10
$100 < I \leq 200$	20
$200 < I \leq 300$	30
$300 < I \leq 400$	40
$400 < I \leq 600$	60
$600 < I \leq 800$	80
$800 < I \leq 1\,000$	100
$1\,000 < I \leq 1\,300$	140
$1\,300 < I \leq 1\,600$	180
$1\,600 < I \leq 2\,500$	240
$2\,500 < I$	agreement between user and manufacturer

The off-time values may be reduced if agreed by the manufacturer.

Table 9 – Operational current determination for utilization categories AC-6a and AC-6b when derived from AC-3 ratings

Rated operational current	Determination from making current for utilization category AC-3
I_e (AC-6a) for switching of transformers having inrush current peaks of not more than 30 times peak of rated current	$0,45 I_e$ (AC-3)
I_e (AC-6b) for switching of single capacitor banks in circuits having a prospective short-circuit current i_k at the location of the capacitor bank	$i_k \frac{x^2}{(x-1)^2}$ with $x = 13,3 \times \frac{I_e \text{ (AC-3)}}{i_k}$ and for $i_k > 205 I_e \text{ (AC-3)}$
The expression for the operational current I_e (AC-6b) emanates from the formula for the highest inrush current peak: $I_{pmax} = \frac{U_e \times \sqrt{2}}{\sqrt{3}} \times \frac{1 + \sqrt{\frac{X_c}{X_L}}}{X_L - X_c}$ where U_e is the rated operational voltage; X_L is the short-circuit impedance of the circuit; X_c is the reactance of the capacitor bank. This formula is valid on condition that capacitance on the supply side of the contactor or starter can be neglected and that there is no initial charge on the capacitor.	

8.2.4.2 Conventional operational performance

Subclause 7.2.4.2 of IEC 60947-1:2007 applies with the following addition.

Contactors or starters shall be capable of making and breaking currents without failure under the conventional conditions stated in Table 10 for the required utilization categories and the number of operating cycles indicated as specified in 9.3.3.6. MPD shall be tested under the same conditions stated in Table 10 with following exceptions:

If the overload release trips during the test, the off-time may be extended up to the point where no tripping occurs.

Table 10 – Conventional operational performance – Making and breaking conditions according to utilization category

Utilization category	Make and break test conditions					
	I_c/H_e	U_r/U_e	$\cos \phi$	On-time s	Off-time s	Number of operating cycles
AC-1	1,0	1,05	0,80	0,05 ^b	e	6 000 ^j
AC-2	2,0	1,05	0,65	0,05 ^b	e	6 000 ^j
AC-3	2,0	1,05	a	0,05 ^b	e	6 000 ^j
AC-4	6,0	1,05	a	0,05 ^b	e	6 000 ^j
AC-5a	2,0	1,05	0,45	0,05 ^b	e	6 000 ^j
AC-5b	1,0 ^e	1,05	e	0,05 ^b	60	6 000 ^j
AC-6	g	g	g	g	g	g
AC-8a	1,0	1,05	0,80	0,05 ^b	e	30 000
AC-8b ^{h,j}	6,0	1,05	a	1 10	9 90 ^d	5 900 100
			— L/R ms			
DC-1	1,0	1,05	1,0	0,05 ^b	e	6 000 ^f
DC-3	2,5	1,05	2,0	0,05 ^b	e	6 000 ^f
DC-5	2,5	1,05	7,5	0,05 ^b	e	6 000 ^f
DC-6	1,0 ^e	1,05	e	0,05 ^b	60	6 000 ^f

ⁱ I_c — current made or broken. Except for AC-5b, AC-6 or DC-6 categories, the making current is expressed in d.c. or a.c. r.m.s. symmetrical values but it is understood that for a.c. the actual peak value during the making operation may assume a higher value than the symmetrical peak value.
^j I_e — rated operational current
 U_r — power frequency or d.c. recovery voltage
 U_e — rated operational voltage

^a $\cos \phi = 0,45$ for $I_e \leq 100$ A; 0,35 for $I_e > 100$ A.
^b The time may be less than 0,05 s, provided that contacts are allowed to become properly seated before re-opening.
^c These off-times shall be not greater than the values specified in Table 8.
^d The manufacturer may choose any value for the Off-time up to 200 s.
^e Tests to be carried out with an incandescent light load.
^f 3 000 operating cycles with one polarity and 3 000 operating cycles with reverse polarity.
^g Under consideration.
^h Tests for category AC-8b shall be accompanied by tests for category AC-8a. The tests may be made on different samples.
ⁱ For manually operated switching devices, the number of operating cycles shall be 1 000 on-load, followed by 5 000 off-load.
^j A lower ratio of I_c/H_e (locked rotor to full load current) may be used if specified by the manufacturer.

Utilization category	Make and break test conditions					
	I_c / I_e	U_r / U_e	$\cos \phi$	On-time s	Off-time s	Number of operating cycles
AC-1	1,0	1,05	0,80	0,05 ^b	^c	6 000 ⁱ
AC-2	2,0	1,05	0,65	0,05 ^b	^c	6 000 ⁱ
AC-3, AC-3e	2,0	1,05	^a	0,05 ^b	^c	6 000 ⁱ
AC-4	6,0	1,05	^a	0,05 ^b	^c	6 000 ⁱ
AC-5a	2,0	1,05	0,45	0,05 ^b	^c	6 000 ⁱ
AC-5b	1,0 ^e	1,05	^e	0,05 ^b	60	6 000 ⁱ
AC-6a	^g	^g	^g	^g	^g	^g
AC-6b	1 ^k	1,05		^l	^m	6 000
AC-8a	1,0	1,05	0,80	0,05 ^b	^c	30 000
AC-8b ^{h, j}	6,0	1,05	^a	1	9	5 900
				10	90 ^d	100
Utilization category	I_c / I_e	U_r / U_e	L / R ms	On-time s	Off-time s	Number of operating cycles
DC-1	1,0	1,05	1,0	0,05 ^b	^c	6 000 ^f
DC-3	2,5	1,05	2,0	0,05 ^b	^c	6 000 ^f
DC-5	2,5	1,05	7,5	0,05 ^b	^c	6 000 ^f
DC-6	1,0 ^e	1,05	^e	0,05 ^b	60	6 000 ^f

I_c = current made or broken. Except for AC-5b, AC-6 or DC-6 categories, the making current is expressed in direct current or alternating current RMS symmetrical values but it is understood that for alternating current the actual peak value during the making operation may assume a higher value than the symmetrical peak value.

I_e = rated operational current

U_r = power frequency or direct current recovery voltage

U_e = rated operational voltage

$\cos \phi$ = power factor of test circuit

L / R = time-constant of test circuit

^a $\cos \phi = 0,45$ for $I_e \leq 100$ A; $0,35$ for $I_e > 100$ A.

^b The time may be less than 0,05 s, provided that contacts are allowed to become properly seated before re-opening. For testing feasibility reason, in agreement with the manufacturer, a longer on-time time may be defined.

^c These off-times shall be not greater than the values specified in Table 8.

^d The manufacturer may choose any value for the off-time up to 200 s.

^e Tests to be carried out with an incandescent light load.

^f If polarity not marked on the device, 3 000 operating cycles with one polarity and 3 000 operating cycles with reverse polarity.

^g The manufacturer shall verify the AC-6a rating by testing with a transformer or may derive the rating from the values for AC-3 according to Table 9.

^h Tests for category AC-8b shall be accompanied by tests for category AC-8a. The tests may be made on different samples.

ⁱ For manually operated switching devices, the number of operating cycles shall be 1 000 on-load, followed by 5 000 off-load.

^j A lower ratio of I_c / I_e (locked rotor to full load current) may be used if specified by the manufacturer.

^k The load shall consist of commercially available capacitor combinations to obtain a steady-state reactive current I_e calculated according to 9.3.3.3.4. Alternatively, capacitive ratings may be derived by capacitor switching tests or assigned on the basis of established practice and experience. As a guide, reference may be made to the formula given in Table 9 which does not take into account the thermal effects due to harmonic currents. The available current capacity at the test terminals shall not be less than the prospective

current "r". It can be determined by analytical evaluation.

^l The on time shall be long enough in order to reach the stabilized current.

^m Off-time according to Table 8. The value of a discharge resistor shall be determined to reach less than 50 V at the end of off-time.

8.2.4.3 Durability

~~Subclause 7.2.4.3 of IEC 60947-1 applies with the following additions.~~

8.2.4.3.1 Mechanical durability

Subclause 7.2.4.3.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with the following addition:

The mechanical durability of a contactor or starter is verified by a special test conducted at the discretion of the manufacturer. Recommendations for conducting this test are given in Annex B.

8.2.4.3.2 Electrical durability

Subclause 7.2.4.3.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with the following addition:

Electrical durability of a contactor or starter is verified by a special test conducted at the discretion of the manufacturer. Recommendations for conducting this test are given in Annex B.

8.2.4.4 Overload current withstand capability of contactors

Contactors with utilization categories AC-3, AC-3e or AC-4 shall withstand the overload currents given in Table 11, as specified in 9.3.5.

Table 11 – Overload current withstand requirements

Rated operational current	Test current ^c	Duration of test ^a
≤ 630 A	$8 \times I_e \text{ max/AC-3}$ $8 \times I_e \text{ max/AC-3e}$	10 s
> 630 A	$6 \times I_e \text{ max/AC-3}^b$ $6 \times I_e \text{ max/AC-3e}$	10 s
^a For starter with class 20 overload protection and above, the choice of the contactor is subject to agreement between the manufacturer and the user. ^b With a minimum value of 5 040 A. ^c This test also covers duties where the current is lower and the test duration is longer, provided that the tested value of I^2t is not exceeded.		

~~NOTE This test also covers duties where the current is less than shown in Table 11 and the test duration is longer than 10 s, provided that the tested value of I^2t is not exceeded.~~

NOTE For coordination purposes, especially for AC-3e, a higher factor of I_e can be used (see B.4).

8.2.4.5 Coil power consumption

The power consumption of the electromagnet of a contactor characterises the power supplying its coil necessary for holding and pick up operations.

Where the power consumption of the electromagnet is given, it shall be tested according to 9.3.3.2.1.2.

8.2.4.6 Pole impedance

Where the pole impedance is given, it shall be tested according to 9.3.3.2.1.3.

8.2.4.7 Ability of a MPSD to make and break under short-circuit conditions

Subclause 7.2.5 of IEC 60947-1:2007 applies with the following additions:

The ability of the MPSD to make, carry and break short-circuit currents is stated in terms of the following:

- Rated ultimate short-circuit breaking capacity I_{cu} (see 5.3.6.1);
- Rated service short-circuit breaking capacity I_{cs} (see 5.3.6.2).

The short-circuit tests shall be in accordance with Annex P.

NOTE A MPSD alone cannot be coordinated with itself. Consequently, it does not require a rated conditional short-circuit current nor to be submitted to test current "r".

8.2.5 Co-ordination with short-circuit protective devices

8.2.5.1 Performance under short-circuit conditions (rated conditional short-circuit current)

The rated conditional short-circuit current of contactors and starters backed up by short-circuit protective device(s) (SCPD(s) or MPSD), combination starters, combination switching devices, protected starters and protected switching devices shall be verified by short-circuit tests as specified in 9.3.4. If a combination starter, combination switching device, protected starter and protected switching device is fulfilling the requirements of 8.2.4.7, it is considered as a MPSD. In this case, no co-ordination test is required unless it is combined with an additional switching device.

These tests are mandatory:

- a) at the appropriate value of prospective current shown in Table 14 or Table 13 (test current "r"), and
- b) at the rated conditional short-circuit current I_q , if higher than test current "r".

The rating of the SCPD shall be adequate for any given rated operational current, rated operational voltage and the corresponding utilization category.

Two types of co-ordination are permissible, "1" or "2". The test conditions for both are given in 9.3.4.2.1 and 9.3.4.2.2.

Type "1" co-ordination requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons or installation and may not be suitable for further service without repair and replacement of parts.

Type "2" co-ordination requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons or installation and shall be suitable for further use. The risk of contact welding is recognized, in which case the manufacturer shall indicate the measures to be taken as regards the maintenance of the equipment.

NOTE Use of an SCPD not in compliance with the manufacturer's recommendations may invalidate the co-ordination.

These tests are applicable to AC motor ratings only.

8.2.5.2 Co-ordination at the crossover current between starter and associated SCPD

Co-ordination at the crossover current between the starter and the SCPD is a special test. The way to verify it is described in B.4.

8.2.5.3 Co-ordination test between AC-3e rated starter and associated SCPD

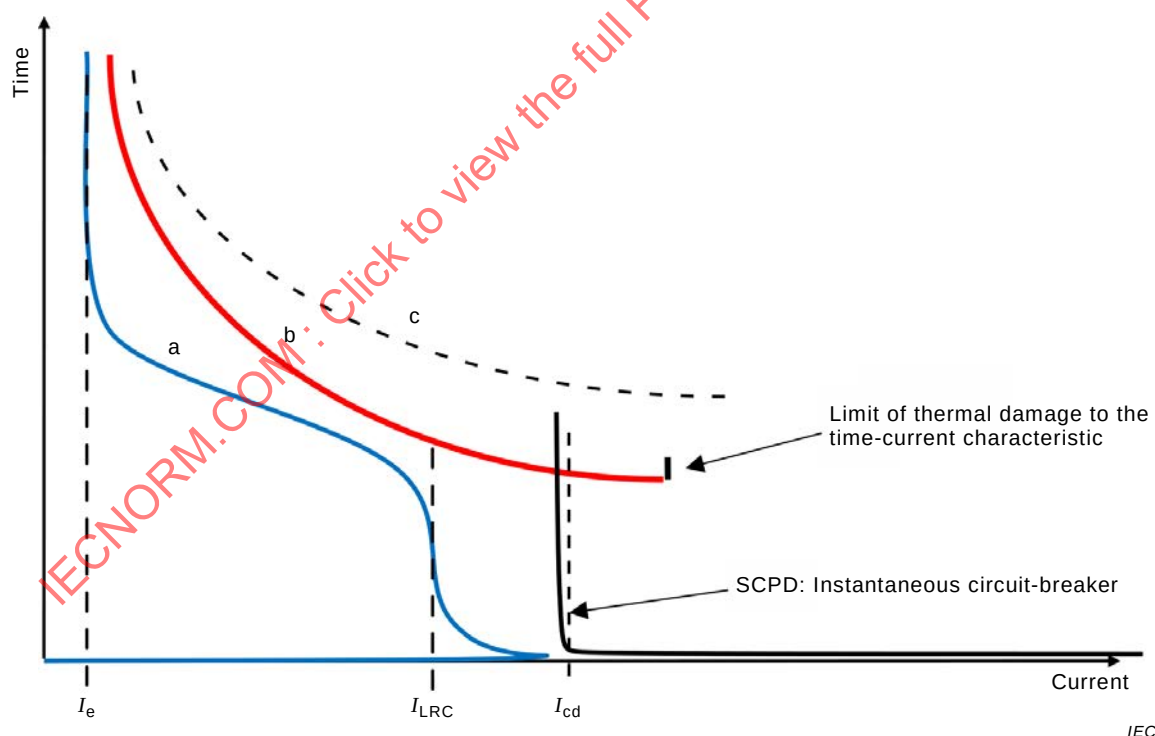
8.2.5.3.1 General

For AC-3e rated starter with type 2 co-ordination, the co-ordination test of 8.2.5.3.2 shall be performed.

This test is intended to verify the co-ordination of the AC-3e rated starter, and the associated SCPD (instantaneous circuit-breaker), in which the overload protection of the starter is operating the contactor in case of short-circuit or fault currents below the tripping current of the SCPD (instantaneous circuit-breaker). The test is performed at a simulated fault current I_{cd} just above the tripping current of the SCPD.

The current I_{cd} is determined by the manufacturer based on the characteristics of the associated SCPD given in item p) of 6.1.2 in order to ensure the co-ordination described in Figure 3 with a power factor given by Table 16 of IEC 60947-1:2007. This test is not necessary if the determined fault current I_{cd} is lower or equal than the tested make and break current for AC-3e.

NOTE Asynchronous motor of design NE or HE can have a higher inrush current and implies a higher setting of the SCPD tripping current. As a consequence, the breaking capacity of the contactor is verified at a higher value than the make and break capacity of Table 7.



Key

- a typical motor starting current
- b mean overload relay time-current characteristic from cold state
- c time-current characteristic withstand capability of contactor according to 9.3.5

Figure 3 – Examples of co-ordination characteristics of a starter

8.2.5.3.2 AC-3e co-ordination test procedure

Test conditions in 8.3.3.5 of IEC 60947-1:2007 apply with the following additions.

- Test procedure: the contactor or starter shall break the test current (I_{cd}) for the number of operating cycles given in Table 15. This is made without the SCPD in the circuit.

Table 15 – Test conditions for I_{cd}

	U_r/U_e	$\cos \phi$	On-time ^b s	Off-time s	Number of operations
I_{cd}	1,05	a	0,05	c	3

NOTE For the next edition, this table will be moved with the current subclause to the end of 9.3.4 and is therefore numbered differently to the other tables in this document.

a Power factor to be selected according to Table 16 of IEC 60947-1:2007.

b Time may be less than 0,05 s provided that contacts are allowed to become properly seated before re-opening.

c See Table 8.

- Behaviour of contactors or starters during and after the I_{cd} test:
 - a) during the test, there shall be no permanent arcing, no flash-over between poles, no blowing of the fusible element in the earth circuit (see 9.3.3.5.2) and no welding of contacts;
 - b) after the test:
 - 1) the contacts shall operate correctly when the contactor or starter is switched by the applicable method of control;
 - 2) the dielectric properties of the contactors and starters shall be verified by a dielectric test on the contactor or starter using an essentially sinusoidal test voltage of twice the rated operational voltage U_e used for the I_{cd} test, with a minimum of 1 000 V. The test voltage shall be applied as specified in 8.3.3.4.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014, items 4.

8.2.5.4 Co-ordination between a MPSD and another short-circuit protective device

For the co-ordination between a MPSD and another short-circuit protective device, see Annex Q.

~~8.2.6 Void~~

~~8.2.7 Additional requirements for combination starters and combination switching devices suitable for isolation~~

~~Under consideration.~~

8.3 Electromagnetic compatibility (EMC)

8.3.1 General

Subclause 7.3.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with the following addition.

Power frequency magnetic field tests are not required because the devices are naturally submitted to such fields. Immunity is demonstrated by the successful completion of the operational performance capability tests (see 9.3.3.5 and 9.3.3.6).

This equipment is inherently sensitive to voltage dips and short time interruptions on the control supply; it shall react within the limits of 8.2.1.2 and this is verified by the operating limits tests given in 9.3.3.2.

The immunity test levels of this document, based on the requirements of IEC 60947-1, correspond to the severe industrial environment defined in IEC 61000-6-2. Higher immunity test levels may be necessary especially for outdoor high voltage substation as defined by IEC 61000-6-5.

8.3.2 Immunity

8.3.2.1 Equipment not incorporating electronic circuits

Subclause 7.3.2.1 of IEC 60947-1:2007 applies.

8.3.2.2 Equipment incorporating electronic circuits

Subclause 7.3.2.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with the following addition.

The test results are specified using the performance criteria given in Table 12.

Table 12 – Specific acceptance criteria for immunity tests

Item	Acceptance criteria		
	A	B	C
General	Normal performance within the specified limits	Temporary degradation or loss of function or performance which is self-recoverable	Temporary degradation or loss of function or performance which requires operator's intervention or system reset. There shall not be any damaged component
Operation of power and control circuits	No unwanted operation – the contactor shall remain in the expected position – the overload relay shall not trip	Temporary unwanted operation which cannot cause tripping Unintentional opening or closing of contacts is not accepted Self-recoverable	Tripping of overload relay Unintentional opening or closing of contacts Not self-recoverable
Operation of displays and auxiliary circuits	No changes to visible display information Only slight light intensity fluctuations of LEDs or movement of characters No unwanted operation of auxiliary contacts	Temporary visible changes, for example unwanted LED illumination Unintentional opening or closing of auxiliary contacts is not accepted.	Permanent loss of display information Unintentional opening or closing of auxiliary contacts is not accepted.
Information processing and sensing functions	Communication and data interchange to external devices without unwanted action or erroneous information	Temporarily disturbed communication with possible external impacts, but self-recoverable	Erroneous processing of information Loss of data and/or information Not self-recoverable

8.3.3 Emission

The level of severity required for environment B covers those required for environment A.

The devices covered by this document do not generate significant levels of harmonics and therefore no harmonic tests are required.

8.3.3.1 Equipment not incorporating electronic circuits

Subclause 7.3.3.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies with the following addition.

Equipment incorporating only components such as diodes, varistors, resistors or capacitors is not required to be tested (e.g. in surge suppressors).

8.3.3.2 Equipment incorporating electronic circuits

Subclause 7.3.3.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies.

9 Tests

9.1 Kinds of test

9.1.1 General

Subclause 8.1.1 of IEC 60947-1:2007 applies.

If there is no distinction between U_s and U_c , requirements apply with U_c .

9.1.2 Type tests

Type tests are intended to verify compliance of the design of contactors and starters of all types and their dedicated wiring accessories with this document. They comprise the verification of:

- a) Temperature-rise limits (see 9.3.3.3);
- b) dielectric properties (see 9.3.3.4);
- c) rated making and breaking capacities (see 9.3.3.5);
- d) change-over ability and reversibility, where applicable (see 9.3.3.5);
- e) conventional operational performance (see 9.3.3.6);
- f) operation and operating limits (see 9.3.3.1 and 9.3.3.2);
- g) ability of contactors to withstand overload current (see 9.3.5);
- h) performance under short-circuit conditions (see 9.3.4);
- i) mechanical properties of terminals (see 8.2.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014);
- j) degrees of protection of ~~enclosed contactors and starters~~ the equipment (see Annex C of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010);
- k) EMC tests, where applicable (see 9.4).

9.1.3 Routine tests

Subclause 8.1.3 of IEC 60947-1:2007 applies where sampling tests (see 9.1.4) are not made.

Routine tests for contactors and starters comprise:

- operation and operating limits (see 9.3.6.2);
- dielectric tests (see 9.3.6.3).

For dedicated wiring purpose accessories delivered separately, only dielectric test applies.

9.1.4 Sampling tests

Sampling tests for contactors and starters comprise:

- operation and operating limits (see 9.3.6.2)
- dielectric tests (see 9.3.6.3).

Subclause 8.1.4 of IEC 60947-1:2007 applies with the following additions.

A manufacturer may use sampling tests instead of routine tests at his own discretion. Sampling shall meet or exceed the following requirements as specified in ~~IEC 60410~~ (see Table 2-A: Single sampling plans for normal inspection of ISO 2859-1:1999:

- sampling based on $AQL \leq 1$;
- acceptance number $A_c = 0$ (no defect accepted);
- rejection number $R_e = 1$ (if 1 defect, the entire lot shall be tested).

Sampling shall be made at regular intervals for each specific lot.

Alternative statistical methods that ensure compliance with the above ~~IEC 60410~~ ISO 2859-1:1999 requirements can be used, e.g. statistical methods controlling continuous manufacturing or process control with capability index.

Sampling tests for clearance verification shall be performed according to 8.3.3.4.3 of IEC 60947-1:2007.

9.1.5 Special tests

9.1.5.1 General

The conducting of special test is at the discretion of the manufacturer.

Special tests include:

- environment tests according to 9.1.5.2;
- mechanical and electrical durability tests ~~and verification of co-ordination at the crossover current between the starter and the SCPD (see Annex B)~~ according to B.2 and B.3. The test results can be used to obtain data needed for functional safety applications (see Annex K);
- verification of co-ordination at the crossover current between the starter and the SCPD according to B.4.

9.1.5.2 ~~Special tests – damp heat, salt mist, vibration and shock~~ Environment tests

For these special tests, Annex Q of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with the following additions.

Where Table Q.1 of IEC 60947-1:2007/AMD2:2014 calls for verification of operational capability, this shall be done according to 9.3.6.2.

The vibration tests shall be done on the equipment in the open and closed positions. The overload relay shall not trip during the test. To check the behavior of main and auxiliary contacts, tests can be done under any current / voltage value.

The shock test on the equipment shall be done in the open position.

For the dry heat test, the equipment shall be in the closed position during the conditioning period (see 5.3.3 of IEC 60068-2-2:2007). For categories A, B and C, the test may be done without current in the poles and for categories D, E and F, the test shall be done under the maximum rated AC-3 current, but may be limited to 100 A for practical reasons. During the last hour, the contactor shall be operated 5 times. During the whole test the overload relay may trip.

For the low temperature test, the test Ad is to be chosen instead of the test Ab and the equipment shall be in the open position during the cooling period. It shall then be energized for the last hour. For categories A, B and C, the test may be done without current in the poles and for categories D, E and F, the test is done under the maximum rated AC-3 current which may be limited to 100 A for practical reasons. During this last hour, the contactor shall be operated 5 times. During the whole test the overload relay shall not trip.

For the damp heat test, for categories A, B and C, the test may be done without current in the poles. For categories D, E and F the equipment shall be energized under the maximum rated AC-3 current for the first cycle and de-energized for the second cycle. The current may be limited to 100 A for practical reasons. After stabilization of the temperature, during the first 2 h of the first cycle and during the last 2 h of the second cycle, the contactor shall be operated 5 times. The overload relay may trip only if it is permitted according to its temperature characteristic.

With the agreement of the manufacturer, the duration of the recovery periods may be reduced.

After the salt mist test, the product may be washed where agreed by the manufacturer.

9.2 Compliance with constructional requirements

9.2.1 General

Subclause 8.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with the following additions:

9.2.2 Electrical performance of screwless-type clamping units

Subclause 8.2.4.7 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with the following changes:

The number of specimens shall be at least 4.

The insertion and disconnection of the conductors shall be made in accordance with the manufacturer's instructions.

A suitable test arrangement is shown in Figure 4. If the measurement points cannot be positioned within the 10 mm to the point of contact, the voltage difference between the ideal and the actual measuring points shall be deducted from the voltage drop measured. This voltage difference within the part of the conductor shall be determined with a suitable measurement method on one specimen at a stabilised temperature. The measurement methods and the results shall be documented in the test report. The test current is I_{th} .

Dimensions in millimetres

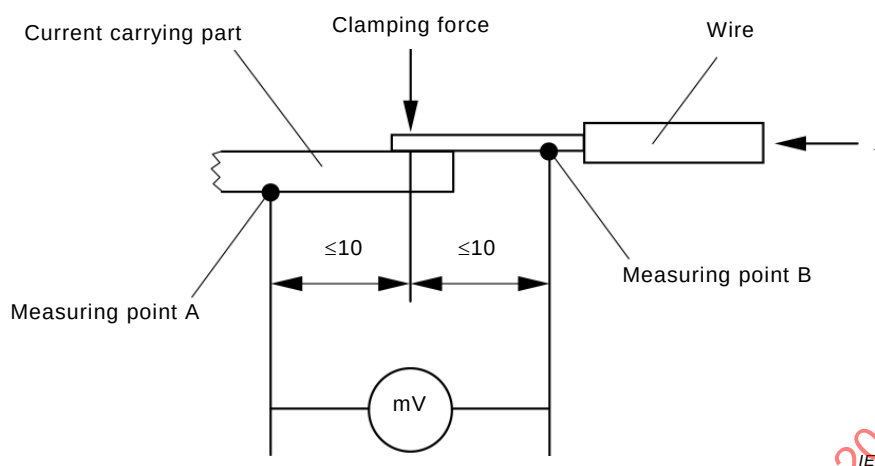


Figure 4 – Voltage drop measurement at contact point of the clamping terminal

NOTE 1 Usually it is possible to equip a IEC 60947-4-1 product with many different types of wires (stranded, solid, flexible etc.) which results in a sufficient number of tests for the same terminal.

NOTE 2 Particular testing method with conductor cross sections larger than 10 mm² is under consideration.

NOTE 3 The device sample can be provided with holes or equivalent arrangements which provide measurement access points for the voltage drop on the terminal.

9.2.3 Ageing test for screwless-type clamping units

Subclause 8.2.4.8 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with the following change:

The test shall be done on the device equipped with the clamping units.

The test current is I_{th} .

NOTE The device sample can be provided with holes or equivalent arrangements which provide measurement access points for the voltage drop on the terminal.

9.2.4 Limited energy source test

A limited energy source circuit shall be tested as follows, with the equipment operating under normal operating conditions.

In case the limited energy source requirement depends on over-current protective device(s), the device(s) shall be short-circuited.

With the equipment operating under normal operating conditions, a variable resistive load is connected to the parts under consideration and adjusted to obtain a level of required limited VA energy. Further adjustment is made, if necessary, to maintain the limited VA energy for a period specified in 8.1.14.

A variable resistive load is connected to the circuit under consideration and adjusted to obtain the limit of apparent power as indicated in Table 19, Table 20, or Table 21, as applicable. Further adjustment is made, if necessary, to maintain the limit of apparent energy for the time period indicated in Table 19, Table 20, or Table 21, as applicable.

The test is passed, if after the test period the available apparent energy does not exceed the limits indicated in Table 19, Table 20, or Table 21, as applicable.

In case the limited energy source requirement depends on over-current protective device(s), the current rating of at least one of the protective device(s) in the current path shall not exceed the limit in Table 20.

These tests shall be conducted under the most unfavourable combination within the manufacturer's operating specifications of the parameters as listed in 5.5.

9.2.5 Breakdown of components

9.2.5.1 General

The breakdown of a component, identified as a result of the circuit analysis of 8.1.16, shall be tested with the product operating with the load creating the more severe condition.

NOTE A possible loss of main function is permissible.

The test is not required:

- when circuit analysis indicates that no other component or portion of the circuit will be overloaded as a result of open- or short-circuit failure mode of another component;
- for components in circuits supplied by limited energy sources in compliance with 8.1.14;
- on power semiconductor devices when equivalent testing is accomplished during short-circuit tests;
- for components that have previously been positively evaluated considering their failure modes and the circuit conditions in which the component is used within the device.

9.2.5.2 Breakdown of components test

Each identified component shall be subjected to a breakdown of components test in open- and or short-circuit failure modes, whichever is most severe.

NOTE 1 The breakdown of components test can be done only with those circuits of the device that can affect the result of the test being fully energized and in operation.

During this test, there shall be no emission of flame or molten metal, nor ignition of cotton. The fusible element shall not open.

Components, such as capacitors or diodes, are short- or open-circuited. For device without a dedicated enclosure, an outer metal enclosure or a wire mesh cage (with surrounded cotton on the cage) that is 1,5 times the size of the device (or different, according to manufacturer declarations) shall be provided to simulate the potential grounded parts around the device. In case of dedicated enclosure, the cotton shall be placed over all openings. The outer dedicated enclosure or wire mesh cage (when provided) and any grounded or exposed dead-metal part shall be connected through a fusible element F, according to subclause 8.3.4.1.2 d) of IEC 60947-1:2007, to the supply circuit.

NOTE 2 The definition of enclosed equipment is given in Annex C of IEC 60947-1:2007, IEC 60947-1:2007/AMD1 2010.

9.3 Compliance with performance requirements

9.3.1 Test sequences

Each test sequence is made on a new sample.

NOTE 1 With the agreement of the manufacturer, more than one test sequence or all test sequences ~~may~~ can be conducted on one sample. However, the tests are conducted in the sequence given for each sample.

NOTE 2 Some tests are included in the sequences solely to reduce the number of samples required, the results have no significance for the preceding or following tests in the sequence. Therefore, for convenience of testing and

by agreement with the manufacturer, these tests ~~may~~ can be conducted on separate new samples and omitted from the relevant sequence. This can only ~~applies~~ apply to the following tests when called for:

- 8.3.3.4.1, item 7) of IEC 60947-1:2007, Verification of creepage distances;
- 8.2.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, Mechanical and electrical properties of terminals;
- Annex C of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, Degrees of protection of enclosed equipment.

The test sequence shall be as follows:

a) Test sequence 1

- 1) verification of temperature-rise (see 9.3.3.3);
- 2) verification of operation and operating limits (see 9.3.3.1 and 9.3.3.2);
- 3) verification of dielectric properties (see 9.3.3.4).

b) Test sequence 2

- 1) verification of rated making and breaking capacities, change-over ability and reversibility, where applicable (see 9.3.3.5);
- 2) verification of conventional operational performance (see 9.3.3.6).

c) Test sequence 3

performance under short-circuit conditions (see 9.3.4);

d) Test sequence 4 (applicable to contactors only)

verification of ability to withstand overload currents (see 9.3.5);

e) Test sequence 5

- 1) verification of mechanical properties of terminals according to 8.2.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014, 9.2.2 and 9.2.3;
- 2) verification of degrees of protection of enclosed contactors and starters (see Annex C of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010).

There shall be no failure in any of the tests.

9.3.2 General test conditions

Subclause 8.3.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies with the following addition.

The selection of samples to be tested for a series of devices with same fundamental design and without significant difference in construction shall be based on engineering judgement.

Except for devices specifically rated for only one frequency, tests performed at 50 Hz are deemed to cover 60 Hz applications and vice-versa.

Unless otherwise specified in the relevant test subclause, the clamping torque for connections shall be that specified by the manufacturer or, if not specified, the torque given in Table 4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014.

Unless otherwise specified, tests of MPSD are to be performed with the maximum rated operational current(s) of a given physical size and similar construction, and are deemed to cover all rated currents of that physical size and construction.

NOTE "Similar construction" means the changes will have no negative impact on the performance of the product. For example, no change in the current carrying parts except current sensing means (e.g. bimetal), arc chamber, etc.

MPSD for unearthed or impedance earth systems (IT) shall be tested according to P.4.

9.3.3 Performance under no load, normal load and overload conditions

9.3.3.1 Operation

It shall be verified that contactors, overload relay and starters operate according to the requirements of 8.2.1.1.2.

To verify the insensitivity of the starter to contactor operation, the starter shall be loaded to attain a steady state temperature as stated in 8.2.2 and the contactor operated in the normal switching sequence three times without intentional delay between operations. The starter shall not trip due to the contactor operation.

When the overload relay has a combined stop and reset actuating mechanism, with the contactor closed, the resetting mechanism shall be operated and this shall cause the contactor to drop out. When the overload relay has either a reset only or separate stop and reset actuating mechanisms, with the contactor closed and the resetting mechanism in the reset position, the tripping mechanism shall be operated and the contactor shall have been caused to drop out. These tests are to verify that the overload tripping action cannot be defeated by holding the resetting mechanism in the reset position.

In the case of rheostatic rotor starters, tests shall be performed to verify that the time setting of time-delay relays and the calibration of any other devices used for controlling the rate of starting are within the limits stated by the manufacturer.

The value of the starting resistors shall be verified for each section to be within $\pm 10\%$ of the stated figures.

It shall also be verified that the rotor switching devices cut out the steps of resistors in the correct sequence.

It shall also be verified that the open-circuit voltages on the tapping terminals of the auto-transformer are in accordance with the designed figures and that the phase sequence at the motor terminals of the two-step auto-transformer starter is correct in both the starting and ON positions of the starter.

9.3.3.2 Operating limits

9.3.3.2.1 Power-operated equipment

9.3.3.2.1.1 General

Contactors and starters shall be tested to verify their performance according to the requirements given in 8.2.1.2.

The drop out test requirements of 8.3.3.2.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies.

9.3.3.2.1.2 Coil power consumption

9.3.3.2.1.2.1 General

The characteristics of the power, supplying a coil, necessary for the electromagnet of a contactor needs to be determined for both the holding power and the pick-up power.

In the case where different coils cover a range of voltages, 5 coils numbered i shall be tested as follows:

The coil with the lowest rated control circuit supply voltage U_s , the coil with the highest rated control circuit supply voltage U_s , plus 3 other coils deemed to be representative of the coils with the highest calculated hold power at the discretion of the manufacturer.

The test shall be performed at ambient temperature $+23\text{ °C} \pm 3\text{ °C}$. The test shall be made without any load in the main and auxiliary circuits. The electromagnet shall be supplied with the rated control circuit supply voltage U_s and at the rated frequency. For a given coil, where a voltage range is declared, the test shall be made at the highest voltage at the respective frequency.

For alternating current controlled electromagnet, the measured values shall be obtained with a RMS measurement method covering at least a bandwidth from 0 Hz to 10 kHz. For direct current controlled electromagnet, the measured values shall be obtained as an average value. For alternating current as well as direct current controlled electromagnet, the resulting power values shall be given within a measurement uncertainty better than 5 %.

For electronically controlled electromagnet, the measurement method shall cover a bandwidth of at least 0 Hz to 100 kHz but not less than ten times the electronic control switching rate.

The declared value by the manufacturer shall be equal or higher than the average value of the 5 tested coils.

9.3.3.2.1.2.2 Holding power for conventional and electronically controlled electromagnet

The current measurement $I_{(i)}$ of the coil shall be performed after the electromagnet has been energized and has reached a stable temperature.

The holding power consumption is defined as follows:

$$S_{h(i)} = U_{s(i)} \times I_{(i)} \text{ [VA] for alternating current controlled electromagnet;}$$

$$P_{c(i)} = U_{s(i)} \times I_{(i)} \text{ [W] for direct current controlled electromagnet;}$$

$$S_h = \sum (U_{s(i)} \times I_{(i)}) / 5 \text{ [VA] respectively } P_c = \sum (U_{s(i)} \times I_{(i)}) / 5 \text{ [W].}$$

For electronically controlled electromagnet with alternating current and direct current ratings, the measurement should be performed for both ratings.

NOTE The power dissipation for an alternating current controlled electromagnet can also be expressed in [W], taking into account the power factor.

9.3.3.2.1.2.3 Pick-up power for direct current controlled electromagnet with separate pick-up and hold-on windings or alternating current controlled electromagnet

The pick-up measurement shall be performed directly after the measurement of the hold current (see 9.3.3.2.1.2.2).

The current measurement $I_{(i)}$ respectively $\hat{I}_{(i)}$ of the coil shall be performed immediately after the electromagnet has been de-energized, the contactor has been held in the OFF position and re-energized.

The pick-up power consumption is defined as follows:

$$S_{p(i)} = U_s \times \hat{I}_{(i)} \text{ [VA]}$$

$S_p = \sum U_{S(i)} \times \hat{I}_{(i)} / 5$ [VA] for alternating current and direct current controlled electromagnet

For direct current controlled electromagnet, the power consumption is expressed in VA in order to represent the total apparent power because of its nonlinear waveform but it may also be expressed in W.

NOTE 1 Unless otherwise stated in the manufacturer literature, for direct current conventional controlled electromagnet, the pick-up power is equal to the holding power.

NOTE 2 Depending on the design of the contactor with separate pick-up and hold-on windings, care is taken not to burn the coil by taking a short measurement (electromagnet energized for less than 1 s or 2 times the pick-up time published by the manufacturer if greater than 1 s).

9.3.3.2.1.2.4 Pick-up power for electronically controlled electromagnet

The pick-up measurement is under consideration.

9.3.3.2.1.3 Pole impedance

The pole impedance shall be determined during the test given in 9.3.3.3.4 and with the conditions given in 8.2.2.1.

The voltage drop U_d shall be measured between the line and load terminals (terminals included) of the contactor or starter preferably at the same time the temperature-rise is measured (see Figure 5).

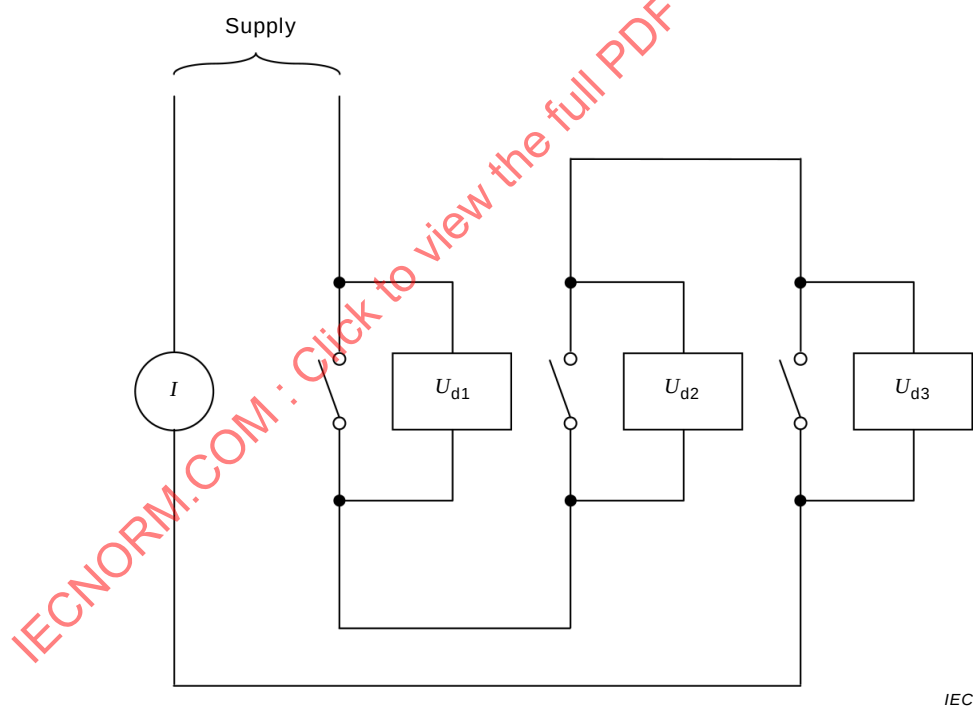


Figure 5 – Example of a pole impedance measurement for a 3 pole contactor

The impedance per pole is defined as follows:

$$Z = U_d / I_{th} [\Omega]$$

Care should be taken that voltage drop measurement does not significantly affect the temperature-rise nor affect significantly the impedance.

NOTE The method is the same irrespective of the number of poles of the contactor or starter.

9.3.3.2.2 Relays and releases

a) Operation of under-voltage relays and releases

Under-voltage relays or releases shall be tested for compliance with the requirements of 8.2.1.3. ~~Each limit shall be verified three times.~~

~~For the drop-out test, the voltage shall be reduced from the rated value to zero at a uniform rate in approximately 1 min.~~

When associated with a switching device, the release shall be fitted to the switching device having the maximum current rating for which the release is suitable.

1) Drop-out voltage

The voltage shall be reduced from rated control circuit supply voltage at a rate to reach 0 V in approximately 30 s.

The test for the lower limit is made without previous heating of the release coil. In the case of a release with a range of rated control circuit supply voltage, this test applies to the maximum voltage of the range. When associated with a switching device, the test for the lower limit is made without current in the main circuit.

The test for the upper limit is made starting from a constant temperature corresponding to the application of rated control circuit supply voltage to the release and rated current in the main poles. This test may be combined with the temperature-rise test of 9.3.3.3. In the case of a release with a range of rated control circuit supply voltage, this test is made at the minimum rated control circuit supply voltage.

2) Test for limits of operation when associated with a switching device

Starting with the main circuit open, at the temperature of the test room, and with the supply voltage at 35 % rated maximum control supply voltage, it shall be verified that the switching device cannot be closed by the operation of its actuator. When the supply voltage is raised to 85 % of the minimum control supply voltage, it shall be verified that the switching device can be closed by the operation of its actuator.

3) Performance under over-voltage conditions

When associated with a switching device, the test is made without current in the main circuit. The test at 110 % of the rated supply voltage shall be made for 30 min or until the temperature has reached thermal equilibrium and without impairing its functions. Verification shall be made according 2) above.

b) Shunt-coil operated releases

~~Shunt-coil operated releases shall be tested for compliance with the requirements of 8.2.1.4. Operation shall be verified at 70 % and 110 % of rated voltage under all operating conditions of the starter.~~

Shunt releases shall be tested for compliance with the requirements of 8.2.1.4 at the ambient temperature. When associated with a switching device, the release shall be fitted to the switching device having the maximum rated current for which the release is suitable.

In the case of a release having a range of rated control circuit supply voltages, the test voltages shall be 70 % of the minimum rated control circuit supply voltage and 110 % of the maximum rated control voltage.

c) Thermal, electronic and time-delay magnetic overload relays

Overload relays and starters shall be connected using conductors in accordance with Table 9, Table 10 and Table 11 of IEC 60947-1:2007 for test currents corresponding to:

- 100 % of the current setting of the overload relay for overload relays of trip classes 2, 3, 5 and 10A for all overload relay types (see Table 2) and 10, 20, 30 and 40 for electronic overload relay types;
- 125 % of the current setting of the overload relay for thermal overload relays of trip classes 10, 20, 30 and 40 (see Table 2) and for overload relays for which a maximum tripping time greater than 40 s is specified (see 5.7.3).

It shall be verified that relays and releases operate according to the requirements of 8.2.1.5.1 with all poles energized.

The characteristics defined in 8.2.1.5.1 shall be verified at $-5\text{ }^{\circ}\text{C}$, $+20\text{ }^{\circ}\text{C}$, $+40\text{ }^{\circ}\text{C}$. In addition, any declared time-current characteristics outside the $-5\text{ }^{\circ}\text{C}$, $+40\text{ }^{\circ}\text{C}$ range shall be verified at minimum and maximum temperatures. However, for relays or releases declared compensated for ambient temperature, in case of temperature range declared by the manufacturer is outside the range given in Table 3, the characteristics at $-5\text{ }^{\circ}\text{C}$ and/or $+40\text{ }^{\circ}\text{C}$ need not be verified if, when tested at the declared minimum and maximum temperatures, the corresponding tripping current values are in compliance with the limits specified for $-5\text{ }^{\circ}\text{C}$ and/or $+40\text{ }^{\circ}\text{C}$ in that Table 3.

For electronic overload relays, the thermal memory test verification of 8.2.1.5.1.2 shall be carried out at $+20\text{ }^{\circ}\text{C}$.

Three-pole thermal or electronic overload relays energized on two poles only shall be tested as stated in 8.2.1.5.2 on all combinations of poles and at the maximum and minimum current settings for relays with adjustable settings.

d) Instantaneous magnetic overload relays

Each relay shall be tested separately. The current through the relay shall be increased at a rate suitable for an accurate reading to be made. The values shall be as stated in 8.2.1.5.3.

e) Short-circuit releases

Subclause 8.3.3.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with the following additions:

The ambient air temperature shall be measured as for the temperature-rise tests (see 8.2.2). Any separate release shall be mounted as under normal service conditions. The complete MPSD shall be mounted in accordance with 8.2.2.

For MPSD with adjustable short-circuit releases, tests shall be made at:

- 1) minimum current setting; and
- 2) maximum current setting,

in each case with conductors corresponding to the rated operational current I_e .

For tests for which the tripping characteristic is independent of the temperature of the terminals (e.g. electronic overload releases, magnetic releases), connection data (type, cross-section, length) may be different from those required in 8.3.3.3.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014.

The tests may be made at any convenient voltage.

The operation of short-circuit releases shall be verified at 80 % and 120 % of the short-circuit current setting of the release. The test currents shall have no asymmetry.

At a test current having a value equal to 80 % of the short-circuit current setting, the release shall not operate, the current being maintained for 0,2 s.

At a test current having a value equal to 120 % of the short-circuit current setting, the release shall operate within 0,2 s.

For MPSD with an electronic over-current release, the operation of the short-circuit releases may be verified by one test only on each pole individually.

For MPSD with electromagnetic over-current releases, the operation of multipole short-circuit releases shall be verified by one test only on each combination of two phase poles in series. In addition, the operation of the short-circuit releases shall be verified once on each pole individually, at 120 % of either the value declared by the manufacturer for individual poles, or the short-circuit current setting (if no value is declared for individual poles), at which value they shall operate within 0,2 s.

f) Under-current relays

The limits of operation shall be verified in accordance with 8.2.1.5.4.1.

g) Under-current relays in automatic change-over

The limits of operation shall be verified in accordance with 8.2.1.5.4.2.

h) Stall relays

The limits of operation shall be verified in accordance with 8.2.1.5.5.

For current sensing stall relays, the verification shall be made for the minimum and for the maximum set current values and for the minimum and maximum stall inhibit time (four settings).

For stall relays operating in conjunction with a rotation sensing mean, the verification shall be made for the minimum and maximum stall inhibit time. The sensor can be simulated by an appropriate signal on the sensor input of the stall relay.

i) Jam relays

The limits of operation shall be verified in accordance with 8.2.1.5.6.

The verification shall be made for the minimum and for the maximum set current values and for the minimum and maximum jam inhibit time (four settings).

For each of the four settings, the test shall be made under the following conditions:

- apply a test current of 95 % of the set current value. The jam relay shall not trip;
- increase the test current to 120 % of the set current value. The jam relay shall trip according to the requirements given in 8.2.1.5.6.

9.3.3.2.3 Verification of main contact position for manual starter and MPSP suitable for isolation

For manual starter and MPSP suitable for isolation, a test shall be made to verify the effectiveness of the indication of the main contact position in accordance with 8.2.5 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010.

9.3.3.3 Temperature-rise

9.3.3.3.1 Ambient air temperature

Subclause 8.3.3.3.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies.

9.3.3.3.2 Measurement of the temperature of parts

Subclause 8.3.3.3.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.

9.3.3.3.3 Temperature-rise of a part

Subclause 8.3.3.3.3 of IEC 60947-1:2007 applies.

9.3.3.3.4 Temperature-rise of the main circuit

Subclause 8.3.3.3.4 of IEC 60947-1:2007 applies with the following additions. The main circuit shall be loaded as stated in 8.2.2.4.

All auxiliary circuits which normally carry current shall be loaded at their maximum rated operational current (see 5.6) and the control circuits shall be energized at their rated voltages. The starter shall be fitted with an overload relay complying with 5.7.4 and selected as follows:

– Non-adjustable relay

The current setting shall be equal to the maximum operational current of the starter and the test shall be made at this current;

– Adjustable relay

The maximum current setting shall be that which is nearest to but not greater than the maximum operational current of the starter.

The test shall be made with that overload relay for which the current setting is nearest to the maximum of its scale.

NOTE 1 The selection method described above is designed to ensure that the temperature-rise of the field wiring terminals of the overload relay and the power dissipated by the starter are not less than those that will occur under any combination of relay and contactor. In cases where the effect of the overload relay on these values is insignificant (i.e. electronic overload relays), the test current ~~shall~~ can always be the maximum operational current of the starter.

For equipment intended for utilization category AC-6b, the test current for the temperature-rise test shall be equal to 1,35 times I_e (the rated capacitive current). I_e shall be calculated as follow:

- $I_e = Q \text{ (var)} / U_e$ for single-phase rating, where U_e is the minimum rated voltage;
- $I_e = Q \text{ (var)} / (U_e \times \sqrt{3})$ for three-phases rating, where U_e is the minimum rated voltage.

NOTE 2 This calculation is based on a thermal factor due to the capacitor tolerance (15 %) plus the harmonic effect.

The test shall be done with cross section of conductor based on 1,35 times I_e (the rated capacitive current).

9.3.3.3.5 Temperature-rise of control circuits

Subclause 8.3.3.3.5 of IEC 60947-1:2007 applies with the following addition.

The temperature-rise shall be measured during the test of 9.3.3.3.4.

9.3.3.3.6 Temperature-rise of coils and electromagnets

Subclause 8.3.3.3.6 of IEC 60947-1:2007 applies with the following additions.

The coil with the highest measured holding power consumption, for a given frequency AC or DC, according to 9.3.3.2.1.2.2 is deemed to be representative for all coils, for the same contactor, and shall be used for the temperature-rise test.

- a) Electromagnets of contactors or starters intended for uninterrupted or 8 h duty are subjected only to the conditions prescribed in 8.2.2.7.1, with the corresponding rated current flowing through the main circuit for the duration of the test. The temperature-rise shall be measured during the test of 9.3.3.3.4.
- b) Electromagnets of contactors or starters intended for intermittent duty shall be subjected to the test as stated above, and also to the test prescribed in 8.2.2.7.2 dealing with their duty class, with no current flowing through the main circuit.
- c) Specially rated (temporary and periodic duty) windings shall be tested as stated in 8.2.2.7.3, without the current in the main circuit.

9.3.3.3.7 Temperature-rise of auxiliary circuits

Subclause 8.3.3.3.7 of IEC 60947-1:2007 applies with the following addition.

The temperature-rise shall be measured during the test of 9.3.3.3.4.

9.3.3.3.8 Temperature-rise of starting resistors for rheostatic rotor starters

The temperature-rise of resistors shall not exceed the limits specified in Table 3 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014, when the starter is operated at its rated duty (see 5.3.4) and according to its starting characteristics (see 5.3.5.6.2).

The current through each section of the resistors shall be thermally equivalent to the current during the starting time when the controlled motor is operating with the maximum starting

torque and the starting time for which the starter is rated (see 5.3.4 and 5.3.5.6.2); in practice, the current value I_m can be used.

Starting operations shall be evenly spaced in time according to the number of starts per hour.

The temperature-rise of the enclosures and of the issuing air shall not exceed the limits specified in Table 3 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014.

NOTE It is not practical to test the performance of starting resistors of every combination of motor output and rotor voltage and current; ~~it is recommended only that~~ a sufficient number of tests can be made to prove, by interpolation or deduction, compliance with this document.

9.3.3.3.9 Temperature-rise of the auto-transformer for two-step auto-transformer starters

The temperature-rise of the auto-transformer shall not exceed the limits specified in Table 5 increased by 15 ~~%~~ K (see 8.2.2) and those specified in Table 3 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014, when the starter is operated at its rated duty (see 5.3.4).

The current through each winding of the auto-transformer shall be thermally equivalent to the current carried when the controlled motor is operating with the maximum starting current and starting time for which the starter is rated (see 5.3.5.6.3); this condition is assumed to be reached when the current drawn from the auto-transformer during the starting time is equal to the maximum starting current specified in 5.3.5.6.3 multiplied by:

$$0,8 \times \frac{\text{starting voltage}}{U_e} \quad (\text{see 5.3.1.4})$$

The operating cycles shall be evenly spaced in time according to the number of starts per hour (see 5.3.4.3).

In the event of two successive operating cycles (see 5.3.4.3), the temperature-rise of the auto-transformer may exceed the maximum value given in 8.2.2 but no damage shall result to the auto-transformer.

In the case of an auto-transformer with several sets of taps, the test shall be made with the taps giving the highest power loss in the transformer; it shall be made over a period of time sufficient for the temperature-rise to reach a constant value.

In order to facilitate this test, star-connected impedances may be used in place of a motor.

9.3.3.4 Dielectric properties

~~Subclause 8.3.3.4 of IEC 60947-1 applies with the following modifications.~~

9.3.3.4.1 Type tests

Subclause 8.3.3.4.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, and IEC 60947-1:2007/AMD2:2014 applies with the addition of:

- the following sentences, at the end of item 1):

The metal foil shall be applied to all surfaces where these are likely to be touched by people during normal operation or adjustment of the equipment and where such surfaces can also be touched by the standard test finger.

The metal foil shall not be applied for power frequency withstand verification after switching and short-circuit tests.

- the following sentence, after the second paragraph of item 2) b):

Circuits of a contactor or starter including devices which have been subjected to U_{imp} test voltages lower than those specified in 7.2.3.1 of IEC 60947-1:2007 and 8.3.3.4.2 of IEC 60947-1:2007 may be disconnected for the test, according to the manufacturer's instructions.

- the following sentence, after the paragraph of item 2) c) ii):

Where the control circuit normally connected to the main circuit is disconnected (according to 8.3.3.4.1, item 2) b) of IEC 60947-1:2007), the method used to maintain the main contacts closed shall be indicated in the test report.

- the following sentence at the end of 8.3.3.4.1, item 8) of IEC 60947-1:2007:

For equipment suitable for isolation, the leakage current shall be measured through each pole with the contacts in the open position, at a test voltage of $1,1 U_e$ and shall not exceed 0,5 mA.

Verification of impulse withstand voltage across open contacts is not required for equipment not suitable for isolation (see 8.3.3.4.1, item 2) c) iv) of IEC 60947-1:2007).

9.3.3.5 Making and breaking capacities

9.3.3.5.1 General test conditions

Subclause 8.3.3.5 of IEC 60947-1:2007 applies with the following additions.

The tests shall be made, under the operating conditions stated in Table 7, without failure, see 9.3.3.5.5 f).

The control supply voltage shall be 100 % of U_s , except that, for the make only test of utilization categories AC-3, AC-3e and AC-4, the control supply voltage shall be 110 % of U_s for half the number of operating cycles and 85 % of U_s for the other half.

Connections to the main circuit shall be similar to those intended to be used when the contactor or starter is in service with the cross-section given in Table 9, Table 10 and Table 11 of IEC 60947-1:2007 for a utilization category. If necessary, or for convenience, the control and auxiliary circuits, and in particular the ~~magnet~~ coil of the contactor or starter, may be supplied by an independent source. Such a source shall deliver the same kind of current and the same voltage as specified for service conditions.

The overload relay and the SCPD of the starter may be short-circuited for the purpose of carrying out the rated making and breaking capacity tests.

9.3.3.5.2 Test circuit

Subclause 8.3.3.5.2 of IEC 60947-1:2007 applies.

9.3.3.5.3 Characteristics of transient recovery voltage

Subclause 8.3.3.5.3 of IEC 60947-1:2007 applies to utilization categories AC-2, AC-3, AC-3e, AC-4, AC-8a and AC-8b (see Table 7).

It is not necessary to adjust factor γ or the oscillatory frequency for testing making capacity only (in AC-3, AC-3e and AC-4).

9.3.3.5.4 Void

~~Subclause 8.3.3.5.4 of IEC 60947-1 applies with the following addition:~~

~~The switching overvoltages shall be verified on the load side between phases for multipole devices and across the load for single pole devices.~~

~~The test procedure is under consideration.~~

9.3.3.5.5 Rated making and breaking capacities

If the contactor in a starter has separately satisfied the requirements of item a) hereafter for the utilization category of the starter, the starter need not be tested.

a) Rated making and breaking capacities of contactors

The contactor shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 7. See also item d) hereafter for reversing contactors.

Contactors of utilization categories AC-3, AC-3e and AC-4 shall be subjected to 50 making only operations followed by 50 making and breaking operations.

b) Rated making and breaking capacity of direct-on-line and ~~two-direction~~ reversing starters (AC-3 and AC-3e) and stator switching devices of rheostatic rotor starters (AC-2)

The starter shall make and break the current corresponding to its utilization category for the number of operating cycles given in Table 7.

Starters of utilization category AC-3 and AC-3e shall be subjected to 50 making only operations followed by 50 making and breaking operations.

c) Rated making and breaking capacities and change-over ability of star-delta starters (AC-3 and AC-3e) and two-step auto-transformer starters (AC-3 and AC-3e)

The starter shall make and break the currents corresponding to its utilization category given in Table 7.

Both the starting and the ON or delta position of the starters shall first be subjected to 50 making only operations, the current being broken by a separate switching device.

The starter shall then be subjected to the 50 making and breaking operations. Each operating cycle shall consist of the following sequences:

- make the current in the starting or star position;
- break the current in the starting or star position;
- make the current in the ON or delta position;
- break the current in the ON or delta position;
- off period.

The load circuit shall be connected to the starter as would be the windings of a motor. The rated operational current of the starter (I_e) is the current in the ON or delta position.

NOTE In the case of star-delta starters, it is important that the test currents be measured in star and delta since the supply impedance has a significant effect on the transformation ratio.

When a transformer has more than one output voltage, it shall be connected to give the highest starting voltage.

The on-time in the starting and ON positions and the off-time shall be as stated in Table 7.

d) Rated making and breaking capacities of direct-on-line ~~and reversing~~ starters with plugging or frequent inching (jogging) (AC-4)

The starters shall make and break the currents given in Table 7.

The 50 making only operations shall be done first, the current being broken by a separate switching device, followed by the 50 making and breaking operations.

The load circuit shall be connected to the starter as would be the windings of a motor.

For starters incorporating two contactors, two contactors A and B shall be used and wired as in normal application. Each sequence of the 50 operations shall be:

close A – open A – close B –
open B – off period

The change-over from "open A" to "close B" shall be made as fast as the normal control system will allow.

Mechanical or electrical interlocking means provided in the starter or available for associating contactors as reversing devices shall be used.

If the reversing circuit arrangement is such that both contactors can be energized simultaneously, ten additional sequences shall be conducted with both contactors energized simultaneously.

- e) Rated making and breaking capacities of the rotor switching devices of a rheostatic rotor starter

Verification of the making and breaking capacities of the rotor switching devices shall be performed as in 9.3.3.5.5 b) for AC-2 category where $I_e = I_{er}$, the maximum rated rotor current for which the starter is designed. $U_e = U_{er}$ (rated rotor operational voltage) and U/U_e shall be 0,8. The power factor shall be 0,95. The starting resistors may be disconnected for these tests and, for starters having more than two steps, the test shall be performed on each switching device in turn. Since the rotor switching devices in starters having more than two steps do not break and make at the full rotor voltage, the voltage for these tests may be reduced in the ratio:

$$\frac{\text{Starting resistance switched}}{\text{Total starting resistance}}$$

When a starter is so connected that the circuit is opened by the stator switch before the rotor switching devices open, no verification of the breaking capacity is necessary.

For rotor switching devices which have previously satisfied the requirements corresponding to those specified above, no further tests are needed.

- f) Behaviour and condition of the contactor or starter during and after the making and breaking capacity, change-over and ~~reversing~~ plugging tests

During the tests within the limits of the specified making and breaking capacities of 9.3.3.5 and the verification of conventional operational performance of 9.3.3.6.1 to 9.3.3.6.6, there shall be no permanent arcing, no flash-over between poles, no blowing of the fusible element in the earth circuit (see 9.3.3.5.2) and no welding of the contacts.

The contacts shall operate when the contactor or starter is switched by the applicable method of control.

9.3.3.6 Operational performance capability

9.3.3.6.1 General

Subclause 8.3.3.6 of IEC 60947-1:2007 applies with the following additions.

Tests concerning the verification of conventional operational performance are intended to verify that a contactor or starter is capable of fulfilling the requirements given in Table 10.

Connections to the main circuit shall be similar to those intended to be used when the contactor or starter is in service with the cross-section given in Table 9, Table 10 and Table 11 of IEC 60947-1:2007 for a utilization category.

The overload relay and the SCPD of the starter may be short-circuited for the purpose of carrying out the tests.

The test circuit given in 9.3.3.5.2 is applicable and the load is to be tuned according to 9.3.3.5.3.

The control voltage shall be 100 % of the rated control circuit supply voltage.

If the contactor in a starter has separately satisfied the requirements of 9.3.3.6.1 for the utilization category of the starter, the starter need not be tested.

9.3.3.6.2 Conventional operational performance of contactors

The contactor shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 10. See also 9.3.3.6.5.

9.3.3.6.3 Conventional operational performance of direct-on-line and ~~two direction~~ reversing starters (AC-3, AC-3e) and stator switching devices of rheostatic rotor starters (AC-2)

The starter shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 10.

9.3.3.6.4 Conventional operational performance of star-delta starters (AC-3, AC-3e) and two-step auto-transformer starters (AC-3, AC-3e)

The starter shall make and break the current corresponding to its utilization category for the number of operating cycles given in Table 10.

The test procedure shall be as stated in 9.3.3.5.5, item c), except that the 50 making only operations are not done.

9.3.3.6.5 Conventional operational performance of direct-on-line ~~and reversing~~ starters ~~s~~ with plugging or frequent inching (jogging) (AC-4)

The starter shall make and break the current corresponding to its utilization category for the number of operating cycles given in Table 10.

The test procedure shall be as stated in 9.3.3.5.5, item d), except that the 50 making only operations and the 10 additional sequences of simultaneous energizing are not done.

9.3.3.6.6 Conventional operational performance of the rotor switching devices of a rheostatic rotor starter

Verification of conventional operational performance of the rotor switching devices shall be performed as in 9.3.3.6.1 for the AC-2 category given in Table 10.

The test procedure shall be as stated in 9.3.3.5.5, item e).

9.3.3.6.7 Behaviour of the contactor or starter during, and its condition after, the conventional operational performance tests

The requirements of 9.3.3.5.5, item f), shall be fulfilled and then the verification of power frequency withstand according to 8.3.3.4.1, item 4), of IEC 60947-1:2007 shall be made.

For equipment suitable for isolation, the leakage current shall be measured through each pole, with the contacts in the open position, at a test voltage of $1,1 U_e$ and shall not exceed 2 mA.

For equipment provided with mirror contacts, the additional test of F.7.3 shall be carried out.

9.3.4 Performance under short-circuit conditions

9.3.4.1 General conditions for short-circuit tests

9.3.4.1.1 General requirements for short-circuit tests

This subclause specifies test conditions for verification of compliance with the requirements of 8.2.5.1. Specific requirements regarding test procedure, test sequences, condition of equipment after the test and types of co-ordination are given in 9.3.4.1 and 9.3.4.2.

The short-circuit test requirements of a MPSD are given in 8.2.4.7.

Subclause 8.3.4.1.1 of IEC 60947-1:2007 applies with the following modification.

If devices tested in free air may also be used in an individual enclosure, they shall be additionally tested in the smallest of such enclosures stated by the manufacturer. For devices tested only in free air, information shall be provided to indicate ~~as~~ that the device has not ~~suitable~~ been evaluated for use in an individual enclosure.

NOTE An individual enclosure is an enclosure designed and dimensioned to contain one device (starter, etc.) only.

The individual enclosure shall be in accordance with the manufacturer specifications. In case of multiple enclosure options are provided, the individual enclosure with the smallest volume shall be taken.

Enclosed stationary and moveable assemblies ~~are~~ shall be tested according to the relevant part of IEC 61439 series.

9.3.4.1.2 Test circuit for the verification of short-circuit ratings

Subclause 8.3.4.1.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies except that, for type "1" co-ordination, the fusible element F and the resistor R_L are replaced by a solid 6 mm² wire of 1,2 m to 1,8 m in length, connected to the neutral, or with the agreement of the manufacturer, to one of the phases.

NOTE This larger size of wire is not used as a detector but to establish an "earth" condition allowing the damage to be evaluated.

9.3.4.1.3 Power-factor of the test circuit

Subclause 8.3.4.1.3 of IEC 60947-1:2007 applies.

If Table 14 is used, the power factor is given in this table.

9.3.4.1.4 Time-constant of the test circuit

Subclause 8.3.4.1.4 of IEC 60947-1:2007 applies.

9.3.4.1.5 Calibration of the test circuit

Subclause 8.3.4.1.5 of IEC 60947-1:2007 applies.

9.3.4.1.6 Test procedure

Subclause 8.3.4.1.6 of IEC 60947-1:2007 applies with the following additions.

The contactor or the starter and its associated SCPD, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall be mounted and connected as in normal use with the cross-section given in Table 9, Table 10

and Table 11 of IEC 60947-1:2007 for a utilization category. They shall be connected in the test circuit using a maximum of 2,4 m of cable corresponding to the operational current of the starter for each main circuit.

~~If the SCPD is separate from the starter, it shall be connected to the starter using the cable specified above. (The total length of cable shall not exceed 2,4 m.)~~

Three-phase tests are considered to cover single-phase applications.

9.3.4.1.7 Void

9.3.4.1.8 Interpretation of records

Subclause 8.3.4.1.8 of IEC 60947-1:2007 applies.

9.3.4.2 Conditional short-circuit current of contactors, starters, combination starters, combination switching devices, protected starters and protected switching devices

9.3.4.2.1 General requirements for the conditional short-circuit current test

The contactor or starter and the associated SCPD, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall be subjected to the tests given in 9.3.4.2.2 and 9.3.4.2.3. The tests shall be so conducted that conditions of maximum motor current I_e and of maximum U_e ~~for utilization category AC-3~~ are covered.

For a magnetically operated contactor or starter, the magnet shall be held closed by a separate electrical supply at the rated control circuit supply voltage U_s . The SCPD used shall be as stated in 8.2.5.1. If the SCPD is a circuit-breaker with an adjustable current setting, the test shall be done with the circuit-breaker adjusted to the maximum setting for the declared type of co-ordination and discrimination.

During the test, all openings of the enclosure shall be closed as in normal service and the door or cover secured by the means provided.

A starter covering a range of motor ratings and equipped with interchangeable overload relays shall be tested with the overload relay with the highest impedance and the overload relay with the lowest impedance together with the corresponding SCPDs.

For type "1" co-ordination, a new test sample may be used for each operation stated in 9.3.4.2.2 and 9.3.4.2.3.

For type "2" co-ordination, one sample shall be used for the tests at the prospective current "r" (see 9.3.4.2.2) and one sample for the tests at current I_q (see 9.3.4.2.3).

By agreement of the manufacturer, the tests at r and I_q may be carried out on the same sample.

9.3.4.2.2 Test at the prospective current "r"

The circuit shall be adjusted to the prospective test current corresponding to the rated operational current I_e according to Table 13 or preferably Table 14 at the discretion of the manufacturer. Both tables are considered equivalent for the product to comply with this document.

The contactor or starter and the associated SCPD, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall then be connected in the circuit. The following sequence of operations shall be performed:

- a) one breaking operation of the SCPD shall be performed with all the switching devices closed prior to the test ("O" operation);
- b) one breaking operation of the SCPD shall be performed by closing the contactor or starter on to the short-circuit ("CO" operation).

Table 13 – Value of the prospective test current according to the rated operational current

Rated operational current I_e (AC-3)a A	Prospective current "r" kA
$0 < I_e \leq 16$	1
$16 < I_e \leq 63$	3
$63 < I_e \leq 125$	5
$125 < I_e \leq 315$	10
$315 < I_e \leq 630$	18
$630 < I_e \leq 1\,000$	30
$1\,000 < I_e \leq 1\,600$	42
$1\,600 < I_e$	Subject to agreement between manufacturer and user
a If the contactor or starter is not specified according to utilization category AC-3, the prospective current "r" shall correspond to the highest rated operational current for any utilization category claimed by the manufacturer.	

Rated operational current I_e ^a A	Prospective current "r" kA
$I_e \leq 16$	1
$16 < I_e \leq 63$	3
$63 < I_e \leq 125$	5
$125 < I_e \leq 315$	10
$315 < I_e \leq 630$	18
$630 < I_e \leq 1\,000$	30
$1\,000 < I_e \leq 1\,600$	42
$1\,600 < I_e$	Subject to agreement between manufacturer and user
^a If the contactor or starter is not specified according to utilization category AC-2, AC-3, AC-3e and AC-4, the prospective current "r" shall be subject of agreement between manufacturer and user.	

Table 14 – Value of the prospective test current according to the rated operational current (harmonized table)

Rated operational current I_e ^{a, e}	Prospective current "r" ^f	Power factor
A	kA ^f	
$I_e \leq 12$	1	0,7 to 0,8
$12 < I_e \leq 50$ ^b	3	0,7 to 0,8
$50 < I_e \leq 100$ ^c	5	0,7 to 0,8
$100 < I_e \leq 250$ ^d	10	0,5 to 0,7
$250 < I_e \leq 500$	18	0,2 to 0,3
$500 < I_e \leq 800$	30	0,2 to 0,3
$800 < I_e \leq 1\ 300$	42	0,2 to 0,3
$1\ 300 < I_e$	Subject to agreement between manufacturer and user	
NOTE Table 14 has been introduced for harmonization purpose with UL 60947-4-1 and is equivalent to UL 60947-4-1.		
^a If the contactor or starter is not specified according to utilization category AC-2, AC-3, AC-3e and AC-4, the prospective current "r" shall be subject of agreement between manufacturer and user.		
^b at 690 V and above: $12 < I_e \leq 63$.		
^c at 690 V and above: $63 < I_e \leq 125$.		
^d at 690 V and above: $125 < I_e \leq 250$.		
^e Rated operational current may be marked "motor full load current" in North America.		
^f Prospective current "r" may be called "standard fault current" in North America.		

9.3.4.2.3 Test at the rated conditional short-circuit current I_q

NOTE This test is done if the current I_q is higher than the current "r".

The circuit shall be adjusted to the prospective short-circuit current I_q equal to the rated conditional short-circuit current.

If the SCPD is a fuse and the test current is within the current-limiting range of the fuse, then, if possible, the fuse shall be selected to permit the maximum peak let-through current (I_p) and the maximum let-through energy (I^2t).

The contactor or starter and the associated SCPD, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall then be connected to the circuit.

The following sequence of operations shall be performed:

- one breaking operation of the SCPD shall be performed with all the switching devices closed ("O" operation) prior to the test.
- one breaking operation of the SCPD shall be performed by closing ("CO" operation) the contactor or starter on to the short-circuit.
- in the case of a combination starter or a protected starter, with the switching device of the SCPD having a short-circuit breaking capacity or rated conditional short-circuit current less than the rated conditional short-circuit current of the combination starter or protected starter the following additional test shall be made. One breaking operation of the SCPD shall be performed by closing ("CO" operation) the switching device (switch or circuit-breaker) on to the short-circuit, the contactor or starter already being closed. This operation may be performed either on a new sample (starter and SCPD) or on the first sample with the agreement of the manufacturer. After this operation only conditions a) to g) of 9.3.4.2.4 shall be verified.

9.3.4.2.4 Results to be obtained

The contactor, starter, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall be considered to have passed the tests at the prospective current " r " and, where applicable, the prospective current I_q , if the following conditions are met for the claimed type of co-ordination.

Both types of co-ordination (all devices):

- a) The fault current has been successfully interrupted by the SCPD, the combination starter or the combination switching device and the fuse or fusible element or solid connection between the enclosure and supply shall not have melted.
- b) The door or cover of the enclosure has not been blown open and it is possible to open the door or cover. Deformation of the enclosure is considered acceptable provided that the degree of protection by the enclosure is not less than IP2X.
- c) There is no damage to the conductors or terminals and the conductors have not been separated from the terminals.
- d) There is no cracking or breaking of an insulating base to the extent that the integrity of mounting of a live part is impaired.

Both types of co-ordination (combination starters, combination switching devices, protected starters and protected switching devices only):

- e) The circuit-breaker or the switch is capable of being opened manually by its operating means.
- f) Neither end of the SCPD is completely separated from its mounting means to an exposed conductive part.
- g) If a circuit-breaker with rated ultimate short-circuit breaking capacity less than the rated conditional short-circuit current assigned to the combination starter, the combination switching device, the protected starter or the protected switching device is employed, the circuit-breaker shall be tested to trip as follows:
 - 1) circuit-breakers with instantaneous trip relays or releases: at 120 % of the trip current.
 - 2) circuit-breakers with overload relays or releases: at 250 % of the rated current of the circuit-breaker.

Type "1" co-ordination (all devices):

- h) There has been no discharge of parts beyond the enclosure. Damage to the contactor and the overload relay is acceptable. The starter other than MPSD may be inoperative after each operation. The starter shall therefore be inspected and the contactor and/or the overload relay and the release of the circuit-breaker shall be reset if necessary and, in the case of fuse protection, all fuse-links shall be replaced.

Type "1" co-ordination (combination and protected starters only):

- i) The adequacy of insulation in accordance with 8.3.3.4.1, item 4), of IEC 60947-1:2007 is verified after each operation (at currents " r " and " I_q ") by a dielectric test on the complete unit under test (SCPD plus contactor/starter but before replacement of parts) using a power frequency withstand voltage of twice the rated operational voltage U_e but not less than 1 000 V. The test voltage shall be applied to the incoming supply terminals, with the switch or the circuit-breaker in the open position, as follows:
 - between each pole and all other poles connected to the frame of the starter;
 - between all live parts of all poles connected together and the frame of the starter;
 - between the terminals of the line side connected together and terminals of the other side connected together.

For equipment suitable for isolation, the leakage current shall be measured through each pole, with the contacts in the open position, at a test voltage of $1,1 U_e$ and shall not exceed 6 mA.

Type "2" co-ordination (all devices):

- j) No damage to the overload relay or other parts has occurred, except that welding of contactor or starter contacts other than MPSD contacts is permitted, if they are easily separated (e.g. by energizing several times the coil of the contactor or moving the operating means or using a tool such as a screwdriver for separating the welded contact according to the manufacturer instructions) without significant deformation (without impairing the insulation of the contactor according to d) and i)), but no replacement of parts is permitted during the test, except that, in the case of fuse protection, all fuse-links shall be replaced.

In the case of welded contacts as described above, the functionality of the device shall be verified by carrying out 10 operating cycles under the conditions of Table 10 for the applicable utilization category.

- k) The tripping of the overload relay shall be verified at a multiple of the current setting and shall conform to the published tripping characteristics, according to 5.7.5, both before and after the short-circuit test.

- l) The adequacy of the insulation in accordance with 8.3.3.4.1, item 4), of IEC 60947-1:2007 shall be verified by a dielectric test on the contactor, the starter, the combination starter, the combination switching device, the protected starter or the protected switching device, using a power frequency withstand voltage of twice the rated operational voltage U_e but not less than 1 000 V.

In the case of combination starters, combination switching devices, protected starters and protected switching devices, additional tests according to 8.3.3.4.1, item 4), of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 shall be made across the main poles of the device with the contacts of the switch or of the circuit-breaker open and the contacts of the starter closed.

For equipment suitable for isolation, the leakage current shall be measured through each pole, with the contacts in the open position, at a test voltage of $1,1 U_e$ and shall not exceed 2 mA.

Fuse-links, if any, are shorted.

9.3.5 Overload current withstand capability of contactors

For the test, the contactor shall be mounted, wired and operated as specified in 9.3.2.

All poles of the contactors are simultaneously subjected to one test with the overload current and duration values stated in 8.2.4.4. The test is performed at any convenient voltage and it starts with the contactor at room temperature.

After the test, the contactor shall be substantially in the same condition as before the test. This is verified by visual inspection.

NOTE The I^2t value (Joule integral) calculated from this test cannot be used to estimate the performance of the contactor under short-circuit conditions.

9.3.6 Routine tests and sampling tests

9.3.6.1 General

The tests shall be carried out under the same conditions as those specified for type tests in the relevant parts of 9.1.2 or under equivalent conditions. However, the limits of operation in 9.3.3.2 may be verified at the prevailing ambient air temperature and on the overload relay alone, but a correction may be necessary to allow for normal ambient conditions.

If devices are tested separately, their combination shall be tested with the dielectric test and other relevant operational tests. However, if the combination is built up with already tested connection systems or auxiliaries, an additional dielectric test is not necessary.

9.3.6.2 Operation and operating limits

For electromagnetic, pneumatic and electro-pneumatic contactors or starters, tests are carried out to verify operation within the limits specified in 8.2.1.2.

For manual starters, tests are carried out to verify the proper operation of the starter (~~see 8.2.1.2, 8.2.1.3 and 8.2.1.4~~). Manual operation of MPSD shall be verified according to 9.3.6.4.

The calibration of the short-circuit release of a MPSD shall be verified according to 9.3.6.5.

NOTE 1 In these tests, it is not necessary to reach thermal equilibrium. The lack of thermal equilibrium ~~may~~ can be compensated by using a series resistor or by appropriately decreasing the voltage limit.

Tests shall be made to verify the calibration of relays. In the case of a time delay overload relay, this may be a single test with all poles equally energized at a multiple of the current setting, to check that the tripping time conforms (within tolerances) to the curves supplied by the manufacturer; in the case of an instantaneous magnetic overload relay, the test shall be carried out at 1,1 times the current setting. For under-current relays, stall relays and jam relays, tests shall be carried out to verify the proper operation of these relays (see 8.2.1.5.4, 8.2.1.5.5 and 8.2.1.5.6).

NOTE 2 In the case of a time-delay magnetic overload relay comprising a time-delay device working with a fluid dashpot, calibration ~~may~~ can be carried out with the dashpot empty, at a percentage of the current setting indicated by the manufacturer and capable of being justified by a special test.

9.3.6.3 Dielectric tests

9.3.6.3.1 General

Subclause 8.3.3.4.2 of IEC 60947-1:2007 applies with the following addition.

In the case of a rheostatic rotor starter, all the poles of the rotor switching devices will normally be connected through the starting resistors; the dielectric test is therefore confined to the application of the test voltage between the rotor circuit and the frame of the starter.

The use of the metal foil is not necessary.

NOTE The combined test of 8.3.3.4.2 of IEC 60947-1:2007 is ~~permitted~~ possible.

9.3.6.3.2 Routine power frequency test for devices incorporating voltage limiting components

At the discretion of the manufacturer, the device incorporating voltage limiting components are to be tested with the following sequence a) to b):

a) Application of the test voltage

The test shall be performed in accordance with 8.3.3.4.2 2) of IEC 60947-1:2007. The value of the test voltage shall be the U_V RMS value (max. operational voltage of the voltage limiting components) or the maximum U_V DC value of the voltage limiting components with a tolerance of -10 %.

Acceptance criteria: The over-current relay of the test apparatus shall not trip (lower tripping limit).

b) Verification of the proper function of the voltage limiting components

The test shall be performed in accordance with 8.3.3.4.2 2) of IEC 60947-1:2007. The value of the test voltage shall be chosen by the manufacturer so that a current is generated between the upper tripping limit and the lower tripping limit of the test apparatus.

Acceptance criteria: The current shall be between a) and b) and the voltage limiting component shall not be damaged.

NOTE The main purpose of this test is to check the proper operation of the voltage limiting component.

9.3.6.4 Mechanical operation tests of a MPSD

The following tests shall be carried out without current in the main circuit, except when required for the operation of releases. During the tests, no adjustments shall be made and the operation shall be satisfactory.

The following tests shall be made:

- two close-open operations;
- two trip-free operations.

NOTE For the definition of a trip-free mechanical switching device, see 2.4.23 of IEC 60947-1:2007.

9.3.6.5 Verification of the calibration of the short-circuit release of a MPSD

The verification of the calibration of the instantaneous short-circuit releases shall check the non-operation and operation of the releases at the values of current given in 9.3.3.2.2 e) without measurement of break time being required.

The tests may be made by loading two poles in series with the test current, using all possible combinations of poles having releases, or by loading each pole having a release individually with the test current.

One method of determining the tripping level consists in applying a slowly rising test current, starting from a value below the lower limit until tripping of the MPSD occurs. Tripping shall occur between the lower and upper limits of test current.

9.4 EMC tests

9.4.1 General

~~Subclauses 8.3.2.1, 8.3.2.3 and 8.3.2.4 of IEC 60947-1 apply with the following additions:~~

~~With the agreement of the manufacturer, more than one EMC test or all EMC tests may be conducted on one and the same sample, which may initially be new or may have passed test sequences according to 9.3.1. The sequence of the EMC tests may be any convenient sequence.~~

Subclause 8.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 completed with 9.4.2 and 9.4.3 of this document applies with the following additions.

Where a range of contactors or starters comprise similar control electronics, within similar frame sizes, it is only necessary to test a single representative sample of the contactor or starter as specified by the manufacturer.

The test report and the instruction manual shall include any special measures that have been taken to achieve compliance, for example the use of shielded or special cables. If auxiliary equipment is used with the contactor or starter in order to comply with immunity or emission requirements, it shall be included in the report and the instruction manual.

The test sample shall be in the open or closed position, whichever is the worse, and shall be operated with the rated control **circuit** supply.

9.4.2 Immunity

The tests of Table 16 are required. Special requirements are specified from 9.4.2.1 to 9.4.2.7.

If, during the EMC tests, conductors are to be connected to the test sample, the cross-section and the type of the conductors are optional but shall be in accordance with the manufacturer's literature.

Table 16 – EMC immunity tests

Type of test	Test level required
Electrostatic discharge immunity test IEC 61000-4-2	Corresponding test level of Table 23 of IEC 60947-1 applies.
Radiated radio-frequency electromagnetic field immunity test (80 MHz to 1 GHz and 1,4 GHz to 2 GHz) IEC 61000-4-3	Corresponding test level of Table 23 of IEC 60947-1 applies.
Electrical fast transient/burst immunity test IEC 61000-4-4 ^a	Corresponding test level of Table 23 of IEC 60947-1 applies.
1,2/50 µs—8/20 µs surge immunity test IEC 61000-4-5	Corresponding test level of Table 23 of IEC 60947-1 applies.
Conducted disturbances induced by radio-frequency fields immunity test ^{b, c} (150 kHz to 80 MHz) IEC 61000-4-6	Corresponding test level ^d of Table 23 of IEC 60947-1 applies.
^a The contactor shall be operated at least one time during the test and the overload relay is loaded at 0,9 times the current setting with a maximum of 100 A. ^b Applicable to ports only interfacing with cables whose total length according to the manufacturer's functional specification may exceed 3 m. ^c The test level can also be defined as the equivalent current into a 150 Ω load. ^d Except for the ITU broadcast frequency band 47 MHz to 68 MHz, where the level shall be 3 V.	

Type of test	Test level required
Electrostatic discharge	Corresponding test level of Table 23 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.
Radiated radio-frequency electromagnetic field	Corresponding test level of Table 23 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.
Electrical fast transient/bursts ^a	Corresponding test level of Table 23 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.
Surges (1,2/50 µs – 8/20 µs)	Corresponding test level of Table 23 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.
Conducted disturbances induced by radio-frequency fields ^{b c}	Corresponding test level ^d of Table 23 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.
Voltage dips and short-time interruptions	Corresponding test level of Table 23 Class 3 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.
Harmonics in the supply	9.4.2.9
^a The contactor shall be operated at least one time during the test and the overload relay is loaded at 0,9 times the current setting with a maximum of 100 A. ^b Applicable to ports only interfacing with cables whose total length according to the manufacturer's functional specification may exceed 3 m. ^c The test level can also be defined as the equivalent current into a 150 Ω load. ^d Except for the ITU broadcast frequency band 47 MHz to 68 MHz, where the level shall be 3 V.	

9.4.2.1 Performance of the test sample during and after the test

~~Unless otherwise specified, performance criterion B applies, see 8.3.2.2.~~

~~No loss of performance shall be permitted during or after the tests. After the tests the operating limits of 9.3.6.2 shall be verified at ambient temperature.~~

The product shall perform according to the performance criteria given in Table 12. After the tests the operating limits of 9.3.6.2 shall be verified at ambient temperature.

9.4.2.2 Electrostatic discharge

~~The test shall be conducted using the methods of IEC 61000-4-2.~~

~~Except for metallic parts for which contact discharge is made, only air discharge is required.~~

~~Ten positive and ten negative pulses shall be applied to each selected point, the time interval after each successive single discharge being 1 s.~~

~~Tests are not required on power terminals. The application of conductors is not required, except for energizing the coil.~~

Subclause 8.4.1.2.2 of IEC 60947-1:2007 applies with the following additions.

Discharges shall be applied only to points which are accessible during normal usage. Tests are not required on power terminals and IP00 device (open frame or chassis unit). In this last case, the manufacturer shall provide instructions on how to mitigate the possibility of damage due to static discharge.

The contactor or starter shall comply with performance criterion B of Table 12.

9.4.2.3 Radiated radio-frequency electromagnetic field

~~The tests shall be conducted using the methods of IEC 61000-4-3. The test procedure of IEC 61000-4-3 shall apply.~~

~~The device shall comply with performance criterion A.~~

Subclause 8.4.1.2.3 of IEC 60947-1:2007 applies with the following additions.

The contactor or starter shall comply with performance criterion A of Table 12.

9.4.2.4 Conducted disturbances induced by radio-frequency fields

Subclause 8.4.1.2.6 of IEC 60947-1:2007 applies with the following addition.

This test is only applicable to ports with interfacing cables whose total length according to the manufacturer's functional specification may exceed 3 m.

The device shall comply with performance criterion A of Table 12.

9.4.2.5 Electrical fast transient/bursts

~~The tests shall be conducted using the methods of IEC 61000-4-4 with a repetition rate of 5 kHz.~~

~~The bursts shall be applied to all main, control or auxiliary terminals, whether they comprise electronic or conventional contacts.~~

~~The test voltage shall be applied for the duration of 1 min.~~

Subclause 8.4.1.2.4 of IEC 60947-1:2007 applies with the following additions.

Terminals for control and auxiliary circuits intended for the connection of conductors which extend more than 3 m shall be tested.

The contactor shall be operated at least one time during the test and the overload relay is loaded at 0,9 times the current setting with a maximum of 100 A.

The contactor or starter shall comply with performance criterion B of Table 12.

9.4.2.6 Surges (1,2/50 μ s – 8/20 μ s)

~~The test shall be conducted using the methods of IEC 61000-4-5. Capacitive coupling shall be preferred. The surges shall be applied to all main, control or auxiliary terminals, whether they comprise electronic or conventional contacts.~~

~~The test voltage values are those of Table 14 but shall not exceed the corresponding U_{imp} value(s) given by the manufacturer following 7.2.3 of IEC 60947-1.~~

~~The repetition rate shall be one surge per minute, with the number of pulses being five positive and five negative.~~

Subclause 8.4.1.2.5 of IEC 60947-1:2007 applies with the following additions.

The contactor or starter shall comply with performance criterion B of Table 12.

9.4.2.7 Power frequency magnetic fields

Subclause 8.4.1.2.7 of IEC 60947-1:2007 applies with the following additions.

The contactor or starter shall comply with performance criterion A of Table 12.

9.4.2.8 Voltage dips and short-time interruptions

Subclause 8.4.1.2.8 of IEC 60947-1:2007 applies for class 3 with the performance criterion C of Table 12 except for 0,5 cycle and 1 cycle for which the performance criterion B of Table 12 applies.

For contactors only the general criteria of Table 12 apply. During the test, the contactor or starter may open temporally but it shall remain fully operational without reset.

9.4.2.9 Harmonics in the supply

~~Under consideration.~~

For MPSD with electronic over-current release, the true RMS response, in order to avoid unwanted tripping at 0,9 times the current setting for 10 times the tripping time, shall be verified up to the fifth harmonic component at 50 % of the fundamental component:

- by test according to F.4.1 of IEC 60947-2:2016; or
- by simulation, using models for which the validity has to be demonstrated; or
- by design assessment, i.e. confirmation of the correct application of calculations and design rules, including use of appropriate safety margins.

For other device, harmonic test requirement from F.4.1 of IEC 60947-2:2016 is under consideration.

NOTE Current waveform asymmetry, typically in case of failure of a power semiconductor connected on the network, is creating a significant unbalance and can affect the current detection of an electronic overload protection and therefore a true RMS measurement is relevant.

9.4.3 Emission

~~For equipment designed for environment A, a suitable warning shall be given to the user (for example in the instruction manual) stipulating that the use of this equipment in environment B may cause radio interference in which case the user may be required to employ additional mitigation methods.~~

9.4.3.1 Conducted radio-frequency emission tests

A description of the test, the test method and the test set-up are given in CISPR 11.

It shall be sufficient to test two samples from a range of contactors or starters of different power ratings which represent the highest and lowest power ratings of the range.

~~To pass,~~ The ~~equipment~~ emission shall not exceed the levels given in Table 17.

Table 17 – Terminal disturbance voltage limits for conducted radio-frequency emission test limits (for mains ports)

Frequency band MHz	Environment A dB(μV)	Environment B dB(μV)
0,15—0,5	79 quasi-peak 66 average	66—56 quasi-peak 56—46 average (decrease with log of frequency)
0,5—5,0	73 quasi-peak 60 average	56 quasi-peak 46 average
5—30	73 quasi-peak 60 average	60 quasi-peak 50 average

Frequency band MHz	Environment A dB(μV)	Environment B dB(μV)
0,15 to 0,5	79 quasi-peak 66 average	66 to 56 quasi-peak 56 to 46 average (decrease with log of frequency)
0,5 to 5,0	73 quasi-peak 60 average	56 quasi-peak 46 average
5 to 30	73 quasi-peak 60 average	60 quasi-peak 50 average
NOTE Limits are in accordance with CISPR 11:2015, CISPR 11:2015/AMD1:2016, Group 1 for mains input ports and total rated power less than 20 kVA.		

9.4.3.2 Radiated radio-frequency emission tests

A description of the test, the test method and the test set-up are given in Clause 7 of CISPR 11:2015, CISPR 11:2015/AMD1:2016.

Tests are required where the control and auxiliary circuits contain components with fundamental switching frequencies greater than 9 kHz, for example switch-mode power supplies, etc.

~~To pass, the equipment shall not emit at higher levels than those given in Table 16.~~

The emission shall not exceed the levels given in Table 18.

Table 18 – Radiated emission test limits

Frequency band MHz	Environment A ^a dB(μV/m)	Environment B dB(μV/m)
30—230	30 quasi-peak at 30 m	30 quasi-peak at 10 m
230—1 000	37 quasi-peak at 30 m	37 quasi-peak at 10 m
^a These tests may be carried at 10 m distance with the limits raised by 10 dB.		

Frequency range MHz	Environment A ^a Quasi-peak dB (μV)			Environment B ^a Quasi-peak dB (μV)	
	at 30 m	at 10 m	at 3 m	at 10 m	at 3 m
30 to 230	30	40	50	30	40
230 to 1 000	37	47	57	37	47
^a Tests may be carried out at 3 m distance only to small equipment (equipment, either positioned on a table top or standing on the floor which, including its cables fits in a cylindrical test volume of 1,2 m in diameter and 1,5 m above the ground plane).					

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

Annex A (normative)

Marking and identification of terminals of contactors, starters and associated overload relays

A.1 General

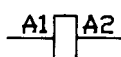
~~The purpose of identifying terminals of contactors and associated overload relays is to provide information regarding the function of each terminal or its location with respect to other terminals or for other use.~~

Annex L of IEC 60947-1:2007 applies with the following addition.

~~A.2 Marking and identification of terminals of contactors~~

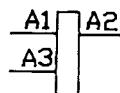
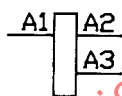
~~A.2.1 Marking and identification of terminals of coils~~

~~In the case of identification by alphanumeric markings, the terminals of a coil for an electromagnetic contactor shall be marked A1 and A2.~~



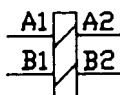
~~For a coil with tapplings, the terminals of the tapplings shall be marked in sequential order A3, A4, etc.~~

EXAMPLE



~~NOTE As a consequence of this, both incoming and outgoing terminals may have even or odd numbers.~~

~~For a coil having two windings, the terminals of the first winding will be marked A1, A2 and those of the second winding B1, B2.~~



A.2 Marking and identification of terminals of main circuits

The terminals of the main circuits shall be marked by single figure numbers and an alphanumeric system according to Figure A.1.

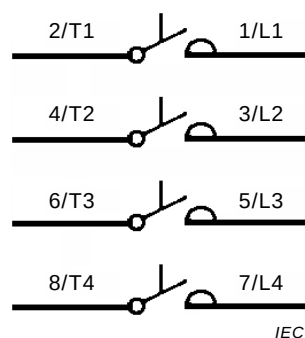


Figure A.1 – Main circuit

NOTE The present alternative methods of marking, i.e. 1-2 and L1-T1, will be progressively superseded by the new method above.

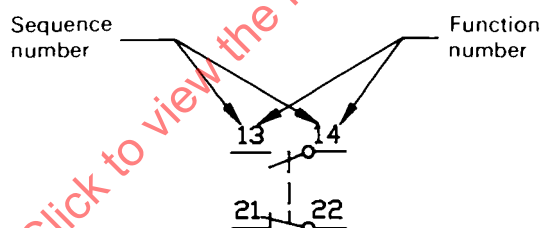
Alternatively, terminals may be identified on the wiring diagram supplied with the device.

~~A.2.3 – Marking and identification of terminals of auxiliary circuits~~

~~The terminals of auxiliary circuits shall be marked or identified on the diagrams by two figure numbers:~~

- ~~— the unit number is a function number;~~
- ~~— the figure of the tens is a sequence number.~~

~~The following examples illustrate such a marking system:~~

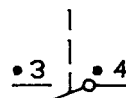
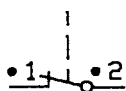


~~A.2.3.1 – Function number~~

~~Function numbers 1, 2 are allocated to circuits with break contacts and function numbers 3, 4 to circuits with make contacts.~~

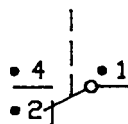
NOTE 1 The definitions for make contacts and break contacts are given in 2.3.12 and 2.3.13 of IEC 60947-1.

~~EXAMPLES~~



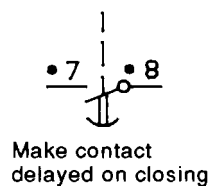
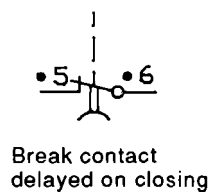
NOTE 2 The dots in the above examples take the place of the sequence numbers which should be added appropriately to the application.

~~The terminals of circuits with change-over contact elements shall be marked by the function numbers 1, 2 and 4.~~



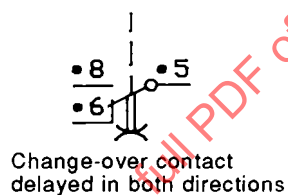
Function numbers 5 and 6 (for break contacts) and 7 and 8 (for make contacts) are allocated to terminals of auxiliary circuits containing auxiliary contacts with special functions.

EXAMPLES



The terminals of circuits with change-over contact elements with special functions shall be marked by function numbers 5, 6 and 8.

EXAMPLE

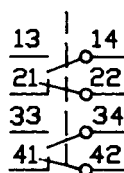


A.2.3.2 Sequence number

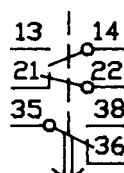
Terminals belonging to the same contact element shall be marked by the same sequence number.

All contact elements having the same function shall have different sequence numbers.

EXAMPLES

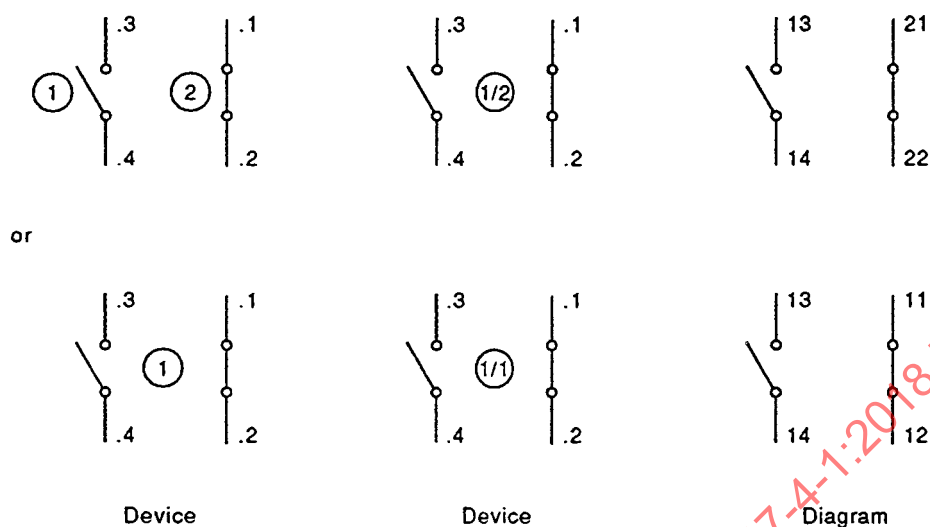


Four contact elements



Three contact elements

The sequence number may be omitted from the terminals only if additional information provided by the manufacturer or the user clearly gives such a number.



NOTE—The dots shown in the above examples are merely used to show the relationship and do not need to be used in practice.

A.3 Marking and identification of terminals of overload relays

The terminals of the main circuits of overload relays shall be marked in the same manner as the terminals of the main circuits of contactors (see A.1). Examples are given in Figure A.2.

The terminals of the auxiliary circuits of overload relays shall be marked in the same manner as the terminals of the auxiliary circuits of contactors with specified functions (see A.2.3 L.3.2 of IEC 60947-1:2007).

The sequence number shall be 9; if a second sequence number is required, it shall be 0.

EXAMPLES

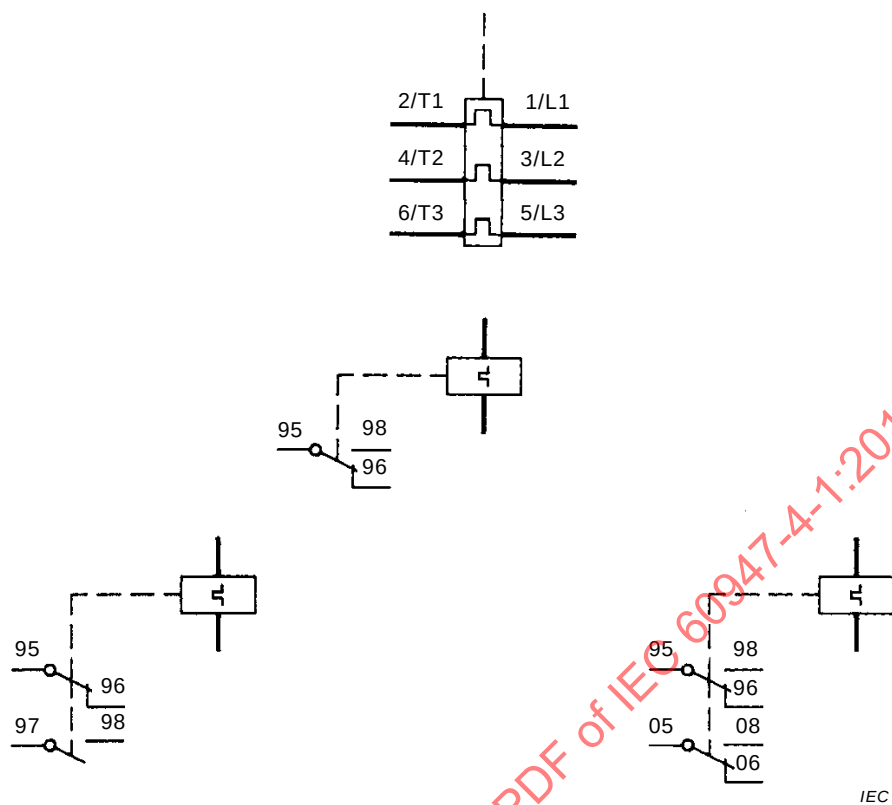


Figure A.2 – Overload relays

Alternatively, terminals may be identified on the wiring diagram supplied with the device.

Annex B (normative)

Special tests

B.1 General

Special tests are done at the discretion of the manufacturer.

B.2 Mechanical durability

B.2.1 General

By convention, the mechanical durability of a design of contactor or starter is defined as the number of no-load operating cycles which would be attained or exceeded by 90 % of all the apparatus of this design before it becomes necessary to service or replace any parts (including electronic parts of electronically controlled electromagnet and any mechanical part); however, normal maintenance according to the information given by the manufacturer (including replacement of contacts), as specified in B.2.2.1 and B.2.2.3, is permitted.

NOTE This method is different than the method of Annex K, for which the value obtained can be different.

The preferred numbers of no-load operating cycles, expressed in millions, are:

0,001 – 0,003 – 0,01 – 0,03 – 0,1 – 0,3 – 1 – 3 and 10.

B.2.2 Verification of mechanical durability

B.2.2.1 Condition of the contactor or starter for tests

The contactor or starter shall be installed as for normal service; in particular, the conductors shall be connected in the same manner as for normal use.

During the test, there shall be no voltage or current in the main circuit. The contactor or starter may be lubricated before the test if lubrication is prescribed in normal service.

B.2.2.2 Operating conditions

The coils of the control electromagnets shall be supplied at their rated voltage and, if applicable, at their rated frequency.

If a resistance or an impedance is provided in series with the coils, whether short-circuited during the operation or not, the tests shall be carried out with these elements connected as in normal operation.

Pneumatic and electro-pneumatic contactors or starters shall be supplied with compressed air at the rated pressure.

Manual starters shall be operated as in normal service.

B.2.2.3 Test procedure

- a) The tests are carried out at the frequency of operations corresponding to the class of intermittent duty. However, if the manufacturer considers that the contactor or starter can satisfy the required conditions when using a higher frequency of operations, he may do so.

- b) In the case of electromagnetic and electro-pneumatic contactors or starters, the duration of energization of the control ~~coil~~ **electromagnet** shall be greater than the time of operation of the contactor or starter and the time for which the ~~coil~~ **electromagnet** is not energized shall be of such a duration that the contactor or starter can come to rest at both extreme positions.

The number of operating cycles to be carried out shall be not less than the number of no-load operating cycles stated by the manufacturer.

The verification of mechanical durability may be made separately on the various components of the starter which are not mechanically linked together, unless a mechanical interlock not previously tested with its contactor is involved.

- c) For contactors or starters fitted with releases with shunt coils or under voltage releases, at least 10 % of the total number of opening operations shall be performed by these releases.
- d) After each tenth of the total number of operating cycles given in B.2.1 has been carried out, it is permissible before carrying on with the test:
- to clean the whole contactor or starter without dismantling;
 - to lubricate parts for which lubrication is prescribed by the manufacturer for normal service;
 - to adjust the travel and the pressure of the contacts if the design of the contactor or starter enables this to be done.
- e) This maintenance work shall not include any replacement of parts.
- f) In the case of star-delta starters, the built-in device causing time-delay between closing on star connection and closing on delta connection, if adjustable, may be set at its lowest value.
- g) In the case of rheostatic starters, the built-in device causing time-delay between closing of the rotor switching devices, if adjustable, may be set at its lowest value.
- h) In the case of auto-transformer starters, the built-in device causing time-delay between closing on the starting position and closing on the ON position, if adjustable, may be set at its lowest value.

B.2.2.4 Results to be obtained

Following the tests of mechanical durability, the contactor or starter shall still be capable of complying with the operating conditions specified in 9.3.6.2 and 9.3.6.3 at room temperature. ~~There shall be no loosening of the parts used for connecting the conductors.~~

Any timing relays or other devices for the automatic control shall still be operating.

B.2.2.5 Statistical analysis of test results for contactors or starters

The mechanical durability of a design of a contactor or starter is assigned by the manufacturer and verified by a statistical analysis of the results of the tests.

For contactors or starters which are produced in small quantities, the tests described in B.2.2.6 and B.2.2.7 do not apply.

However, for contactors or starters which are produced in small quantities and which also differ from a basic design only by minor variations without notable influence on characteristics, the manufacturer may assign mechanical durability on the basis of experience with similar designs, analysis, properties of materials, etc., and on the basis of the analysis of test results on large quantity production of the same basic design.

After this assignment, one of the two tests described below shall be performed. It should be selected by the manufacturer as being the most suitable in each case, for example according to the quantities of planned production or according to the conventional thermal current.

NOTE This test is not intended to be a lot-by-lot or production acceptance test for application by the user.

B.2.2.6 Single 8 test

Eight contactors or starters shall be tested to the assigned mechanical durability.

If the number of failures does not exceed two, the test is considered passed.

B.2.2.7 Double 3 test

Three contactors or starters shall be tested to the assigned mechanical durability.

The test is considered passed if there is no failure, and failed if there is more than one failure. Should there be one failure, then three additional contactors or starters are tested up to assigned mechanical durability and, providing there is no additional failure, the test is considered passed. The test is failed if at any time there is a total of two or more failures.

B.2.2.8 Other methods

Other methods given in ~~IEC 60410~~ can ISO 2859-1 may also be used. The maximum acceptance quality level shall be 10 %. The chosen method shall be indicated in the test report. ~~Methods given in IEC 61649 can also be used.~~

NOTE The single 8 test and the double 3 test are both given in ~~IEC 60410~~ (see Table X-C-2 and Table X-D-2) ISO 2859-1:1999 (see Table 10-C-2 and Table 10-D-2). These two tests have been chosen with the objective of basing them on testing a limited number of contactors or starters on essentially the same statistical characteristics (acceptance quality level: 10 %).

B.3 Electrical durability

B.3.1 General

With respect to its resistance to electrical wear, a contactor or starter is by convention characterized by the number of on-load operating cycles corresponding to the different utilization categories given in Table B.1 which can be made without repair or replacement.

Since, for star-delta, two-step auto-transformer and rheostatic rotor starters, the operation is subjected to large variations in the service conditions, it is deemed convenient not to give standard values for the test conditions. However, it is recommended that the manufacturer indicate the electrical durability of the starter for stated service conditions; this electrical durability may be estimated from the results of tests on the component parts of the starter.

For categories AC-3, AC-3e and AC-4, the test circuit shall comprise inductors and resistors so arranged as to give the appropriate values of current, voltage and power factor given in Table B.1; moreover, for AC-4, the test circuit testing the making and breaking capacity shall be used, see 9.3.3.5.2.

In all cases, the speed of operation shall be chosen by the manufacturer.

The tests shall be taken as valid if the values recorded in the test report differ from the values specified only within the following tolerances:

- current: $\pm 5 \%$;
- voltage: $\pm 5 \%$.

Tests shall be carried out with the contactor or the starter under the appropriate conditions of B.2.2.1 and B.2.2.2 using the test procedure, where applicable, of B.2.2.3, except that replacement of contacts is not permitted.

In the case of starters, if the associated contactor has already satisfied an equivalent test, the test need not be repeated on the starter.

Table B.1 – Verification of the number of on-load operating cycles – Conditions for making and breaking corresponding to the several utilization categories

Utilization category	Value of the rated operational current	Make			Break		
		I_{He}	U/U_e	$\cos \phi^a$	I_e/I_{He}	U_f/U_e	$\cos \phi^a$
AC-1	All values	1	1	0,95	1	1	0,95
AC-2	All values	2,5	1	0,65	2,5	1	0,65
AC-3	$I_e \leq 17 \text{ A}$	6	1	0,65	1	0,17	0,65
	$I_e > 17 \text{ A}$	6	1	0,35	1	0,17	0,35
AC-4	$I_e \leq 17 \text{ A}$	6	1	0,65	6	1	0,65
	$I_e > 17 \text{ A}$	6	1	0,35	6	1	0,35
		I_{He}	U/U_e	L/R^b ms	I_e/I_{He}	U_f/U_e	L/R^b ms
DC-1	All values	1	1	1	1	1	1
DC-3	All values	2,5	1	2	2,5	1	2
DC-5	All values	2,5	1	7,5	2,5	1	7,5

I_e — rated operational current
 U_e — rated operational voltage
 I — current made
 In a.c. the conditions for making are expressed in r.m.s. values but it is understood that the peak value of symmetrical current corresponding to the power factor of the circuit may assume a higher value.
 U — applied voltage
 U_f — power-frequency or d.c. recovery voltage
 I_e — current broken

^a — Tolerance for $\cos \phi$: $\pm 0,05$
^b — Tolerance for L/R: $\pm 15\%$

Utilization category	Value of the rated operational current	Make			Break		
		I / I_e	U / U_e	$\cos \phi^a$	I_c / I_e	U_r / U_e	$\cos \phi^a$
AC-1	All values	1	1	0,95	1	1	0,95
AC-2	All values	2,5	1	0,65	2,5	1	0,65
AC-3, AC-3e	$I_e \leq 17 \text{ A}$	6	1	0,65	1	0,17	0,65
	$I_e > 17 \text{ A}$	6	1	0,35	1	0,17	0,35
AC-4	$I_e \leq 17 \text{ A}$	6	1	0,65	6	1	0,65
	$I_e > 17 \text{ A}$	6	1	0,35	6	1	0,35
		I / I_e	U / U_e	L/R^b ms	I_c / I_e	U_r / U_e	L/R^b ms
DC-1	All values	1	1	1	1	1	1
DC-3	All values	2,5	1	2	2,5	1	2
DC-5	All values	2,5	1	7,5	2,5	1	7,5

I_e rated operational current

U_e	rated operational voltage
I	current made
	In alternating current the conditions for making are expressed in RMS values but it is understood that the peak value of symmetrical current corresponding to the power factor of the circuit may assume a higher value.
U	applied voltage
U_r	power-frequency or direct current recovery voltage
I_c	current broken
^a	Tolerance for $\cos \phi$: $\pm 0,05$.
^b	Tolerance for L/R : $\pm 15 \%$.

B.3.2 Results to be obtained

After the test, the contactor or the starter shall fulfil the operating conditions as specified in 9.3.6.2 of this document at ambient temperature and withstand a dielectric test voltage as given in 8.3.3.4.1, item 4) b), of IEC 60947-1:2007, and applied as in 8.3.3.4.1, item 4), of IEC 60947-1:2007, the test voltage being applied only:

- between all poles connected together and the frame of the contactor or starter, and
- between each pole and all the other poles connected to the frame of the contactor or starter.

B.3.3 Statistical analysis of test results for contactors or starters

B.3.3.1 General

The electrical durability of a design of a contactor or starter is assigned by the manufacturer and verified by a statistical analysis of the results of the tests. One of the three test methods shall be selected by the manufacturer between B.3.3.2, B.3.3.3 and B.3.3.4 as being the most suitable for example according to the quantities of planned production or according to the conventional thermal current.

For contactors or starters which are produced in small quantities, the tests described in B.3.3.2 and B.3.3.3 do not apply. However, for contactors or starters which are produced in small quantities and which also differ from a basic design only by minor variations without notable influence on characteristics, the manufacturer may assign electrical durability on the basis of experience with similar designs, analysis, properties of materials, etc., and on the basis of the analysis of test results on large quantity production of the same basic design.

NOTE This test is not intended to be a lot-by-lot or production acceptance test for application by the user.

B.3.3.2 Single 8 test

Eight contactors or starters shall be tested to the assigned electrical durability. If the number of failures does not exceed two, the test is considered passed.

B.3.3.3 Double 3 test

Three contactors or starters shall be tested to the assigned electrical durability. The test is considered passed if there is no failure, and failed if there is more than one failure. Should there be one failure, then three additional contactors or starters are tested up to assigned electrical durability and, providing there is no additional failure, the test is considered passed. The test is failed if at any time there is a total of two or more failures.

B.3.3.4 Other methods

Other methods given in ~~IEC 60410~~ can ISO 2859-1 may also be used. The maximum acceptance quality level shall be 10 %. The chosen method shall be indicated in the test report.

NOTE The single 8 test and the double 3 test are both given in ~~IEC 60410~~ (see Table X-C-2 and Table X-D-2) ISO 2859-1:1999 (see Table 10-C-2 and Table 10-D-2). These two tests have been chosen with the objective of basing them on testing a limited number of contactors or starters on essentially the same statistical characteristics (acceptance quality level: 10 %).

B.4 Coordination at the crossover current between the starter and associated SCPD

B.4.1 General and definitions

B.4.1.1 General

This annex states different methods of verifying the performance of starters and the associated SCPD(s) at currents below and above the intersection I_{co} of their respective time-current characteristics, provided by the starter and SCPD manufacturer(s), and the corresponding types of co-ordination described in 8.2.5.1.

Co-ordination at the crossover current between the starter and the SCPD can be verified either by the direct method with the special test of B.4.2 or, for type "2" co-ordination only, by the indirect method as in B.4.5.

B.4.1.2 Terms and definitions

B.4.1.2.1 crossover current

I_{co}

current corresponding to the crossover point of the mean or published curves representing the time-current characteristics of the overload relay and the SCPD respectively

Note 1 to entry: The mean curves are the curves corresponding to the average values calculated from the tolerances on the time-current characteristics given by the manufacturer.

~~B.4.1.2.2~~

~~test current I_{cd}~~

~~test current greater than I_{co} , tolerances included, designated by the manufacturer and verified by the requirements given in Table B.2~~

B.4.1.2.2 time-current withstand characteristic capability of contactors/starters

locus of the currents a contactor/starter can withstand as a function of time

B.4.2 Condition for the test for the verification of co-ordination at the crossover current by a direct method

The starter and its associated SCPD shall be mounted and connected as in normal use. All the tests shall be performed starting from the cold state.

B.4.3 Test currents and test circuits

The test circuit shall be according to 8.3.3.5.2 of IEC 60947-1:2007 except that the oscillatory transient voltage need not be adjusted. The currents for the tests shall be:

(i) $0,75 I_{co} \begin{smallmatrix} 0 \\ -5 \end{smallmatrix} \%$; and

(ii) $1,25 I_{co} \begin{smallmatrix} +5 \\ 0 \end{smallmatrix} \%$.

The power factor of the test circuit shall be in accordance with Table 7. In the case of small relays having a high resistance, inductors should be mainly used in order to have a value of power factor as low as possible. The recovery voltage shall be 1,05 times the rated operational voltage.

The SCPD shall be as stated in 8.2.5.1 and of the same rating and characteristics as used in the tests of 9.3.4.2.

If the switching device is a contactor, its coil shall be energized from a separate source at the rated control circuit supply voltage of the contactor coil and connected so that the contactor opens when the overload relay operates.

B.4.4 Test procedure and results to be obtained

B.4.4.1 Test procedure

With the starter and the SCPD closed, the test currents stated in B.4.3 shall be applied by a separate closing device. In each case, the device tested shall be at room temperature.

After each test, it is necessary to inspect the SCPD, reset the overload relay and the release of the circuit-breaker, if necessary, or to replace all fuses if at least one of them has melted.

B.4.4.2 Results to be obtained

After the test at the lower current (i) in B.4.3, the SCPD shall not have operated and the overload relay or release shall have operated to open the starter. There shall be no damage to the starter.

After the test at the higher current (ii) in B.4.3, the SCPD shall have operated before the starter. The starter shall meet the conditions of 9.3.4.2.3 for the type of co-ordination stated by the manufacturer.

B.4.5 Verification of co-ordination at the crossover current by an indirect method

~~NOTE For type "1" co-ordination, the indirect method may be different from the method described in Annex B and is under consideration. For this reason, the indirect method for the verification of co-ordination at the crossover point is only applicable for type "2" co-ordination.~~

The indirect method consists in verifying on a diagram (see Figure B.1a) and Figure B.1b)) that the following conditions for the verification of co-ordination at the crossover current are met:

- the time-current characteristic of the overload relay/release, starting from cold state, supplied by the manufacturer, shall indicate how the tripping time varies with the current up to a value of at least I_{CO} ; this curve has to lie below the time-current characteristic of the SCPD up to I_{CO} ;
- I_{cd} of the starter, tested as in B.4.5.1, shall be higher than I_{CO} ;
- the time-current withstand characteristic of the contactor, tested as in B.4.5.2, shall be above the time-current characteristic (starting from cold state) of the overload relay up to I_{CO} .

B.4.5.1 Test for I_{cd}

Subclause 9.3.4.1 applies with the following addition.

- Test procedure: the contactor or starter shall make and break the test current (I_{cd}) for the number of operating cycles given in Table B.2. This is made without the SCPD in the circuit.

Table B.2 – Test conditions

	U_r/U_e	$\cos \phi$	On-time (see Note 2) s	Off-time s	Number of operations
I_{cd}	1,05	See Note 1	0,05	See Note 3	3
NOTE 1 Power factor to be selected according to Table 16 of IEC 60947-1:2007.					
NOTE 2 Time may be less than 0,05 s provided that contacts are allowed to become properly seated before re-opening.					
NOTE 3 See Table 8.					

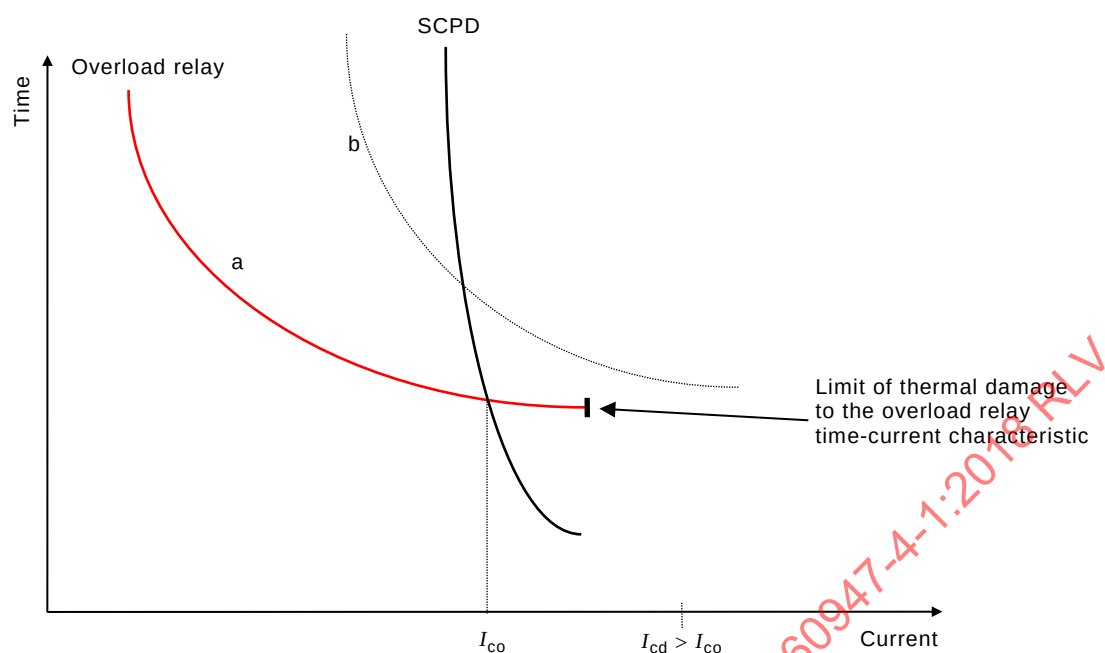
– Behaviour of contactors or starters during and after the I_{cd} test:

- a) during the test, there shall be no permanent arcing, no flash-over between poles, no blowing of the fusible element in the earth circuit (see 9.3.4.1.2) and no welding of contacts;
- b) after the test,
 - 1) the contacts shall operate correctly when the contactor or starter is switched by the applicable method of control;
 - 2) the dielectric properties of the contactors and starters shall be verified by a dielectric test on the contactor or starter using an essentially sinusoidal test voltage of twice the rated operational voltage U_e used for the I_{cd} test, with a minimum of 1 000 V. The test voltage shall be applied ~~for 60 s~~, as specified in 8.3.3.4.1, items 2) c) i) and 2) c) ii) of IEC 60947-1:2007.

B.4.5.2 Time-current characteristic withstand capability of contactors/starters

This characteristic is issued by the manufacturer and the values are obtained according to the test procedure specified in 9.3.5 but with combinations of overload currents and durations to establish the characteristic at least up to I_{co} , in addition to those stated in 8.2.4.4.

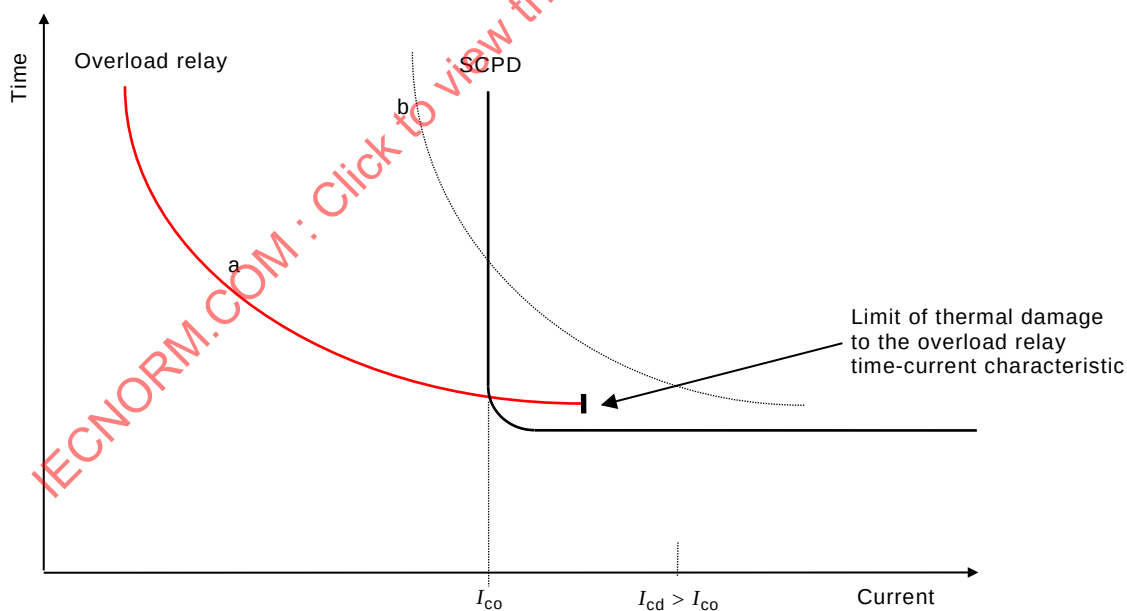
This characteristic is valid for overload currents, starting with the contactor at room temperature. The minimum cooling duration required by the contactor between two such overload tests should be stated by the manufacturer.



IEC

Key

- a mean overload relay time-current characteristic from cold state
- b time-current characteristic withstand capability of contactor

a) Co-ordination with fuse

IEC

Key

- a mean overload relay time-current characteristic from cold state
- b time-current characteristic withstand capability of contactor

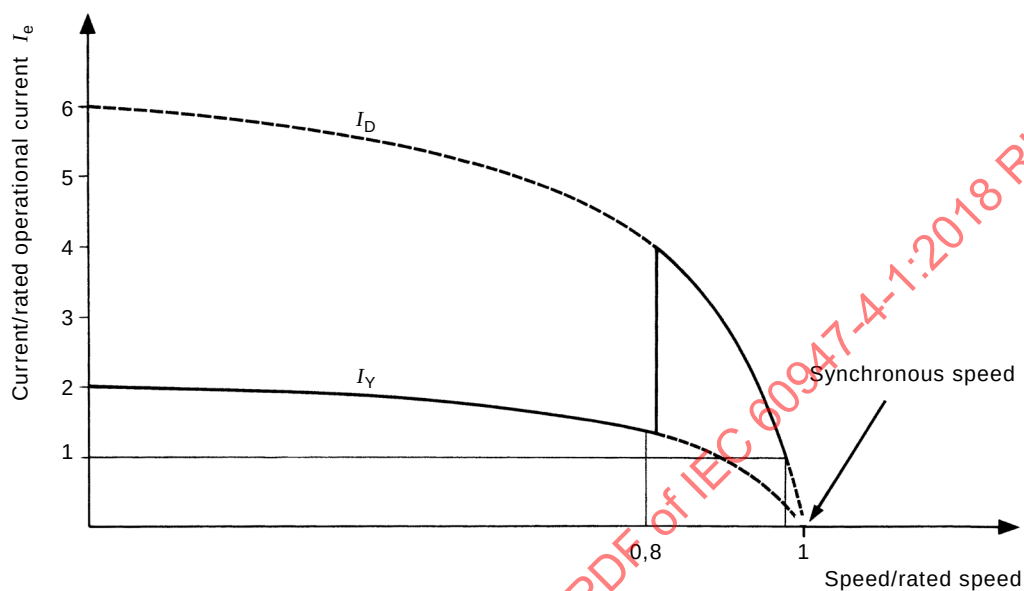
b) Co-ordination with circuit-breaker**Figure B.1 – Examples of time-current withstand characteristic**

Annex C

Void

(informative)

Typical characteristics of starters



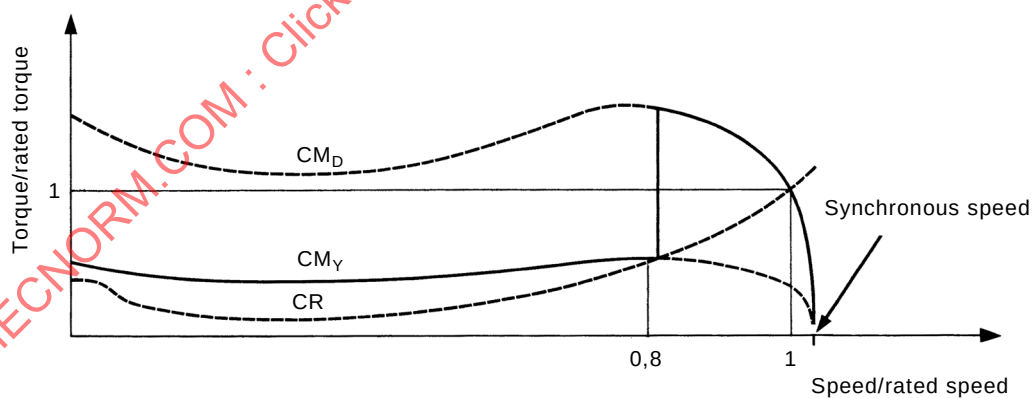
IEC

Key

I_Y Current in star connection

I_D Current in delta connection

a) Typical currents during a star-delta start



IEC

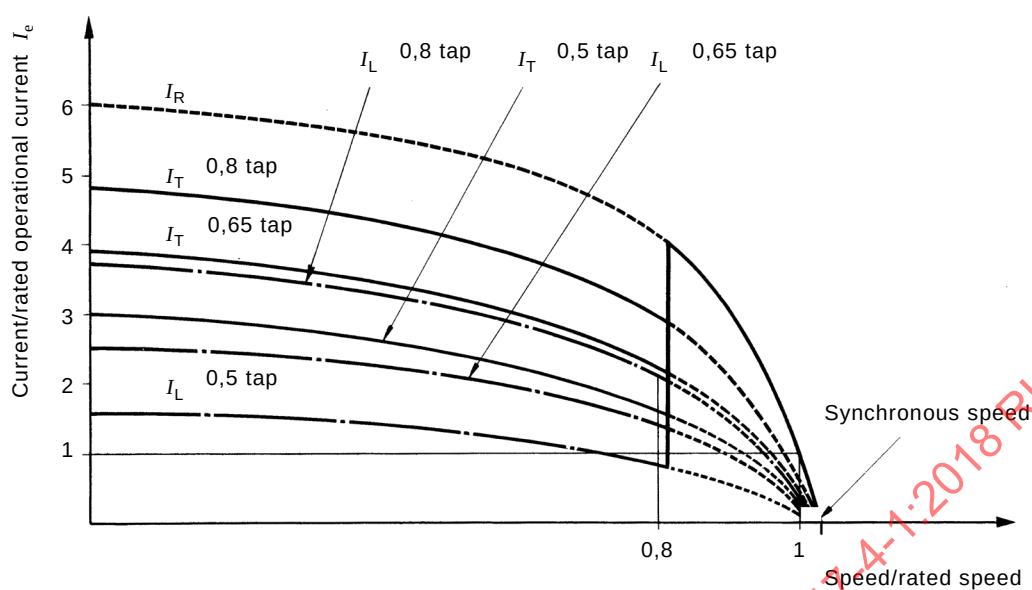
Key

CM motor torque

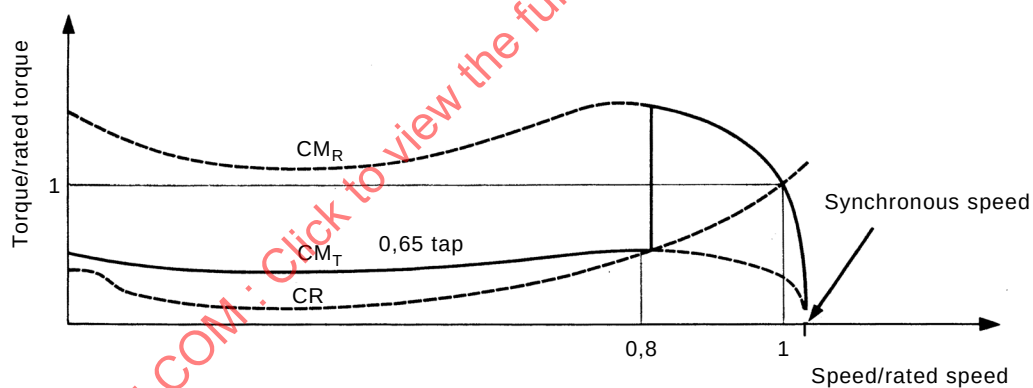
CR load torque

b) Typical torques during a star-delta start

Figure C.1 – Typical curves of currents and torques during a star-delta start (see 3.4.4.1)



IEC

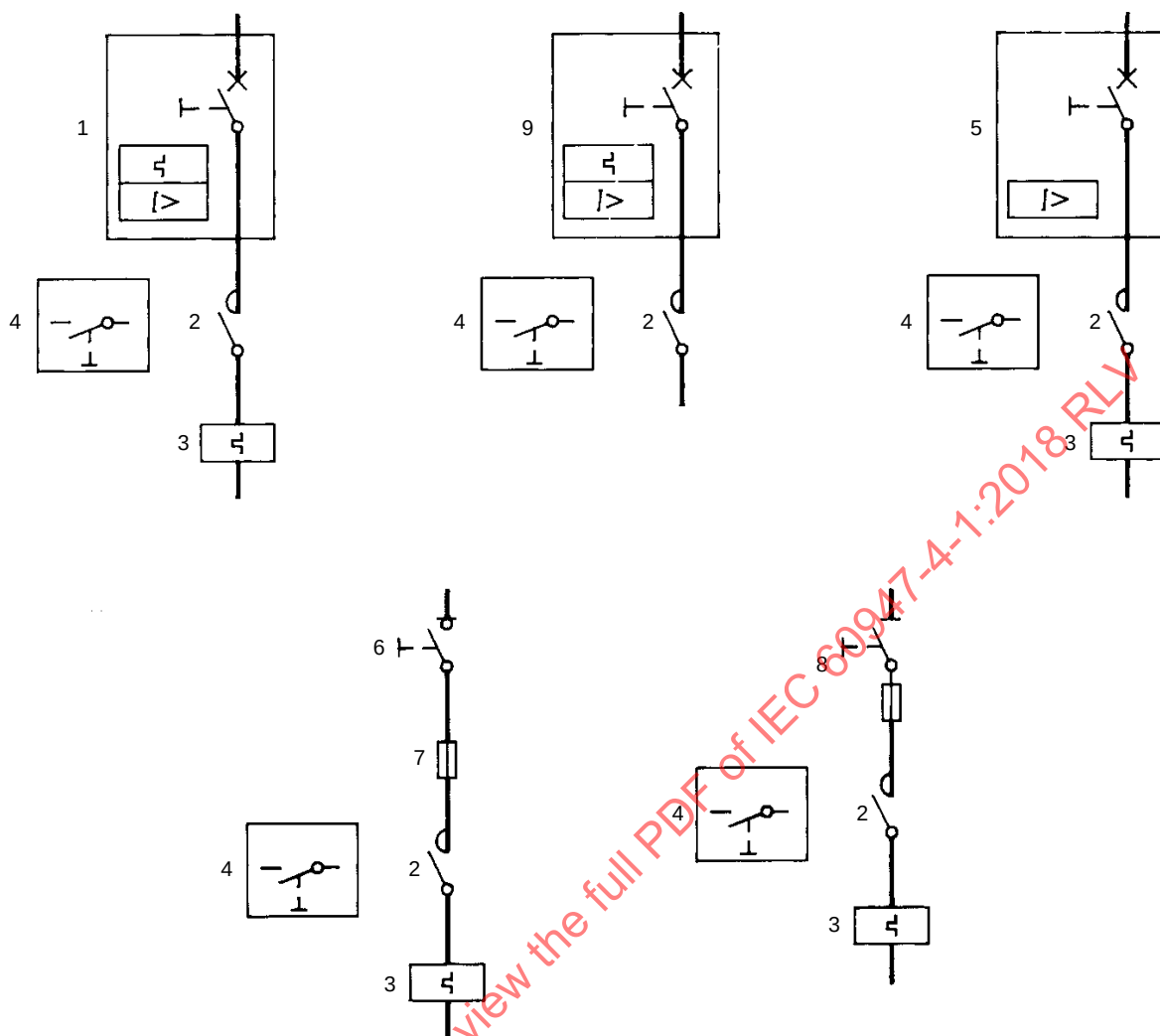
Key I_R motor current at rated voltage I_T motor current at reduced voltage I_L line current at reduced voltage**a) Typical currents during an auto-transformer start**

IEC

Key

CR load torque

 CM_R motor torque at rated voltage CM_T motor torque at reduced voltage**b) Typical torques during an auto-transformer start****Figure C.2 – Typical curves of currents and torques during an auto-transformer start (see 3.4.4.2)**

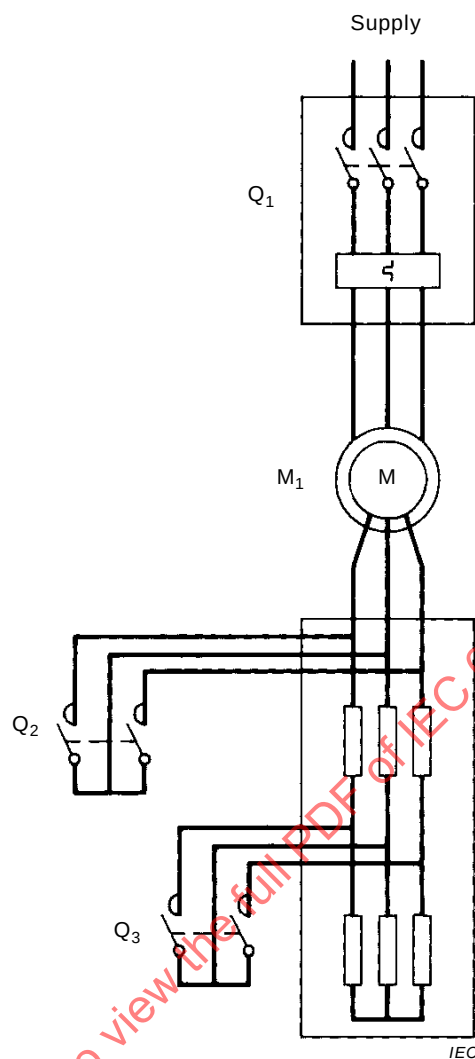


IEC

Key

- 1 circuit-breaker according to IEC 60947-2
- 2 contactor
- 3 overload relay
- 4 control switch
- 5 circuit-breaker magnetic trip only
- 6 switch-disconnector
- 7 fuse
- 8 disconnector fuse
- 9 motor protective switching device (MPSD)

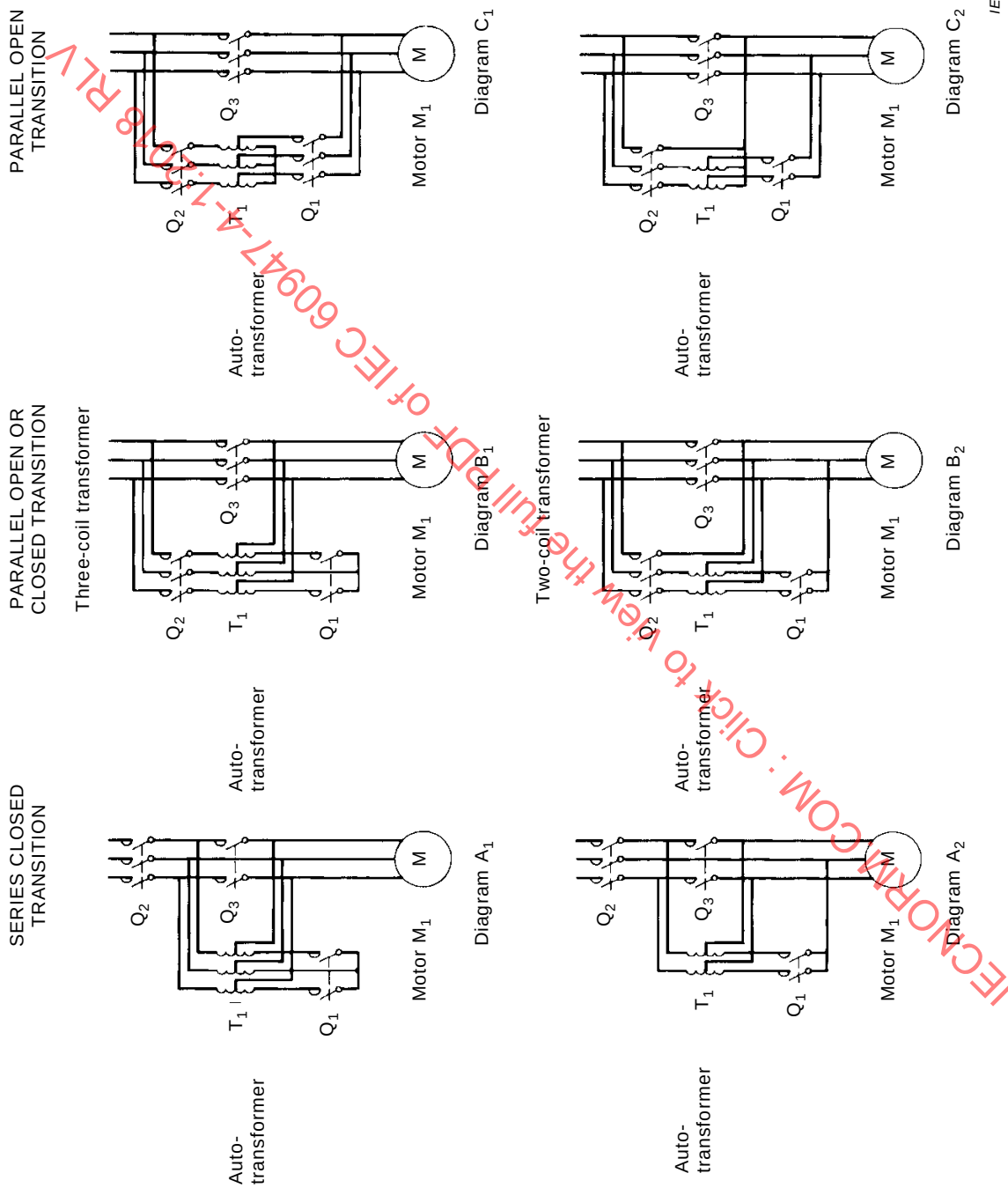
Figure C.3 – Typical variants of protected starters, combination starters, protected switching devices and combination switching devices



Position of the mechanical switching devices

Mechanical switching device	Position of the starter	Starting			
		Stop	1st step	2nd step	3rd step
Q ₁		O	C	C	C
Q ₂		O	O	O	C
Q ₃		O	O	C	C
O mechanical switching device open		Q contactor			
C mechanical switching device closed		M motor			

Figure C.4 – Example of three-phase diagram of a rheostatic rotor starter with three starting steps and one direction of rotation (in the case when all the mechanical switching devices are contactors)



Contact sequence			
Contacts	Start	Transition	On
Q ₁	C	O	O
Q ₂	C	C	C
Q ₃	O	O	C

C = contact closed
O = contact open

Contact sequence				
Contacts	Start	Transition		On
		Open	Close	
			1 2	
Q ₁	C	O	O	O
Q ₂	C	O	C	O
Q ₃	O	O	O	C

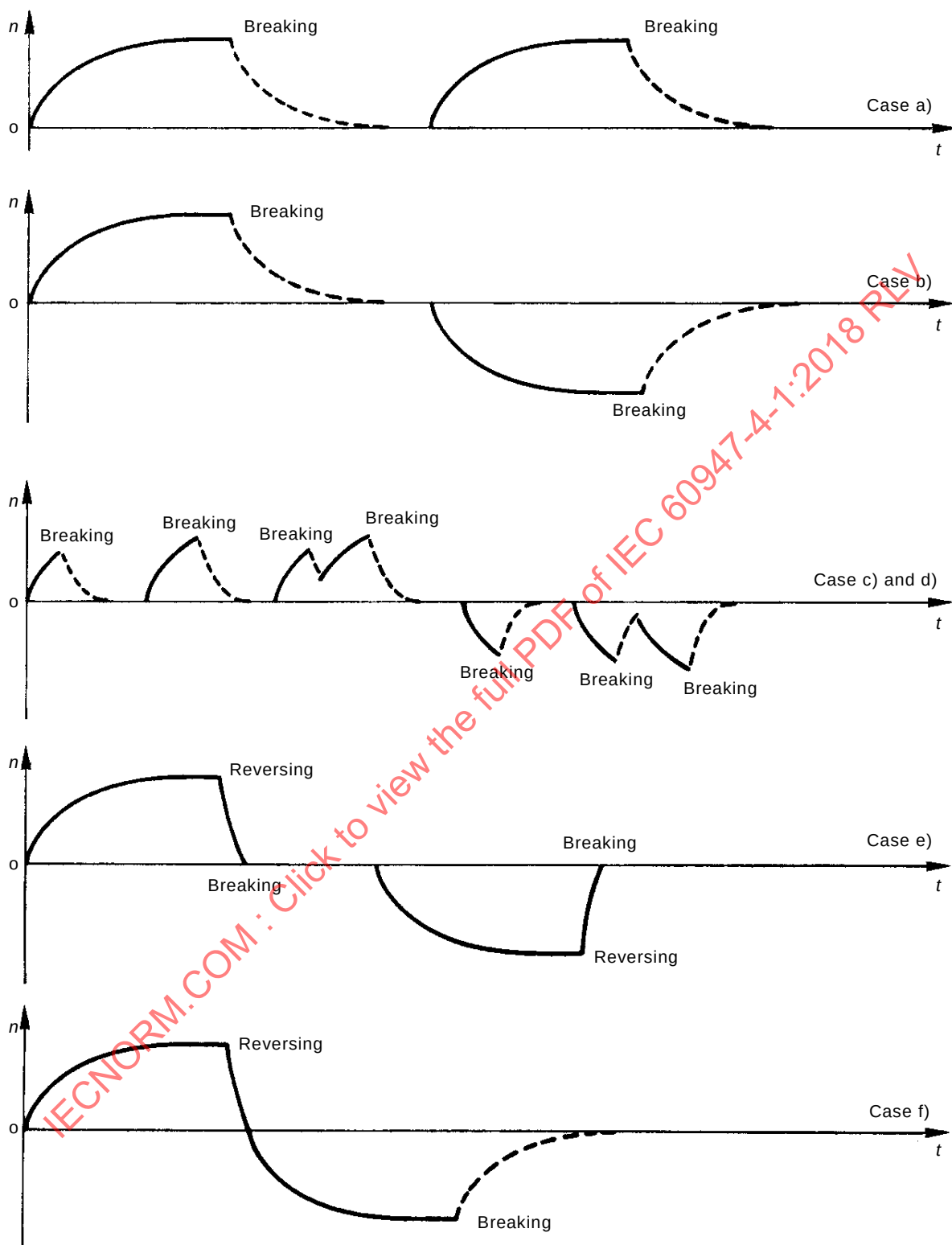
For open transition, Q₁ and Q₂ may be contacts of the same mechanical switching device

Contact sequence			
Contacts	Start	Transition	On
Q ₁	C	O	O
Q ₂	C	C	O
Q ₃	O	O	C

Q₁ and Q₂ may be contacts of the same mechanical device.

NOTE The graphical symbols utilized above correspond to the case where all the mechanical switching devices are contactors.

Figure C.5 – Typical methods and diagrams of starting alternating-current induction motors by means of auto-transformers



IEC

NOTE The dotted parts of the curves correspond to the periods when no current flows through the motor.

Figure C.6 – Examples of speed/time curves corresponding to cases a), b), c), d), e) and f) of 5.3.5.6.1

Annex D (informative)

Items subject to agreement between manufacturer and user

NOTE For the purpose of this annex:

- *agreement* is used in a very wide sense;
- *user* includes testing stations.

Annex J of IEC 60947-1:2007 applies, as far as covered by clauses and subclauses of this document, with the following additions.

Clause or subclause number of this document	Item
1.1.2.3	~~Additional requirements concerning two-direction starters and inching and plugging~~
5.3.4.3 – Note	Overload protection of starters for intermittent duty
5.3.5.6.4	Time interval between two successive starts of auto-transformer starters having a starting time exceeding 15 s
5.4	Types of utilization other than the utilization categories defined in Table 1
5.7.2	Specific applications of instantaneous ~~over-current~~ overload relays or releases and of relays or releases listed in 5.7.2 e)
5.7.3	Protection of the rotor circuit for a rheostatic rotor starter
5.7.3	Protection of the auto-transformer for an auto-transformer starter
5.7.5	Tolerances on time-current characteristics of overload relays (to be indicated by the manufacturer)
5.10.2	Characteristics of devices for automatic acceleration control
5.11; 5.12	Nature and dimensions of the connecting links: a) between an auto-transformer starter and the auto-transformer, if this is provided separately b) between a rheostatic rotor starter and the resistors, if these are provided separately Agreement for items a) and b) is to be concluded between the starter manufacturer and the manufacturer of the transformer, or of the resistors, as the case may be
8.2.2.7.3	Ratings of specially rated windings (to be stated by the manufacturer)
Table 7	Verification of the make conditions when this verification is carried out during the make and break test (manufacturer's agreement)
Table 11	Footnote ^a
Table 13	Value of the prospective current "r" for the conditional short-circuit current test of devices of $I_e > 1\,600\text{ A}$

Annex E

(Void)

(informative)

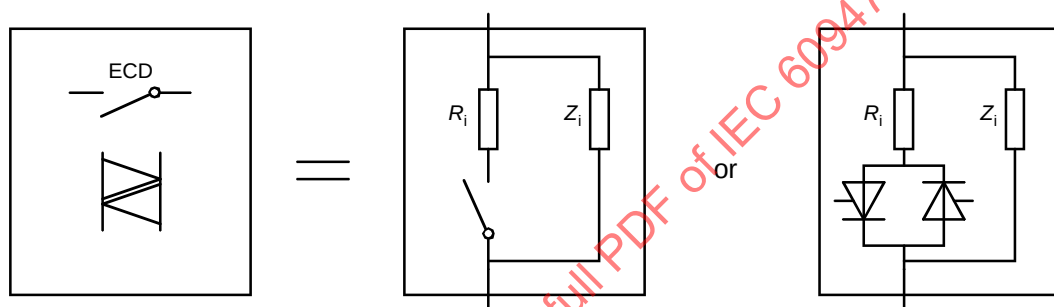
Examples of control circuit configurations

E.1 External control device (ECD)

E.1.1 Definition of an ECD

Any external element which serves to effect the control of the contactor or starter.

E.1.2 Diagrammatic representation of an ECD



IEC 1215/99

E.1.3 Parameters of an ECD

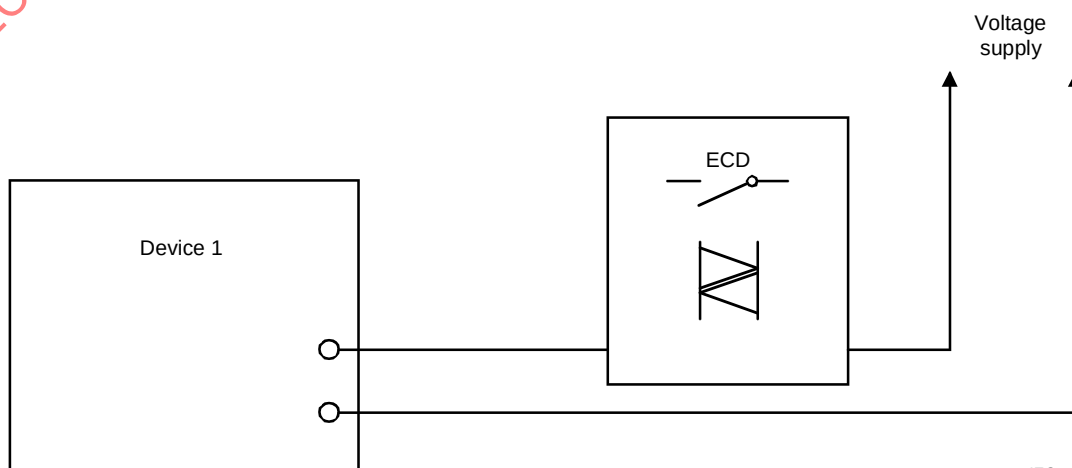
- R_i : internal resistance;
- Z_i : internal leakage impedance.

NOTE In the case where ECD is a mechanical push button, R_i is often neglected and Z_i is often taken as infinity (∞).

E.2 Control circuit configurations

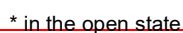
E.2.1 Contactor or starter with external control supply

E.2.1.1 Single supply and control input



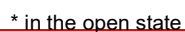
IEC 1216/99

~~E.2.1.2 Separate supply and control inputs~~



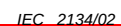
IEC 1217/99

~~E.2.2 Contactor or starter with an internal control supply and control input only~~

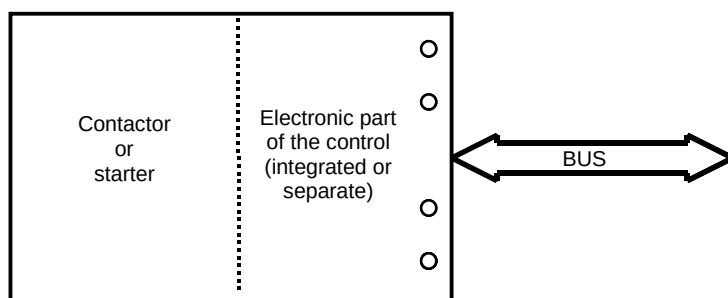


IEC 2133/02

~~E.2.3 Contactor or starter with several external control supplies~~



**E.2.4 Contactor or starter with bus interface
(may be combined with other circuit configurations)**



IEC 2135/02

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

Annex F (normative)

Requirements for auxiliary contact linked with power contact (mirror contact)

F.1 **Scope Application and object**

F.1.1 **Scope Application**

This annex applies to auxiliary contacts mechanically linked with power contacts of a contactor and designated as mirror contacts in order to avoid any confusion with mechanically linked contact elements ~~dealt within~~ covered by Annex L of IEC 60947-5-1:2016. However, that does not prevent a given auxiliary contact to comply with both requirements for mirror contact of this annex and for mechanically linked contact of Annex L of IEC 60947-5-1:2016.

NOTE 1 A typical application of mirror contacts is to have, in the machine control circuit, a highly reliable monitoring of the status of the contactor. However, mirror contact ~~should not~~ cannot be relied upon exclusively as a means to ensure the integrity of a safety function.

NOTE 2 Mirror contacts have previously been referred to as positively safety contacts, forced contacts, linked contacts or positively driven contacts.

NOTE 3 The meaning of “mechanically linked” is also applicable to additional contact blocks which can be mounted by the user.

F.1.2 **Object**

This annex provides additional specifications (definition, requirements and tests) which shall be used for stating the required design characteristics, marking and performance of mirror contact.

F.2 **Terms and definitions**

For the purposes of this annex, the following term and definition applies.

F.2.1

mirror contact

normally closed auxiliary contact which cannot be in closed position simultaneously with the normally open main contact under conditions defined in Clause F.7

Note 1 to entry: One contactor may have more than one mirror contact.

F.3 **Characteristics**

All mirror contacts shall also comply with the relevant requirements given in IEC 60947-5-1:2016.

F.4 **Product information**

Clause ~~6~~ 5 of IEC 60947-5-1:2016 applies with the following addition.

Mirror contacts shall be clearly identified:

- on the contactor itself, or
- in the manufacturer documentation, or

– both.

Where a symbol is used to identify a mirror contact, it shall be as shown in Figure F.1 (IEC 60617- S01462:2003).



Figure F.1 – Mirror contact

F.5 Normal service, mounting and transport conditions

There are no supplementary requirements.

F.6 Constructional and performance requirements

Clause ~~8~~ 7 of IEC 60947-5-1:2016 applies with the following addition.

When any of the main contacts is closed, no mirror contact shall be closed.

~~NOTE – Self-checking of the mirror contact circuit is recommended.~~

F.7 Tests

F.7.1 General

Clause ~~9~~ 8 of IEC 60947-5-1:2016 applies with the following addition.

Tests according to both F.7.2 and F.7.3 shall be carried out.

F.7.2 Tests on products in a new condition

For each mirror contact, the test shall be carried out on m products, where m is the number of main contacts.

NOTE Depending of the product construction, the needed quantity m of products can be minimized based on engineering judgment for covering the worst cases.

A new product is used for testing each mirror contact with each of the main contacts.

The tests shall be carried out on products in a new and clean condition. The test procedure shall be as follows:

- a) To simulate the occurrence of welding on one main pole, one main contact shall be maintained in the closed position, e.g. by welding or gluing each point of contact (e.g. for double breaking contact, welding is carried out at the two contact points). The thickness of welding or gluing shall be such that the distance between contacts is not modified significantly and the method used shall be described in the test report.
- b1) With the operating coil de-energized, an impulse test voltage of 2,5 kV at sea level (correction should be made according to Table F.1 given below, calculated from Table 12

of IEC 60947-1:2007) shall be applied across the mirror contact. There shall be no disruptive discharge.

Table F.1 – Test voltage according to altitude

Sea level	200 m	500 m	1 000 m	2 000 m
2,5 kV	2,37 kV	2,37 kV	2,29 kV	2,12 kV
NOTE This test ensures a minimum gap of 0,5 mm in accordance with Figure A.1, Figure A.2 and Figure A.3 of IEC 60664-1:2007 from which Table 13 of IEC 60947-1:2007 is issued.				

b2) As an alternative to item b1) above, with the operating coil de-energized, the gap of the contact shall be measured with direct means; it shall be more than 0,5 mm. In case of two or more contact gaps in series, the sum of contact gaps shall be more than 0,5 mm.

The sequences a) and b1) or b2) are repeated on new samples for each main contact welded successively.

F.7.3 Test after conventional operational performance (defined under Table 10)

At the end of the conventional operational performance tests according to 9.3.3.6, it shall be verified that, when the ~~coil~~ **electromagnet** is energized, the mirror contact shall withstand its rated insulation voltage U_i .

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

Annex G (informative)

Rated operational currents and rated operational powers of switching devices for electrical motors

G.1 General

The given values in Table G.1 are guide values for the relationship between rated operational currents and rated operational powers. They should be considered for use when information concerning products has to be given to the customers.

The statements of this annex are applicable to all kind of switching devices for electrical motors.

The figures are harmonized within the IEC and therefore state the basis for all the product information given by the manufacturer.

The values given in Table G.1 are typical rated operational currents ($\pm 5\%$) of motors for the corresponding rated operational powers. Design NE and HE motors are within the given variation of $\pm 5\%$.

If the devices are in compliance with these values, they are able to switch on and off most of the existing electrical motors.

These values state a harmonized guideline for design of switching devices.

G.2 Rated operational powers and rated operational currents

Rated operational power is linked with individual rated operational currents at different voltages according to Table G.1.

The guide values for rated operational currents are determined on the basis of a four-pole squirrel-cage motor at 400 V, 1 500 min⁻¹ and 50 Hz. The rated operational currents for the other voltages are calculated on the basis of values at 400 V.

Table G.1 – Rated operational powers and rated operational currents of motors

Rated operational power		Guide values of rated operational currents at											
		110 V to 120 V	200 V	208 V	230 V	220 V to 240 V	380 V to 415 V	400 V	440 V to 480 V	500 V	550 V to 600 V	690 V	
kW ^a	hp ^b	A	A	A	A	A	A	A	A	A	A	A	
0,06	–	–	–	–	0,35	–	–	0,20	–	0,16	–	0,12	
0,09	–	–	–	–	0,52	–	–	0,30	–	0,24	–	0,17	
0,12	–	–	–	–	0,70	–	–	0,44	–	0,32	–	0,23	
0,18	–	–	–	–	1,0	–	–	0,60	–	0,48	–	0,35	
0,25	–	–	–	–	1,5	–	–	0,85	–	0,68	–	0,49	
0,37	–	–	–	–	1,9	–	–	1,10	–	0,88	–	0,64	
–	1/2	4,4	2,5	2,4	–	2,2	1,3	–	1,1	–	0,9	–	
0,55	–	–	–	–	2,6	–	–	1,5	–	1,2	–	0,87	
–	3/4	6,4	3,7	3,5	–	3,2	1,8	–	1,6	–	1,3	–	
–	1	8,4	4,8	4,6	–	4,2	2,3	–	2,1	–	1,7	–	
0,75	–	–	–	–	3,3	–	–	1,9	–	1,5	–	1,1	
1,1	–	–	–	–	4,7	–	–	2,7	–	2,2	–	1,6	
–	1-1/2	12,0	6,9	6,6	–	6,0	3,3	–	3,0	–	2,4	–	
–	2	13,6	7,8	7,5	–	6,8	4,3	–	3,4	–	2,7	–	
1,5	–	–	–	–	6,3	–	–	3,6	–	2,9	–	2,1	
–	–	–	–	–	8,5	–	–	4,9	–	3,9	–	2,8	
2,2	–	19,2	11,0	10,6	–	9,6	6,1	–	4,8	–	3,9	–	
–	3	–	–	–	11,3	–	–	6,5	–	5,2	–	3,8	
3,0	–	–	–	–	15	–	–	8,5	–	6,8	–	4,9	
4	–	30,4	17,5	16,7	–	15,2	9,7	–	7,6	–	6,1	–	
–	5	–	–	–	20	–	–	11,5	–	9,2	–	6,7	
5,5	–	–	–	–	–	–	–	–	–	–	–	–	
–	7-1/2	44,0	25,3	24,2	–	22,0	14,0	–	11,0	–	9,0	–	
–	10	56,0	32,2	30,8	–	28,0	18,0	–	14,0	–	11,0	–	
7,5	–	–	–	–	27	–	–	15,5	–	12,4	–	8,9	
11	–	–	–	–	38,0	–	–	22,0	–	17,6	–	12,8	
15	–	84	48,3	46,2	–	42,0	27,0	–	21,0	–	17,0	–	
–	20	108	62,1	59,4	–	54,0	34,0	–	27,0	–	22,0	–	
15	–	–	–	–	51	–	–	29	–	23	–	17	
18,5	–	–	–	–	61	–	–	35	–	28	–	21	
–	25	136	78,2	74,8	–	68	44	–	34	–	27	–	

[illegible]

Rated operational power		Guide values of rated operational currents at										
		110 V to 120 V	200 V	208 V	230 V	220 V to 240 V	380 V to 415 V	400 V	440 V to 480 V	500 V	550 V to 600 V	690 V
kW ^a		A	A	A	A	A	A	A	A	A	A	A
hp ^b	315	—	—	—	940	—	—	540	—	432	—	313
	—	—	—	—	—	1 030	—	—	515	—	412	—
	335	—	—	—	—	—	—	—	—	—	—	—
500	—	—	—	—	1 061	—	—	610	—	488	—	354
	—	—	—	—	—	1 180	786	—	590	—	472	—
	375	—	—	—	—	—	—	—	—	—	—	—
400	—	—	—	—	1 200	—	—	690	—	552	—	400
	—	—	—	—	—	—	—	—	—	—	—	—
	450	—	—	—	—	—	—	—	—	—	—	—
475	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	1 478	—	—	850	—	680	—	493
	530	—	—	—	—	—	—	—	—	—	—	—
560	—	—	—	—	1 652	—	—	950	—	760	—	551
	—	—	—	—	—	—	—	—	—	—	—	—
	630	—	—	—	1 844	—	—	1 060	—	848	—	615
670	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	2 070	—	—	1 190	—	952	—	690
	750	—	—	—	—	—	—	—	—	—	—	—
800	—	—	—	—	2 340	—	—	1 346	—	1 076	—	780
	—	—	—	—	—	—	—	—	—	—	—	—
	900	—	—	—	2 640	—	—	1 518	—	1 214	—	880
950	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	2 910	—	—	1 673	—	—	—	970
	1 000	—	—	—	—	—	—	—	—	1 339	—	—
Preferred rated values according to IEC 60072-1:1991 (primary series).												
Horsepower and currents values according to Table 45.2 of UL 508:2013 (60 Hz).												

^a Preferred rated values according to IEC 60072-1:1991 (primary series).

^b Horsepower and currents values according to Table 45.2 of UL 508:2013 (60 Hz).

Annex H (normative)

Extended functions ~~within~~ to electronic overload relays

H.1 — Scope

H.1.1 — General

This annex is intended to cover extended functions included in electronic overload relays (see also note of 5.7) not directly related to the overload protection. Extended functions may also ensure some control functions. Control functions are under consideration.

NOTE — Electronic relay with extended functions may also be called in the field with other designation such as: „motor management system“, „motor protector“....

This annex applies only to electronic relays intended for use in a.c. circuits.

H.1.2 — Ground/earth fault detection function

Devices reacting to ground/earth fault currents are used as protective systems. Such devices are frequently used in conjunction with or as an integral part of electronic overload relays to detect ground/earth fault current in equipment in order to provide additional protection against fire and other hazards which may develop as a result of a ground/earth fault of a lasting nature which cannot be detected by the over-current protective function. The behaviour due to the presence of a d.c. component is not considered.

This annex is not applicable to residual current protection devices intended to protect installations; these are covered by IEC 60947-2.

NOTE — This ground/earth fault protection is not intended to provide protection against electric shock.

H.2 — Terms and definitions

For the purposes of this annex, the following terms and definitions apply.

H.2.1

electronic overload relay with ground/earth fault detection

multipole electronic relay which operates when the vectorial sum of the currents flowing in the main circuit has increased above a predetermined value in accordance with specified requirements

NOTE — For an easier reading, the term "ground/earth fault relay" is use in the rest of this annex.

H.2.2

electronic overload relay with current imbalance detection

electronic overload relay which operates in the case of current magnitude imbalance in accordance with specified requirements

NOTE — For an easier reading, the term "current imbalance relay" is use in the rest of this annex.

H.2.3

electronic overload relay with voltage imbalance detection

electronic overload relay which operates in the case of voltage magnitude imbalance in accordance with specified requirements

NOTE — For an easier reading, the term "voltage imbalance relay" is use in the rest of this annex.

H.2.4

electronic overload relay with phase reversal detection

~~multipole electronic overload relay which operates in the case of improper phase sequence at the line side of the starter in accordance with specified requirements~~

~~NOTE For an easier reading, the term "phase reversal relay" is use in the rest of this annex.~~

H.2.5

electronic overload relay with over-voltage detection

~~electronic overload relay which operates when the voltage has increased above a predetermined value in accordance with specified requirements~~

~~NOTE For an easier reading, the term "over-voltage relay" is use in the rest of this annex.~~

H.2.6

electronic overload relay with under-power detection

~~electronic overload relay which operates in the case of a power magnitude below a predetermined value in accordance with specified requirements~~

~~NOTE For an easier reading, the term "under-power relay" is use in the rest of this annex.~~

H.2.7

inhibit current (I_{ic})

~~fault current above which a switching device is not initiated to open~~

H.3 Classification of electronic overload relays

~~Subclauses H.2.1 to H.2.5 gives the classification criteria.~~

H.4 Type of relays

~~Type CI-A and CI-B: a type CI electronic overload relay is one that will initiate opening of the switching device at all levels of fault current.~~

~~Type CII-A and CII-B: a type CII electronic overload relay is one that will not initiate opening of the switching device above a set current level I_{ic} (inhibit current).~~

~~NOTE 1 Type CII(-A or -B) are typically used in conjunction with switching devices having a breaking capacity lower than the maximum expected fault current. The inhibit current setting I_{ic} is adjusted according to the maximum breaking capacity of the switching device.~~

~~NOTE 2 Types (CI or CII) -A differentiates to types (CI or CII) -B according to their operating characteristics (see Table H.1).~~

H.5 Performance requirements

H.5.1 Limits of operation of ground/earth fault relays

~~A ground/earth fault relay, when associated with a switching device, shall operate to open the switching device according to the requirements given in Table H.1. For relays with a ground/earth fault current setting range, the limit of operation of the relay shall be verified at the lowest and highest settings.~~

Table H.1 — Operating time of ground/earth fault relays

Type	Multiples of ground/earth fault current setting	Tripping time T_p ms
CI-A and CII-A	$\leq 0,9$	No trip
	1,1	$10 < T_p \leq 1\,000$
CI-B and CII-B	$\leq 0,75$	No trip
	1,25	$10 < T_p \leq 5\,000$

H.5.2 — Limits of operation of ground/earth fault relays type CII(A and B)

Subclause H.5.1 applies with the following addition:

A ground/earth fault relay type CII, when associated with a switching device, shall not initiate operation of the switching device, in the presence of a ground/earth fault current, when the fault current in any phase reaches or exceeds 95 % the set current level I_{IC} (see H.4) and shall operate to open the equipment when the fault current in any phase is 75 % or less of I_{IC} .

H.5.3 — Limits of operation of voltage imbalance relays

A voltage imbalance relay, when associated with a switching device, shall operate to open the switching device at any value of time but no longer than within 120 % of the time setting and shall operate to prevent the closing of the switching device when the voltage imbalance, defined as the ratio U_{imb} (1) between the maximum voltage deviation of any phase from average voltage U_{avg} and the average current I_{avg} , is above 1,2 times the voltage imbalance setting.

$$U_{imb} = \frac{\max_{i=1}^n |U_i - U_{avg}|}{U_{avg}} \quad (H.1)$$

where

$$U_{avg} = \frac{\sum_{i=1}^n U_i}{n}, \quad n \text{ is the number of phases and } U_i \text{ the r.m.s value of each phase.}$$

When the operating time is below 1 s, the tolerance shall be given by the manufacturer.

H.5.4 — Limits of operation of phase reversal relays

A phase reversal relay, when associated with a switching device, shall permit the closing of the equipment when the voltage sequence of phases on the line side of the starter is the same as the voltage sequence setting. After interchanging two phases, the phase reversal relay shall prevent the closing of the equipment.

H.5.5 — Limits of operation of current imbalance relays

A current imbalance relay, when associated with a switching device, shall operate to open the equipment within 80 % to 120 % of the time setting where the current imbalance, defined as the ratio (1) between the maximum current deviation of any phase from average current I_{avg} and the average current I_{avg} , is above 1,2 times the current imbalance setting, the general tripping requirements defined in 8.2.1.5.1.1 being maintained.

$$\text{Ratio} = \frac{\max_{i=1}^n |I_i - I_{\text{avg}}|}{I_{\text{avg}}} \quad (\text{H.2})$$

where

$$I_{\text{avg}} = \frac{\sum_{i=1}^n I_i}{n}, \quad n \text{ is the number of phases and } I_i \text{ the r.m.s value of each phase.}$$

When the operating time is below 1 s, the tolerance shall be given by the manufacturer.

H.5.6 Limits of operation of over-voltage relays

a) Operating voltage

An over-voltage relay, when associated with a switching device, shall operate to open the equipment and shall operate to prevent the closing of the equipment when the supply voltage is above the set value, if any, or above 110 % of the rated voltage of the relay for a defined duration.

b) Operating time

For a time-delay over-voltage relay, the time-lag shall be measured from the instant when the voltage reaches the operating value until the instant when the relay actuates the tripping device of the equipment.

H.5.7 Limits of operation of under-power relays

An under-power relay shall operate to open the switching device at any value of time but no longer than 120 % of the time setting where the load power is under 0,8 times the under-power setting.

H.6 Tests

H.6.1 Limits of operation of ground/earth fault relays type CI and CII (–A and –B)

The limits of operation shall be in accordance with H.5.1 and verified as follows.

For overload relays with an adjustable ground/earth fault current setting, the test shall be made at the minimum and at the maximum current settings. The test circuit shall be in accordance with Figure H.1 or with electronically controlled current supply for the generation of the fault current. The test shall be made at any convenient voltage and power factor.

The test circuit being calibrated at each of the values of the ground/earth fault operating current specified in the Table H.1, as applicable, and the switch S1 being in the closed position, the test current is suddenly established by closing switch S2.

For ground/earth fault relays type CII, the inhibit current shall be set to a value at least 30 % higher than the maximum ground/earth fault current setting.

H.6.2 Verification of inhibit function of ground/earth fault relays type CII (–A and –B)

For overload relays with an adjustable ground/earth fault current setting, the test shall be made at the lowest setting.

For overload relays with an adjustable inhibit current setting I_{ic} , the test shall be made at the minimum and at the maximum I_{ic} settings.

~~NOTE The inhibit current setting is to be set to a higher value than the minimum ground/earth fault current.~~

~~The impedance Z is adjusted so as to let a current flow in the circuit equal to:~~

~~a) 95 % the inhibit current I_{ic}~~

~~The switch S1 being in the closed position, the test current is established by closing switch S2.~~

~~The overload relay shall not initiate the opening of the switching device.~~

~~b) 75 % the inhibit current I_{ic}~~

~~The switch S1 being in the closed position, the test current is established by closing switch S2.~~

~~The overload relay shall initiate the opening of the switching device.~~

~~Each phase has to be tested separately.~~

~~H.6.3 — Current imbalance relays~~

~~The limits of operation shall be verified in accordance with H.5.5.~~

~~H.6.4 — Voltage imbalance relays~~

~~The limits of operation shall be verified in accordance with H.5.3.~~

~~H.6.5 — Phase reversal relays~~

~~The limits of operation shall be verified in accordance with H.5.4.~~

~~H.6.6 — Over-voltage relays~~

~~The limits of operation shall be verified in accordance with H.5.6.~~

~~H.6.7 — Under-power relays~~

~~The limits of operation shall be verified in accordance with H.5.7.~~

~~H.7 — Routine and sampling tests~~

~~Electronic overload relays with extended functions shall, in addition to tests of 9.3.6, be submitted to additional tests to verify the proper operation of their relevant additional functions, according to H.5.~~

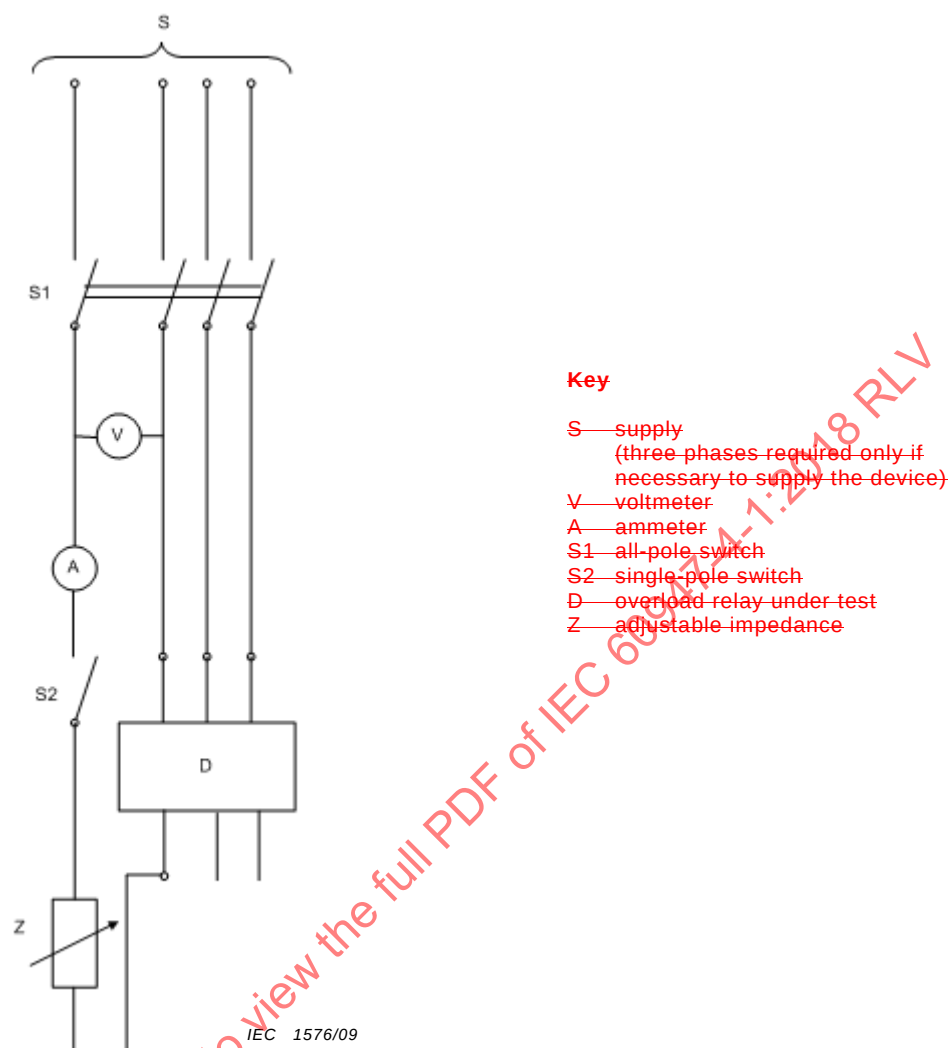


Figure H.1 — Test circuit for the verification of the operating characteristic of a ground/earth fault relay

H.1 General

Annex T of IEC 60947-1:2007:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with the following additions.

Load monitoring indicators for energy efficiency management embedded in electronic overload relays are defined in Annex O.

H.2 Terms and definitions

H.2.1

electronic overload relay with control functions

multipole electronic relay with motor control operations through its inputs and outputs

Note 1 to entry: Example of control functions: reversing control, two speed control, star-delta control, etc.

H.2.2**electronic overload relay with under-voltage restarting function**

electronic relay which operates when the voltage applied to the main circuit or control circuit is reduced below a predetermined value and automatically resets (with or without time delay) when the voltage is recovered

H.2.3**electronic overload relay with main circuit under-voltage restarting function**

electronic overload relay with under-voltage restarting function monitoring only the main circuit

H.2.4**electronic overload relay with control circuit under-voltage restarting function**

electronic overload relay with under-voltage restarting function monitoring only the control circuit

Note 1 to entry: The automatic restarting function can be de-activated.

H.3 Limits of operation of control functions**H.3.1 General**

The operation time sequences, the interactions with the inputs and outputs and the limits of operation shall be described in the manufacturer literature.

For motor restart functions, the ranges and tolerances of time and voltage dip detection and of the delay of restarting after voltage restoration shall be given in the manufacturer literature.

H.3.2 Limits of electronic overload relay with main circuit under-voltage restarting function

When under-voltage or loss of voltage occurs in the main circuit, the relay will operate. The following applies:

- a) if the voltage resumes within T1 (off-time for immediate reset), the overload relay shall control the starter circuit to immediately restore the running condition;
- b) if the voltage resumes between T1 and T2 (off-time for reset), the relay shall reset to the starting sequence;
- c) if the voltage resumes after T2, the relay shall not reset automatically.

T1 and T2 are adjustable, and the value of T2 is greater than T1.

The tolerance of the threshold voltage and of the time settings shall be specified by the manufacturer but no more than $\pm 10\%$. If the time setting value is lower than 1 s, the manufacturer shall state the tolerances.

H.4 Test of the control functions

The test of the control functions shall be verified according to H.3, and each control function should be verified at least 3 times.

For restart functions, the detection time for a voltage dip and the delay of restarting shall be verified according to H.3.

Annex I (informative)

AC-1 contactors for use with semiconductor controlled motor loads

Contactors are often used with semiconductor controllers, starters or drives. Contactors for such applications are not intended to make or break motor load currents at the stated system voltage.

The intended use is to carry motor currents either on the line or on the load side of such ~~controllers, and allow the controller to be removed from the line and/or load in the off condition~~ controller, and to provide a galvanic opening between the controller and the line and/or the load in the OFF-state of the semiconductor controller. A further use is to by-pass controllers, usually for the purpose of reducing thermal losses, in the up-to speed condition. In such applications the contactors should be so controlled and interlocked so as to prevent them being opened or closed when the load current is present.

When the above conditions are met, the contactors may be chosen according to category AC-1.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

Annex J

(Void)

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

Annex K (normative)

Procedure to determine data for electromechanical contactors used in functional safety applications

~~K.1 General~~

~~K.1.1 Introduction~~

~~Provision of these data is optional, at the discretion of the manufacturer.~~

~~K.1.2 Scope and object~~

~~This annex specifies procedures for the provision of specific data characterising the performance of electromechanical contactors in functional safety applications.~~

~~These data are required by functional safety standards including IEC 61508 series, IEC 62061, IEC 61511 series, IEC 61513, ISO 13849-1.~~

~~Specific data for functional safety applications are for example: failure rate per operation, useful life, confidence level and overall life time.~~

~~This annex addresses only the main function of an electromechanical contactor.~~

~~K.1.3 General requirements~~

~~The specific data for functional safety shall be obtained with this procedure.~~

~~The procedure is based on statistical analysis of test results in order to generate reliability data.~~

~~The confidence level related to failure rate calculation during the useful life of the device shall be 60 % unless otherwise specified by the manufacturer.~~

~~NOTE The parameters associated with the reliability data are chosen for being consistent with those of other products also used in functional safety applications.~~

~~The statistical data obtained according to this annex are valid only during the useful life of the contactor.~~

~~In this annex, to keep statistical consistency, the term "time" may refer to the number of operation cycles.~~

~~This annex does not consider replacement of parts of the contactors during test and application.~~

~~K.2 Terms, definitions and symbols~~

~~For the purposes of this annex, the following terms, definitions and symbols apply.~~

K.2.1 Terms and definitions

K.2.1.1

reliability

performance

ability of an item to perform a required function under given conditions for a given time interval

[IEV 191-02-06, modified]

K.2.1.2

useful life

under given conditions, the time interval beginning at a given instant of time, and ending when the failure rate becomes unacceptable

NOTE For contactors, the useful life is expressed in number of operations.

K.2.1.3

constant failure rate period

that period, if any, in the life of a non-repaired item during which the failure rate is approximately constant

[IEV 191-10-09]

K.2.1.4

overall lifetime

lifetime of the device which should not be exceeded in order to maintain the validity of the estimated failure rates due to random hardware failures

NOTE 1 Overall lifetime covers also periods of non-use e.g. storage. The overall lifetime is expressed in number of years

NOTE 2 It corresponds to T_1 according to IEC 62061 and to T_M according to ISO 13849-1.

K.2.1.5

censoring

termination of the test after either a certain number of failures or a certain time at which there are still items functioning

K.2.1.6

suspension

situation in which an item that either has not failed or has not failed in the manner under investigation, i.e. failed due to some other cause, is removed from test

K.2.1.7

no-make-break-current utilization

conditions in which the switching device makes and breaks without load

K.2.1.8

time to failure

operating time accumulated from the first use, or from restoration, until failure

NOTE For contactors, the time to failure is expressed in number of operations.

K.2.2 Symbols

n	number of samples tested
r	number of failures
t	number of operating cycles
η	Weibull characteristic life or scale parameter
β	Weibull shape parameter
ϵ	number of operations per hour
A_u	assessed failure rate (upper limit) at confidence level of 60 % expressed in per operation
A	failure rate expressed in per hour
A_D	dangerous failure rate expressed in per hour

K.3 Method based on durability test results**K.3.1 General method**

As the failures of such products are of a random nature, the method is based on results given by a continuous appropriate monitoring of the contactors under the appropriate durability test.

K.3.2 Test requirements

Mechanical durability shall be determined in accordance with B.2.1 to B.2.2.4. For the no-make-break-current utilisation the mechanical durability is applicable.

Electrical durability shall be determined in accordance with B.3.1 to B.3.2 using utilization category AC-3 unless otherwise stated by the manufacturer.

The test environment shall be in accordance with Clause 7.

Product modifications which do not impact the data listed in K.5 do not require retesting of the product.

K.3.3 Characterization of a failure mode

The occurrence of one or more of the failure modes listed in Table K.1 or the attainment of the specified number of operating cycles given by the manufacturer shall lead to the conclusion of the test for that device.

Table K.1 — Failure mode of contactors

Failure-modes	Characteristics for a normally open contactor
Failure to open	— current remaining after the coil is de-energised
Failure to close	— no current in one or more poles after the coil is energised
Short-circuit between poles	— insulation failure between poles
Short-circuit between pole and any adjacent part	— insulation failure with any adjacent part

K.3.4 — Weibull modelling

K.3.4.1 — Modelling method

The reliability data are obtained by modelling the test result data with the Weibull distribution according to IEC 61649.

The median rank regression (MRR) shall be used if the number of failures is equal or less than 20. If the number of failures is greater than 10, the maximum likelihood estimation (MLE) method can be used to get the point estimates of the distribution parameters β and η after checking the Kolmogorov-Smirnov goodness-of-fit test (H) with the Fisher distribution (F_γ) at $\gamma = 60\%$:

$$H \geq F_\gamma(2\lfloor(r-1)/2\rfloor, 2\lfloor r/2\rfloor)$$

where the symbol $\lfloor x \rfloor$ is used to denote the largest integer less than or equal to x .

NOTE 1 — IEC 61649 provides details and examples of calculation.

NOTE 2 — Small number of samples will increase the uncertainty of estimating the life parameters, which will result in a lower value of the lower limit of the failure rate per operation.

If a test is terminated at a specified time, T , before all items have failed, then the data are said to be time censored. An item on test that has not failed by the failure mode in question is a suspension. Normally, suspensions are included in the analysis by adjustment of the ranking. However, this annex provides a method for the estimation of Weibull parameters that is simplified by the omission of suspensions. Further discussion of censoring and suspension is covered in IEC 60300-3-5 and associated computations are covered by IEC 61649.

K.3.4.2 — Median rank regression

Median Rank Regression (MRR) is a method for estimating the parameters of the distribution using linear regression techniques with the variables being the median rank and operation cycle.

If a table of median ranks and a means to calculate median ranks using the Beta distribution is not available, Bernard's approximation, Equation (K.1), may be used where:

$$F_i = \frac{(i - 0,3)}{(N + 0,4)} \times 100 \% \quad (K.1)$$

where

N — is the sample size, and

~~i is the ranked position of the data item of interest.~~

NOTE—This equation is mostly used for $N \leq 30$; for $N > 30$ the correction of the cumulative frequency can be neglected: $F_i = (i/N) \times 100\%$.

Small sample size makes it difficult to gauge the goodness of fit. The coefficient of determination is the most commonly used for checking the Weibull distribution. This can be calculated using Equation (K.2):

$$r^2 = \frac{\left(\sum_{i=1}^n x_i y_i - \frac{\sum_{i=1}^n x_i \sum_{i=1}^n y_i}{n} \right)^2}{\left(\sum_{i=1}^n x_i^2 - n(\bar{x})^2 \right) \left(\sum_{i=1}^n y_i^2 - n(\bar{y})^2 \right)} \quad (\text{K.2})$$

where (x_i) and (y_i) , $i=[1..n]$ are the median ranks and the failure time respectively.

r^2 is the proportion of variation in the data that can be explained by the Weibull hypothesis. The closer this is to 1, the better the data are fitted to a Weibull distribution; the closer to 0 indicates a poor fit.

The following are the steps to plot data sets.

- First, rank the times in operation cycle from earliest to latest;
- Use Bernard's approximation (K.1) to calculate the median ranks;
- Plot the failure times (x) versus the median ranks $F_i(y)$ on 1 x 1 Weibull paper or log-log paper to derive x_{ln} and y_{ln} ;

- Calculate $\hat{\beta}$ by a straight regression function to get the equation for the line

$$y_{ln} = \hat{\beta} \cdot x_{ln} + b;$$

- Calculate $\hat{\eta} = e^{\left(\frac{b}{\hat{\beta}} \right)}$;

- Plot the regression line on the graph to verify the fit.

Normally for an electromechanical contactor, $\hat{\beta}$ is greater or equal to 1.

K.3.5 Useful life and upper limit of failure rate

K.3.5.1 Numerical method

Assuming a constant failure rate, the useful life is determined as the lower confidence level of the number of cycles by which 10 % of the device population will have failed ($B_{10|lower\ limit}$).

For 20 or fewer data points, with or without censoring times, the Weibull parameters $\hat{\beta}$ and $\hat{\eta}$ obtained with Median Rank Regression (MRR) in K.3.4.2 shall be used.

~~K.3.5.2 Point estimate of the fractile (10 %) of the time to failure~~

Compute $\hat{B}_{10}$ using Equation (K.3), the point estimate of B_{10} , the time by which 10 % of the population will have failed:

$$\hat{B}_{10} = \hat{\eta} \left[\ln \left(\frac{1}{0,9} \right) \right]^{1/\hat{\beta}} \quad (\text{K.3})$$

~~K.3.5.3 Useful life~~

Compute the lower (1 – y)100 % confidence level of B_{10} using Equations (K.4), (K.5), (K.6) and (K.7):

$$h_1 = \ln [-\ln(0,9)] \quad (\text{K.4})$$

$$\delta_1 = \frac{-A_6 x^2 - r h_1 + x \sqrt{(A_6^2 - A_4 A_5) x^2 + r A_4 + 2 r h_1 A_6 + r A_5 h_1^2}}{r - x^2 A_5} \quad (\text{K.5})$$

where:

$x = u_y$

is the y fractile of the normal distribution. Unless otherwise specified by the manufacturer, a 60 % lower confidence level shall be used (hence $y_{\square\square} = 0,4$ and $u_{y_{\square\square}} = 0,2533$).

A_4 , A_5 and A_6

are computed as follows, using the ratio $q = r/n$:

$A_4 = 0,49q - 0,134 + 0,622q^{-1}$;

$A_5 = 0,2445 (1,78 - q) (2,25 + q)$;

$A_6 = 0,029 - 1,083 \ln(1,325q)$.

$$Q_1 = e^{\left(-\frac{\delta_1 + h_1}{\hat{\beta}} \right)} \quad (\text{K.6})$$

$$B_{10|\text{lowerlimit}} = Q_1 \hat{B}_{10} \quad (\text{K.7})$$

This value of $B_{10|\text{lowerlimit}}$ is considered as the useful life.

~~K.3.5.4 Upper limit of failure rate~~

The upper limit of failure rate per operation is given by the following Equation (K.8):

$$\lambda_u = \frac{-\ln(0,9)}{B_{10|\text{lowerlimit}}} \approx \frac{1}{10 \times B_{10|\text{lowerlimit}}} \quad (\text{K.8})$$

~~K.3.5.5 Test conditions~~

Normal conditions are given in Clause 7.

Other conditions are subject to agreement between user and manufacturer. In such cases, the given values shall be obtained under these conditions.

K.3.6 Reliability data

The resulting reliability data are:

- Failure rate per operation: λ_u ;
- Useful life value = B_{10} (lower limit);

K.4 Method based on experience of returns from the field

This method can use the same statistical calculations but failure data collected from the field can be related to a very wide range of environments and utilization categories.

This method is under consideration.

K.5 Data to be provided

A set of reliability data of the product shall include a combination of the following relevant characteristics:

- failure rate per operation λ_u (see K.3.6);
- useful life (see K.3.6);
- confidence level if different from 60 %;
- no make-break-current or utilization category if different from AC-3 utilization;
- maximum switching rate;
- maximum operational voltage, if different from U_e ;
- maximum operational current for the specified utilization category, if different from I_e ;
- overall life time = 20 years unless otherwise specified by the manufacturer;
- environment conditions if different from the normal conditions.

NOTE 1— The failure rate λ , expressed in “per hour”, is given by the failure rate, expressed in “per operation”, λ_u , multiplied by the number of operations per hour c :

$$\lambda = \lambda_u \times c$$

NOTE 2— The overall life time of 20 years is generally used as a statistical reference for reliability analysis.

The hardware fault tolerance for one contactor is generally zero.

NOTE 3— In IEC 62061, a hardware fault tolerance of N means that $N+1$ faults could cause a loss of the function.

The Table K.2 gives the typical failure ratio used to calculate the rate of dangerous failure λ_D ; this dangerous failure rate is calculated with the following equation:

$$\lambda_D = \lambda \times F$$

Table K.2 — Typical failure ratios for normally open contactors

Failure modes	Typical failure ratios F associated with AC3 electrical durability test results for normally open contactors ^a	Typical failure ratios F associated with mechanical durability test results for normally open contactors ^a
Failure to open ^b	73 %	50 %
Failure to close	25 %	50 %
Short-circuit between poles	1 %	0 %
Short-circuit between poles and any adjacent part (e.g. auxiliary, earth plate, coil)	1 %	0 %
NOTE — If a contactor is used in such a way that a hazardous situation can be caused by a failure mode for which the failure ratio is above 40%, the system may need a diagnostic function and appropriate fault reaction function(s).		
^a The typical values result from tests performed on different contactors		
^b The diagnostic coverage of the subsystem incorporating a contactor with mirror contacts can be 99 % if an appropriate fault reaction function(s) is provided.		

K.6 — Example**K.6.1 — Test results**

A total of 15 contactors ($n = 15$) have been tested at the same time until all have failed. The 15 times to failure ($r = 15$) are ordered with i in the Table K.3.

Table K.3 — Example of 15 sorted ascending times to failure of contactors

i	Cycles t_i
1	1 000 000
2	1 250 000
3	1 400 000
4	1 550 000
5	1 650 000
6	1 750 000
7	1 850 000
8	1 950 000
9	2 050 000
10	2 150 000
11	2 280 000
12	2 420 000
13	2 500 000
14	2 700 000
15	2 800 000

K.6.2 — Weibull distribution and median rank regression

The calculation of median ranks gives the following results:

i	Cycles t_i	Median ranks	i	Cycles t_i	Median ranks
1	1 000 000	4,5 %	9	2 050 000	56,5 %
2	1 250 000	11,0 %	10	2 150 000	63,0 %
3	1 400 000	17,5 %	11	2 280 000	69,5 %
4	1 550 000	24,0 %	12	2 420 000	76,0 %
5	1 650 000	30,5 %	13	2 500 000	82,5 %
6	1 750 000	37,0 %	14	2 700 000	89,0 %
7	1 850 000	43,5 %	15	2 800 000	95,5 %
8	1 950 000	50,0 %			

The coefficient of determination $r^2 = 0,998$. This value, close to 1, indicates a good fit to a Weibull distribution.

The linear regression with two natural logarithm scales gives: $y = 3,908x - 57$.

From this equation, the distribution parameters can be derived: $\hat{\beta} = 3,908$ and $\hat{\eta} = 2\,149\,131$.

The fitting result obtained by MRR gives the assurance of a good Weibull distribution (see Figure K.1).

K.6.3 — Useful life and failure rate

To calculate the lower confidence level of the number of cycles by which 10 % of the contactors will have failed, this example follows the subclause K.3.5.

The point estimate $\hat{B}_{10} = 1\,212\,879$

The factor $Q_1 = 0,960\,1$ and $B_{10|lower\,limit} = 1\,164\,541$

Finally, the upper limit of the failure rate $\lambda_u = 9,05 \times 10^{-8}$

The result of this numerical method is illustrated by the Figure K.1.

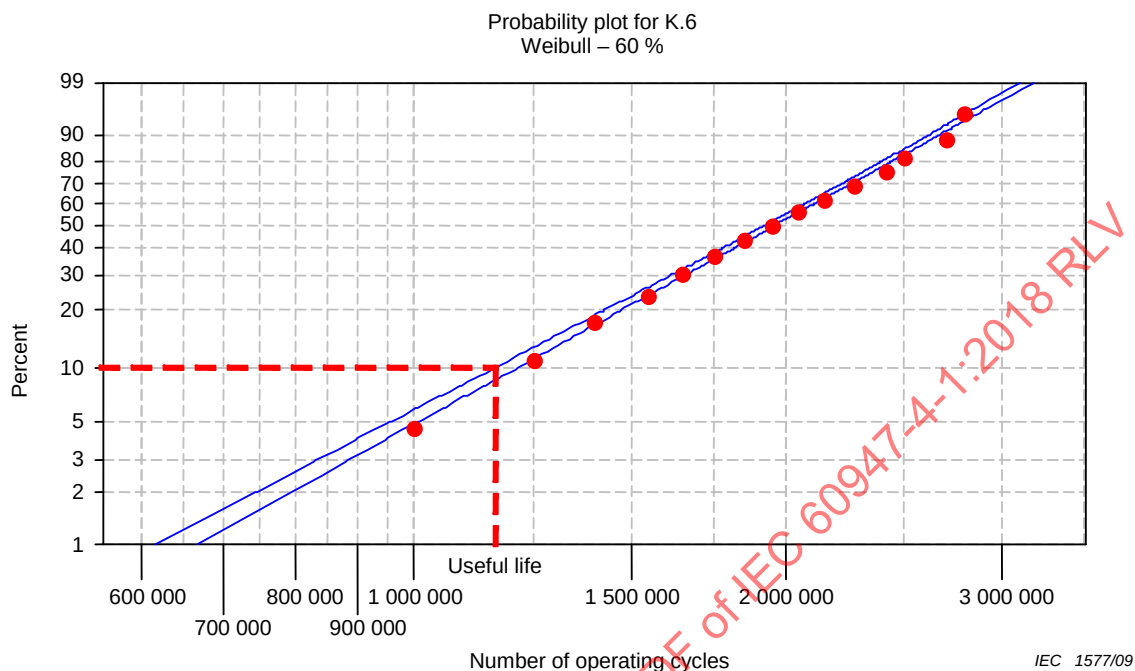


Figure K.1 — Plot of Weibull median rank regression

K.1 General

Annex K of IEC 60947-1:2007/AMD2:2014 applies with the following additions.

K.2 Test requirements

Mechanical durability shall be determined in accordance with B.2.2.1 to B.2.2.4. For the no-make-break-current utilisation, the mechanical durability is applicable.

Electrical durability shall be determined in accordance with B.3.1 to B.3.2 using utilization category AC-3, AC-3e unless otherwise stated by the manufacturer.

The test environment shall be in accordance with Clause 7.

K.3 Characterization of a failure mode

Table K.1 gives the typical failure modes of a contactor.

Table K.1 – Failure mode of contactors

Failure modes	Characteristics for a normally open contactor
Failure to open	– current remaining after the electromagnet is de-energised
Failure to close	– no current in one or more poles after the electromagnet is energised
Short-circuit between poles	– insulation failure between poles
Short-circuit between pole and any adjacent part	– insulation failure with any adjacent part

K.4 Failure ratios of a contactor

In addition to the data listed in K.5 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014, the typical failure ratios of a contactor are given by Table K.2.

The hardware fault tolerance for one contactor is generally zero.

NOTE In IEC 62061, a hardware fault tolerance of N means that N+1 faults can cause a loss of the function.

Table K.2 – Typical failure ratios for normally open contactors

Failure modes	Typical failure ratios <i>F</i> associated with AC-3 electrical durability test results for normally open contactors ^a	Typical failure ratios <i>F</i> associated with mechanical durability test results for normally open contactors ^a
Failure to open ^b	73 %	50 %
Failure to close	25 %	50 %
Short-circuit between poles	1 %	0 %
Short-circuit between poles and any adjacent part (e.g. auxiliary, earth plate, coil)	1 %	0 %
If a contactor is used in such a way that a hazardous situation can be caused by a failure mode for which the failure ratio is above 40 %, the system may need a diagnostic function and appropriate fault reaction function(s).		
^a The typical values result from tests performed on different contactors.		
^b The diagnostic coverage of the subsystem incorporating a contactor with mirror contacts can be 99 % if an appropriate fault reaction function(s) is provided.		

Annex L

(normative)

Assessment procedure for electromechanical overload protection used in safety applications and especially in explosive atmospheres

L.1 Application and object

L.1.1 Application

Provision of this assessment is optional, at the discretion of the manufacturer.

This electromechanical overload protection function is only a supplementary risk reduction measure within a motor driven system. In addition, thermal protection based on a thermal sensing element (see IEC 60947-8) may be applied.

L.1.2 Object

This annex specifies the procedure to achieve the minimum SIL 1-capability or equivalent performance level required for the use of the functional unit “electromechanical overload protection” in safety applications. The electromechanical overload protection is considered as a part of a complete safety function. For low demand application the main focus is to minimize the systematic failures which can be achieved by using a quality management system during the whole lifecycle.

The evaluation of the overall safety function at a system level is not addressed in this annex.

NOTE 1 In Europe, EN 50495 is applicable.

NOTE 2 A typical example is the overload protection of a motor which is located in an explosive atmosphere (Type of protection “e” according to IEC 60079-0).

NOTE 3 The quality system ISO/IEC 80079-34, applies.

L.2 Terms, definitions and symbols

For the purposes of this annex, the following terms, definitions and symbols apply.

L.2.1 Terms and definitions

L.2.1.1

safe state

state of the safety device which leads to a safe condition of the EUC

Note 1 to entry: In this annex, the safe state is the condition of the interruption of the motor load circuit.

L.2.1.2

hardware fault tolerance

HFT

ability of a safety device to continue to perform a required function in the presence of faults

L.2.1.3

SIL-capability

characteristic of functional units that comply with the requirements of IEC 61508-2 and IEC 61508-3 suitable for use in functions which are allocated a SIL 1, 2 or 3 respectively

[SOURCE: IEC 60079-29-3:2014, 3.15]

L.2.1.4**systematic failure**

failure, related in a deterministic way to a certain cause, which can only be eliminated by a modification of the design or of the manufacturing process, operational procedures, documentation or other relevant factors

Note 1 to entry: Corrective maintenance without modification will usually not eliminate the failure cause.

Note 2 to entry: A systematic failure can be induced by simulating the failure cause.

Note 3 to entry: Examples of causes of systematic failures include human error in:

- the safety requirements specification;
- the design, manufacture, installation, operation of the hardware.

[SOURCE: IEC 61508-4:2010, 3.6.6, modified – Third example of Note 3 and Note 4 deleted]

L.2.1.5**electromechanical overload protection**

protection of a rotating electrical machine in case of excessive temperatures resulting from certain conditions of overload by means of thermo mechanical detection that initiate the interruption of the motor load circuit

Note 1 to entry: Electromechanical overload protection is typically provided by thermal overload relays or motor protective switching devices (MPSD).

L.2.1.6**safety integrity level****SIL**

discrete level (one out of a possible four), corresponding to a range of safety integrity values, where safety integrity level 4 has the highest level of safety integrity and safety integrity level 1 has the lowest

[SOURCE: IEC 61508-4:2010, 3.5.8, modified – Notes to entry deleted]

L.2.1.7**risk priority number****RPN**

one of the methods of quantitative determination of criticality is the Risk Priority Number

[SOURCE: derived from IEC 60812:2006, 5.3.2]

L.2.2 Symbols and abbreviations

HFT	Hardware Fault Tolerance
EUC	Equipment under control
FMEA	Failure mode effect analysis
RPN	Risk priority number
MPSD	Motor protective switching device
SIL	Safety integrity level
FRU	Field replaceable unit
FTA	Fault tree analysis

L.3 Procedure

L.3.1 General

This procedure consists of assessing and mitigating the risk of each sub function failure of the electromechanical overload protection listed under L.3.2 The risk assessment shall identify the failure modes and the behaviour of each sub function as well as to define measures to minimize the risk.

For this procedure, any experience of use, accident, incident or malfunction history of the actual or similar design shall be considered.

The safety function of the electromechanical overload protection is composed of the following sub functions:

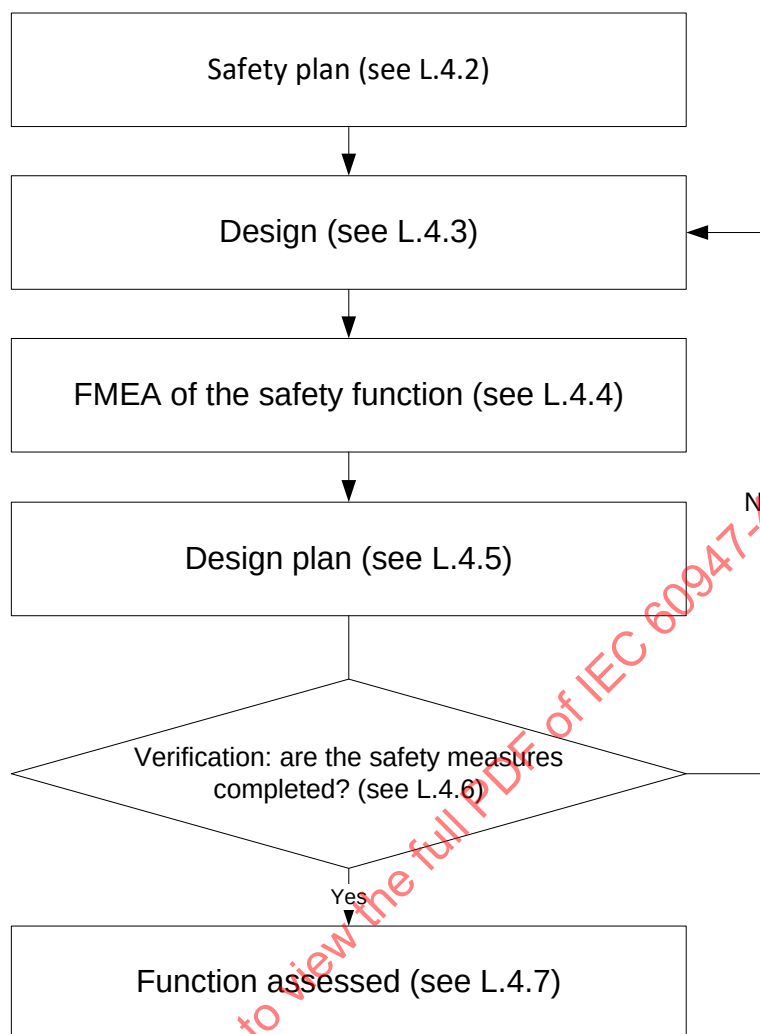
- continuously sensing of the motor current;
- comparing the sensing current to the setting based on the current of the motor and detecting thermal overload current;
- operating the release system in case of detection of thermal overload current in order to initiate the interruption of the motor load circuit.

The safety function shall be performed reliably under the specified environmental and operational conditions of the electromechanical overload protection.

NOTE The magnetic trip function of a MPSD is not part of this safety function.

L.3.2 Safety design process

The safety design process can be implemented as shown in Figure L.1. Each item shall be fulfilled. Iterations are usually necessary to reduce the risk of hazard as far as practicable.



IEC

Figure L.1 – Safety design process

L.4 Requirements

L.4.1 General

Existing designs that have been evaluated for use in safety applications are assumed to fulfil the basic safety principles of this annex and do not need a re-evaluation.

L.4.2 Safety plan

L.4.2.1 General

The safety plan related to technical performance includes the following items:

- the relevant activities specified in development and realisation lifecycle and modifications;
- the procedures and resources to record and maintain information relevant to the functional safety of thermal overload protection:
 - results of the hazard identification and risk assessment;
 - procedures necessary to achieve and maintain functional safety of thermal overload protection.
- the verification plan (L.4.2.2).

L.4.2.2 Verification plan

A verification plan includes the following items:

- selection of verification strategies and techniques;
- selection of verification activities;
- acceptance criteria;
- evaluation of verification results;
- functional assessment;
- actions to be taken in the event of failure to meet the acceptance criteria.

The verification plan should indicate whether devices with thermal overload protection are to be subjected to routine test, type test and/or sample test and which special tests are necessary.

L.4.3 Design

L.4.3.1 Characteristics

The characteristic of the electromechanical protection shall be described with the following:

- 5.7.3 b);
- minimum SIL-capability 1;
- useful lifetime;
- environmental conditions.

L.4.3.2 Functional design

The overload protection function should be decomposed in functional blocks. High level diagrams should be created, highlighting all the functions essential to the system. The detail of the decomposition will depend on the failure mode analysis itself (see Figure L.2 and Figure L.3).

As a minimum, the block diagram should contain the following:

- breakdown in blocks where a failure will result into the loss of the overload protection;
- all appropriately labelled inputs and outputs and identifications by which each block is consistently referenced.

L.4.4 Failure mode and effects analysis of the safety function

L.4.4.1 General

By principle electromechanical overload protection is realized by electromechanical reliable parts without wear effect. Therefore, the probabilistic determination methods are not suitable.

Systematic failures are avoided by use of proven in use principles and by the quality management system within the full life cycle. Thermal overload protection is a proven technology, if the device is developed in accordance with this document. However additional measures may be necessary depending on the results of the failure mode and effects analysis (FMEA).

Experience has shown that random failures are negligible. Therefore, no calculation is required, as the failure rate is low enough for fault exclusion.

The main potential risk of failures is due to electromechanical stress. The risk of failures for these simple constructions shall be reduced by using well known elements which are

designed based on engineering knowledge, field experience and incident reports. Therefore, the following analysis will be focussed on systematic failure.

L.4.4.2 Failure mode and effects analysis

The purpose of the FMEA is to analyse the design, by examining systematically all possible sources of failure of components and determining the effects of these failures on the behaviour and safety of the overload protection.

The analysis usually takes place through a meeting of engineers. Each component is analysed in turn to give a set of failure modes for the component, their causes and effects (locally and at overall system level), detection procedures and recommendations. If the recommendations are acted upon, they are documented as remedial action taken.

Any proven methods can be used (e.g. FMEA, or FTA, Markov graphs or Petri nets), however examples of Table L.1, Table L.2 and Table L.3 are appropriate for analysing an electromechanical overload protection function.

L.4.5 Design plan

The design plan shall provide measures to address incorrect specifications, implementations or modification issues.

L.4.6 Verification

During the safety design process (see L.3.2) and according to the verification plan (L.4.2.2), it shall be checked and recorded after each design phase that the requirements of the design phase have been fulfilled. Verification can be performed using assessment, analysis, examination, review and/or testing.

NOTE The verification can include for example:

- 1) review of the documentation of the respective phase,
- 2) design reviews,
- 3) functional tests.

L.4.7 Function assessed

When the verification (see L.4.6) leads to the conclusion that all specified requirements are met, the minimum SIL-capability level 1 is considered as achieved.

L.5 Documentation

L.5.1 Technical safety documentation

The documentation shall contain information as follows:

- test reports or analysis of fault behaviour leading to the loss of the safety function or reference to qualified example;
- risk assessment;
- documentation related to the decisions taken from the risk assessment.

L.5.2 Safety instructions

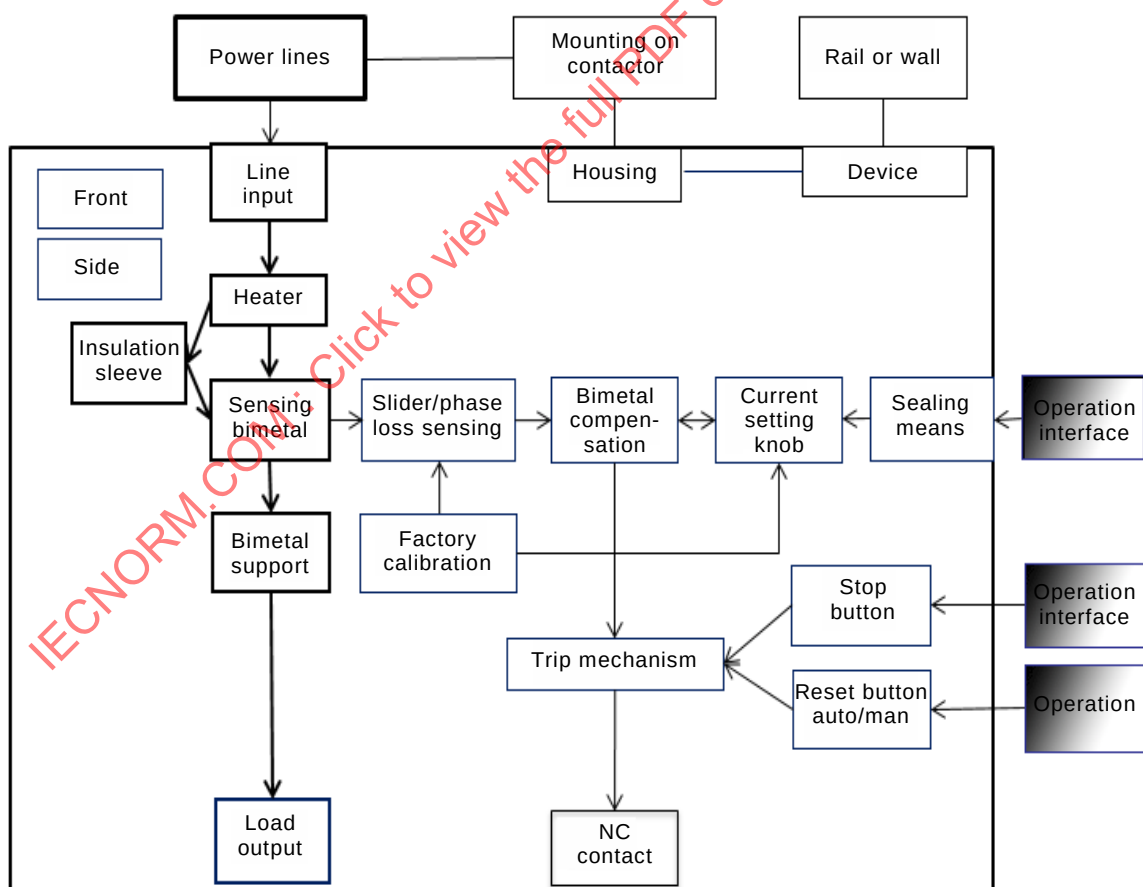
The manufacturer of an electromechanical overload protection shall provide safety instructions in a separate part of the instruction manual. The safety instructions shall contain information according to IEC 60079-14 and the necessary information for the design and the operation of the safety-related system, e.g.:

- description of the device and its safety function;
- safety relevant instructions for installation, calibration, putting into service and use including any required inspection procedure;
- nominal values for the interfaces (voltage, current, power, etc.);
- the associated type of protection, if relevant;
- safety level (e.g. SIL-capability) depending on the system architecture;
- hardware fault tolerance (HFT);
- safe state and power off condition;
- interface for the safety function;
- ambient and operational conditions;
- operation limits;
- useful lifetime.

L.6 Example

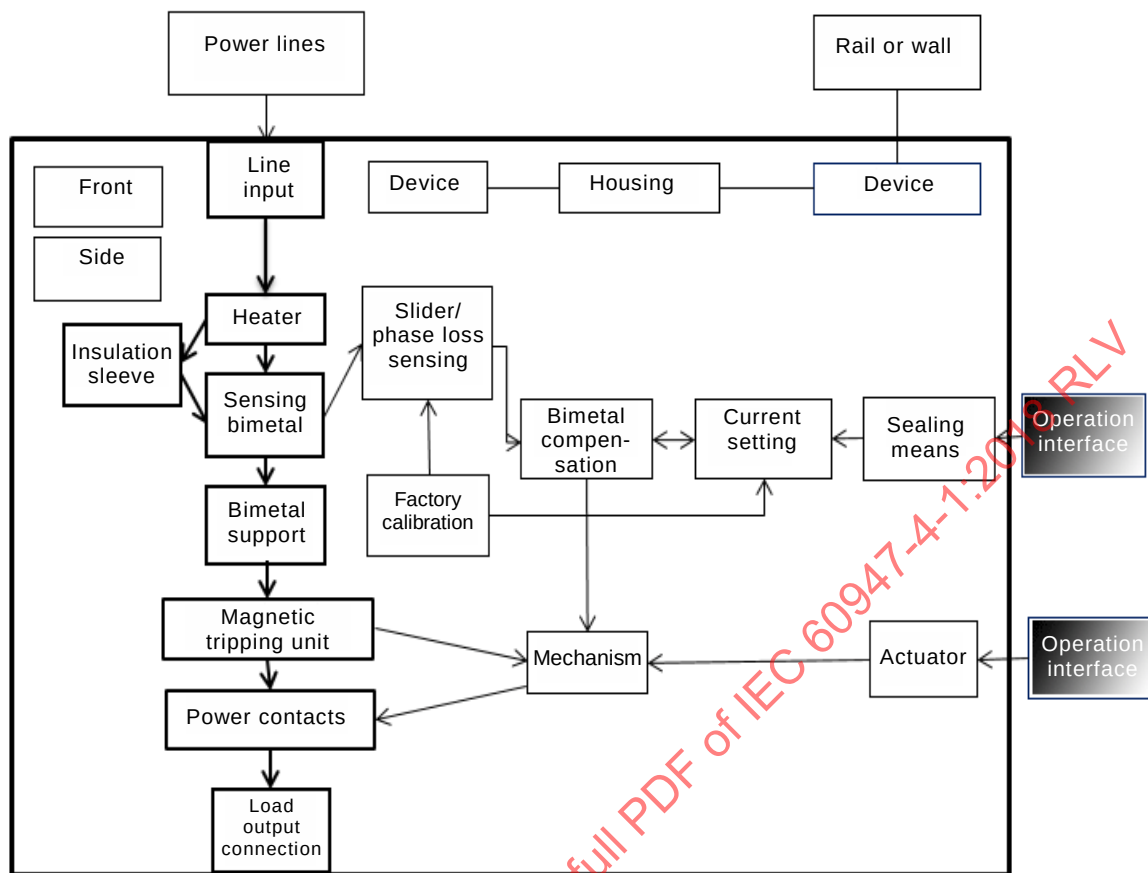
L.6.1 architecture description

Figure L.2 and Figure L.3 shows the examples of functional decomposition of a thermal overload relay and MPSD (respectively). See also Annex B to IEC 61508-6:2010.



IEC

Figure L.2 – Typical structure of a thermal overload relay



IEC

Figure L.3 – typical structure of MPD

L.6.2 FMEA

Table L.1 – Severity

Level	Criticality	Failure mode
1 to 4	Insignificant	Failure mode of a minor nature without any noticeable degradation in product performance
5 to 7	Moderately significant	Failure mode which could causes harm to one person or the system failure, normally reversible or repairable in short term
8 and 9	Significant	Failure mode which could causes harm to several persons or damage in wider environment, normally reversible or repairable in long term
10	Critical	Failure mode which could causes the death of people or injuries normally irreversible

Table L.2 – Occurrence

Ranking	Qualitative approach Likelihood of failure
1	Remote possibility of happening. Similar parts are used for similar functions in previous designs and failures have been non-existent.
2 and 3	Low failure rate with similar parts having similar functions in previous designs.
4 to 6	Moderate failure rate with similar parts having similar functions in previous designs.
7 and 8	Frequent failure rate with similar parts or devices having similar functions in previous designs.
9	High likelihood of failure where there is almost certainty of failure in major proportions.
10	Failure is virtually guaranteed to occur in major proportions.

Table L.3 – Detection levels

Ranking	Detection	Component fault detection	System fault detection
1	Almost certain	Design control will almost certainly detect a potential cause/mechanism and subsequent failure mode.	Proactive detection, Isolation to FRU (Field Replaceable Unit), Visual Indication or Report.
2	Very high	Very high chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Isolation to FRU, Visual Indication or Report.
3	High	High chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Isolation for FRU, Standard Test Equipment.
4	Moderately high	Moderately high chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Isolation to FRU, Specialized Test Equipment.
5	Moderate	Moderate chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Isolation, but to Non-FRU, Visual Indication or Report.
6	Low	Low chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Isolation, but to Non-FRU, Standard Test Equipment.
7	Very low	Very low chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Isolation, but to Non-FRU, Specialized Test Equipment.
8	Remote	Remote chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Undetectable, No Isolation or Incorrect Isolation.
9	Very remote	Very remote chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Undetectable, not applicable.
10	Absolute uncertainty	Design control will not or cannot detect a potential cause/mechanism and subsequent failure mode.	Hazardous action, not applicable.

Table L.4 shows an example on how to take the decision of further action depending on the RPN.

Table L.4 – Conclusion

RPN	Initial	R1	R2	Final	Action
1 to 40	52	51	0	0	No action
41 to 60	2	0	0	0	Action recommended to reduce number
61 to 1000	1	0	0	0	Not accepted, action mandatory to reduce number

Table L.5 shows the example of an FMEA for thermal overload relay.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

[illegible]

I T E M	PART DESCRIPTION	POTENTIAL FAILURE MODE	POTENTIAL EFFECTS of FAILURE related to the safety function	S	POTENTIAL CAUSES OF FAILURES	O	EXISTING CONDITIONS				RECOMMENDED ACTIONS	STATUS/ ACTION TAKEN	RESULTING 1				RESPONSIBLE PARTY	RESULTING 2				FINAL				RESPONSIBLE PARTY																																																																																																																																																																																																																																																																									
							D E T c	C o m p e n s a t i o n a g a i n s t f a i l u r e	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e			S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e		S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e		S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y	D e t e r m i n a t i o n	R e s o u r c e s	P r o v i s i o n a g a i n s t f a i l u r e	S e v e r i t y

I T E M	PART DESCRIPTION	POTENTIAL FAILURE MODE	POTENTIAL EFFECTS of FAILURE related to the safety function	S	POTENTIAL CAUSES OF FAILURES	O	EXISTING CONDITIONS				RECOMMENDED ACTIONS	STATUS/ ACTION TAKEN	RESULTING 1				RESULTING 2				RESPONSIBLE				FINAL				RESPONSIBLE PARTY
							D	R	P	N			S	O	D	R	P	N	S	O	D	R	P	N	S	O	D	R	
				V	a	b	Compensating provision against failure	5	20																				
48				1	pollution	4																							
49				1	contact damaged	1			1																				
50				1	contact bridge damaged	3			5	15																			
Housing																													
51	housing	breakdown of insulation	Short-circuit between the phases or between phase and aux. Contacts	5	improper molded or broken	1	routine test, type test	1	5																				
52				5	material long term degradation	3	type test (RTI Check)	5	75	proven in use	done																		
53				5	transportation damage	3	suitable design of packaging and drop test	1	15																				
54		mechanical failure	early, no or late tripping	5	loss of material performance	1		5	25																				
a	SEV: Severity Level (see Table L.1)																												
b	OCC: Occurrence Ranking (see Table L.2)																												
c	DET: Detection Levels Ranking (see Table L.3)																												
d	RPN is calculated by multiplying SEV x OCC x DET																												

Annex M (normative)

DC contactors for use in photovoltaic (PV) applications

M.1 Application

PV applications have particular characteristics and require equipment with specific performance. This annex gives the relevant performance requirements for these applications.

NOTE The abbreviation “PV” (photovoltaic) is used in this annex.

M.2 Object

This annex applies to direct current contactors, rated up to 1 500 V DC, intended for use with photovoltaic (PV) systems as defined by IEC 60364-7-712 and hereafter referred to as “PV contactor”.

A contactor for PV utilization is intended for providing galvanic opening of the circuit to be used between the PV module(s) and a semiconductor switching device. The purpose is to provide galvanic separation. Consequently, in normal operational condition, the contactor is carrying full current but making and breaking with low current (e.g. leakage current). However, in abnormal operational condition, the contactor shall be able to make and break full load current.

Contactors used in PV systems are subjected to electrical, environmental and operational conditions which differ from the general conditions taken into account in the body of present standard. The requirements have thus been adapted to reflect these conditions of use.

The object of this annex is to state:

- the requirements for contactors to be used with semiconductor controller on the direct current side of PV applications;
- the tests to verify that the product performance is consistent with the PV application and the expected life in PV environmental condition.

M.3 Terms and definitions

For the purposes of this annex, the following definition applies.

M.3.1 critical load current

I_{crit}
value of breaking current, within the range of service conditions, at which the arcing time is significantly extended

Note 1 to entry: This phenomenon, crucial for PV applications, is due to the low magnetic field coming from the arc current, creating a slow moving arc.

[SOURCE: IEC 60947-1:2007, 2.5.16, modified – Addition of Note 1 to entry]

M.3.2 rated conventional switching current

I_{scl}

rated current assigned to a contactor for switching the current controlled to a low level by a semiconductor, taking into the account the rated operational voltage, the rated frequency and the rated duty

Note 1 to entry: This current is typically lower than I_e .

M.4 Classification

Clause 4 applies.

M.5 Characteristics

M.5.1 General

Clause 5 applies with the following additions.

M.5.2 Rated impulse withstand voltage

The rated impulse voltage (U_{imp}) of PV contactor shall comply with Table M.1.

Table M.1 – Rated impulse voltage levels for PV contactors

Maximum value of rated operational voltage (V)	Value of rated impulse voltage (V)
100	800
150	1 500
300	2 500
600	4 000
1 000	6 000
1 500	8 000
NOTE These values are based on requirements in IEC 60364-7-712 for overvoltage category II.	

M.5.3 Utilization category

The utilization categories define the intended application and are given in Table M.2.

Each utilization category is characterized by the values of the currents and voltages, expressed as multiples of the rated operational current and rated operational voltage, as well as the time constant of the circuit. The conditions for making and breaking given in Table M.4 correspond to the application listed in Table M.2.

Table M.2 – Utilization categories

Utilization category	Typical applications
DC-PV3	Carrying full current and switching ON and OFF PV circuit(s) at low current.
DC-PV4	Switching ON and OFF circuits where significant over-current can occur, where several circuit branches are connected in parallel and to the same semiconductor switching device.

M.6 Product information

Subclause 6.2 applies with the following additions:

A contactor rated for use not only on PV installations shall have the PV ratings clearly separated from the other ratings.

A PV contactor shall be marked “IEC 60947-4-1 Annex M”. The rated conventional switching current I_{scI} shall be marked on the contactor.

A PV contactor shall have the following information marked under the conditions of 6.2):

- method and diagram of series connection of poles as necessary for each rating;
- operational characteristics according to M.7.2;
- direction of current, if the device is unidirectional.

The following data shall be made available in the manufacturer's published information:

- appropriate connection to the PV generator and load, if applicable;
- suitability for indoor or outdoor use.

M.7 Normal service, mounting and transport conditions

M.7.1 General

Clause 7 applies, with exception of 6.1.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 which is replaced by the following.

M.7.2 Ambient air temperature

The equipment shall be able to operate in an ambient air temperature given in Table M.3 according to the rating table of thermal current provided by the manufacturer.

Table M.3 – Ambient air temperature conditions

Environmental class	Maximum ambient temperature without de-rating	Minimum ambient temperature	Comment
Unenclosed	+40 °C	–5 °C	Guidance on de-rating for higher ambient air temperature up to +70 °C may be provided. In addition, guidance on operation at temperature lower than -5 °C may also be given.
Enclosed – Outdoor	+40 °C (without solar effects)	–25 °C	Rating apply when the enclosed equipment is subject to solar radiation of 1,2 kW/m ² and the maximum ambient temperature. Guidance may be provided on de-rating of enclosed equipment to be installed in locations with a higher maximum ambient temperature and/or lower minimum ambient temperature.

Ambient air temperature is that existing in the vicinity of the equipment if supplied without an enclosure, or in the vicinity of the enclosure if supplied with an enclosure.

M.7.3 Altitude

Item q) of 6.1.2 applies.

Altitude up to 4 000 m is under consideration.

M.8 Constructional and performance requirements

M.8.1 Constructional requirements

Subclause 8.1 applies with the following modifications:

The minimum rated impulse voltage shall be in accordance with Table M.1.

M.8.2 Performance requirements

M.8.2.1 General

Subclause 8.2 applies with the following modifications.

The minimum rated impulse voltage shall be in accordance with Table M.1.

M.8.2.2 Making and breaking capacities

Contactors or starters shall be capable of making and breaking currents without failure under the conditions stated in Table M.4 for the required utilization categories.

**Table M.4 – Verification of rated making and breaking capacities –
Conditions for making and breaking corresponding to the DC-PV category**

Utilization categories	I_c/I_e	U/U_e	L/R ms	On-time ^b s	Off-time s	Number of operating cycles ^a
DC-PV3	1,5	1,05	1	0,05	^c	50
DC-PV4	4	1,05	1	0,05	^c	50
^a If polarity not marked on the device, 25 operating cycles with one polarity and 25 operating cycles with reverse polarity						
^b The time may be less than 0,05 s, provided that contacts are allowed to become properly seated before reopening.						
^c Maximum off-time given in Table 8 which can be reduced in agreement with the manufacturer.						

M.8.2.3 Conventional operational performance

Subclause 7.2.4.2 of IEC 60947-1:2007 applies with the following addition.

Contactors or starters shall be capable of making and breaking currents without failure under the conventional conditions stated in Table M.5 for the required utilization categories.

Table M.5 – Conventional operational performance – Making and breaking condition corresponding to the DC-PV category

Utilization categories	I_c/I_{sc1} ^a	U/U_e	L/R ms	On-time ^c s	Off-time s	Number of operating cycles ^b
DC-PV3	1	1,05	1	0,05	^d	6 000
DC-PV4	1	1,05	1	0,05	^d	6 000
^a I_{sc1} shall be defined by the manufacturer. ^b If the polarity not marked on the device, 3 000 operating cycles with one polarity and 3 000 operating cycles with reverse polarity ^c The time may be less than 0,05 s, provided that contacts are allowed to become properly seated before reopening. ^d Maximum off-time given in Table 8 which can be reduced in agreement with the manufacturer.						

M.8.2.4 Critical load current performance

The main circuits of an equipment shall be capable of making and breaking its critical load current according to M.9.7.

M.8.3 Electromagnetic compatibility (EMC)

Subclause 8.3 applies.

M.9 Tests

M.9.1 General

Clause 9 applies with the following modification of the type tests and their sequences.

Each test sequence is made on a new sample.

NOTE With the agreement of the manufacturer, more than one test sequence or all test sequences can be conducted on one sample. However, the tests are conducted in the sequence given for each sample.

For all tests, the connection of poles of the PV contactor shall be as in accordance with the manufacturer installation instructions.

M.9.2 Type tests

Type tests shall be performed according to the sequences of Table M.6.

Table M.6 – Overall scheme of test sequences

Sequences	Test
Making and breaking capacities and conventional operational performance (see M.9.3)	Verification of rated making and breaking capacities. Verification of conventional operational performance Behaviour of the contactor and its condition
Thermal cycling test (see M.9.4)	Thermal cycling test Mechanical operation Temperature-rise verification Verification of operation and operating limits Dielectric test according to M.9.6
Climatic test (see M.9.5)	Climatic test
Critical load current test (see M.9.7)	Critical load current test Behaviour of the contactor and its condition
Mechanical properties (see M.9.8) and Degree of protection of enclosed contactors (see M.9.9)	Mechanical properties Verification of degrees of protection of enclosed contactors
EMC (see M.9.10)	EMC test
Clearance and creepage distance (see M.9.11)	Measurement of creepage and clearance distances

M.9.3 Making and breaking capacities and conventional operational performance

The test sequence 2 of 9.3.1, the requirements of Subclauses M.8.2.2 and M.8.2.3 apply. The behaviour of the contactor during, and its condition after the conventional operational performance tests shall be verified according to 9.3.3.6.6.

M.9.4 Thermal cycling test

PV contactors shall be subjected to temperature cycling according to IEC 60068-2-14:2009, test Nb, consisting of 50 cycles, each cycle consisting of 1 h at – 40 °C followed by 1 h at + 85 °C. Temperature change rate shall be 1 K/min. At the conclusion of the 50 cycles, the devices shall be returned to room temperature of 25 ± 5 °C for a minimum of 3 h.

The device shall then be subjected to:

- a visual inspection to confirm that there is no distortion or damage to parts that will affect normal operation and protection;
- one open and close operation to confirm normal mechanical operation;
- test sequence 1 as in 9.3.1.

M.9.5 Climatic test

PV contactors shall be subjected to the climatic tests of Annex Q, category B of IEC 60947-1:2007, IEC 60947-1/AMD1:2010, IEC 60947-1/AMD2:2014, environment subject to temperature and humidity, except that the dry heat test and the low temperature test are not required, as they are deemed to be covered by the thermal cycling test of M.9.3.

Where Table Q.1 of IEC 60947-1/AMD2:2014 requires the verification of operational performance capability, this shall be made by performing the test of 9.3.6.2.

M.9.6 Dielectric test

Subclause 9.3.3.4 applies with the following modifications:

Test voltage for verification of impulse withstand voltage shall use Table M.1 with altitude correction according to Table 12 of IEC 60947-1:2007.

M.9.7 Critical load current test

M.9.7.1 Test circuit

Subclause 8.3.3.5.2 of IEC 60947-1:2007 applies with the following addition.

The time constant of the test circuit shall be 1 ms.

M.9.7.2 Determination of critical load current

The test shall be made at the maximum operational direct current voltage (U_e max) assigned by the manufacturer to the contactor.

At the discretion of the manufacturer, a higher value of time constant may be used. The same value of time constant should be used for all tests carried out to determine the critical load current. In this case, it should be stated in the test report.

The PV contactor shall be opened 5 times on to each of the test currents. Start at 4 A, and go up to I_e in steps of two times the previous current until a maximum arcing time is determined. If the extinction time does not show a peak with shorter times each side, within the range of test currents, there is no critical load current. If a maximum in arcing time is shown, this is at the critical load current (see Figure M.1). Test currents shall be within the nominal value ± 10 %. At the manufacturer's discretion, the test at each value of current may be carried out on a new sample.

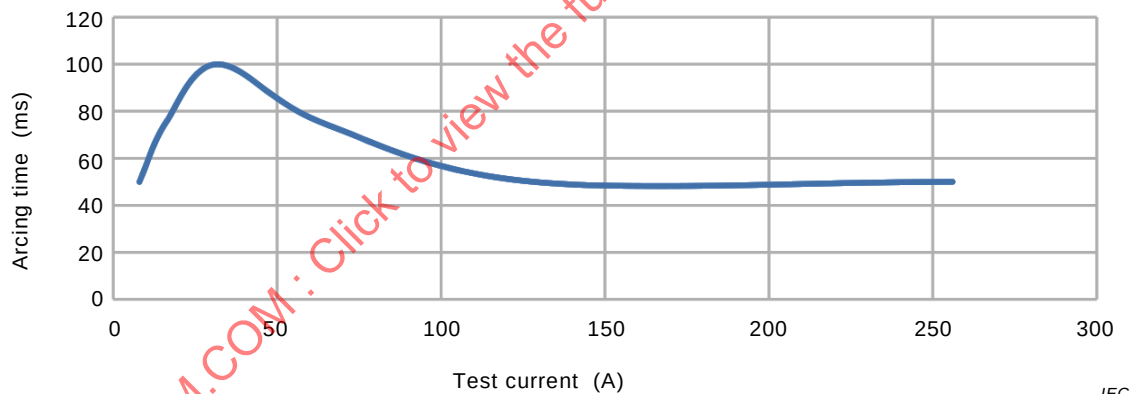


Figure M.1 – Critical current

During each cycle, the PV contactor shall remain closed for a time sufficient to ensure that the full current is established, but not exceeding 2 s. The number of operation cycles per hour shall be in accordance with Table M.7.

Table M.7 – Number of operating cycles corresponding to the critical load current

Category	Rating of the product A	Number of operating cycles per hours
DC-PV3 and DC-PV4	$I_e \leq 315$	120
	$315 < I_e \leq 630$	60
	$630 < I_e \leq 2\,500$	20
	$I_e < 2\,500$	10

If the direction of current flow is specified by the manufacturer, the test shall be made with the current flowing in the specified direction, as indicated by the polarity and line/load marking; if not, 5 operations shall be made in the forward direction, and 5 in the reverse direction.

M.9.7.3 Critical load current

The arcing time during the test shall be recorded and shall not exceed 1 000 ms.

When all operations are carried out with the current flow in the same direction, for each value of test current the average arcing time is calculated for each direction.

I_{crit} is the current corresponding to the maximum average arcing time. If no critical load current is identified below the rated operational current, the critical load current performance test need not be carried out.

M.9.7.4 Critical load current performance

The test requirements of 9.3.3.6 applies with the following modifications.

The test may be carried out with the same sample as in M.9.7.2. The test supply shall be connected in accordance with the generator – load and polarity markings where applicable. For contactors capable of current flow in both directions, the supply shall be connected so as to provide the longest arc duration at the critical load current, as determined in M.9.7.2 and Table M.8.

Table M.8 – Critical load current performance

Utilization categories	I	U/U_e	L/R ms	On-time s	Off-time s	Number of operating cycles
DC-PV3	I_{crit}	1,05	1	0,05	^a	100
DC-PV4	I_{crit}	1,05	1	0,05	^a	100
^a See Table M.7.						

The behaviour of the contactor during, and its condition after, the critical load current performance tests shall be verified according to 9.3.3.6.6.

M.9.8 Mechanical properties

The verification of mechanical properties of terminals shall be performed according to 8.2.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, and IEC 60947-1:2007/AMD2:2014, and 9.2.2).

M.9.9 Degree of protection of enclosed contactors

The verification of the degrees of protection of enclosed contactors and starters shall be performed according to Annex C of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010.

M.9.10 EMC

Electromagnetic compatibility shall be verified in accordance with 9.4.

M.9.11 Clearance and creepage distances

Clearance and creepage distances shall be measured to confirm compliance with 8.1.4 (see Annex G of IEC 60947-1:2007 for guidance on measurement of clearance and creepage distances).

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

Annex N

(normative)

Additional requirements and tests for equipment with protective separation

N.1 General

The purpose of this annex is to provide additional requirements to Annex N of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014.

N.2 Definitions

For the purposes of this document, the terms and definitions of Clause N.2 of IEC 60947-1:2007, as well as the following terms and definitions applies.

N.2.1

touch current

electric current passing through a human body or through an animal body when it touches one or more accessible parts of an electrical installation or electrical equipment

[SOURCE: IEC 60050-826:2004, 826-11-12]

N.3 Requirements

N.3.1 Test method for implementing protective impedance

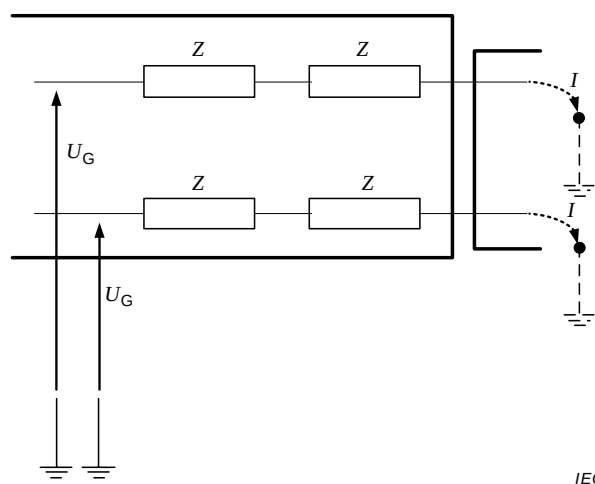
Protective impedance shall be arranged so that under both normal and single fault conditions, according respectively to 4.2 and 4.3 of IEC 61140:2016, the touch current and the discharge energy available shall be limited.

The protective impedances shall be designed and tested to withstand the impulse voltages and temporary overvoltages for the circuits to which they are connected.

Compliance with the requirement for the limitation of touch current is checked by test of N.3.2.

Compliance with a limited value of 0,5 mJ for the discharge energy shall be checked by performing calculations and/or measurements to determine the voltage and capacitance.

Figure N.1 shows examples of the method used to implement protective impedance.

**Key**

- Z impedance
 U_G hazardous voltage, earthed or unearthed
 I touch current

NOTE 1 To provide protection in single-fault conditions, use the following equation $I = \frac{U_G}{Z}$

NOTE 2 This figure is reproduced from Figure A.2 of IEC 62477-1:2012.

Figure N.1 – Protection by means of protective impedance

N.3.2 Touch current measurement

The equipment under test shall be set up in an insulated state without any connection to the earth and shall be operated at rated voltage. Under these conditions, the touch current shall be measured between the touchable parts and the earth according to the test circuit of Figure N.2.

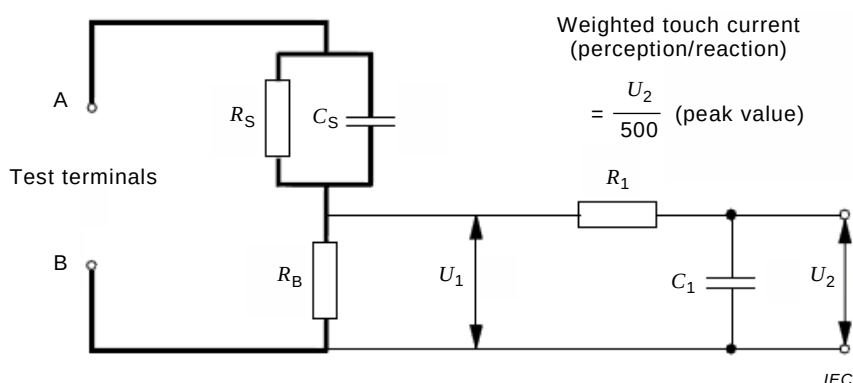
For an equipment to be connected to an earthed neutral system, the neutral of the mains of the test site shall be directly connected to earth.

For an equipment to be connected to an earthed neutral system or impedance system, the neutral of the mains of the test circuit shall be directly connected to earth.

The following maximum values of touch current (alternating current values for frequencies up to 100 Hz) are permitted:

- a steady-state current flowing between simultaneously accessible conductive parts not exceeding 0,5 mA AC or DC under normal operating conditions;
- values not exceeding 3,5 mA AC or 10 mA DC under single fault conditions.

As shown in Figure N.2, the voltage U_2 is measured and the current is calculated by dividing the measured voltage U_2 by 500.



Voltmeter or oscilloscope (RMS or peak reading)

input resistance: $> 1 \text{ M}\Omega$

input capacitance: $< 200 \text{ pF}$

frequency range: 15 Hz up to 1 MHz (appropriate for the highest frequency of interest)

Key

R_S 1 500 Ω

R_B 500 Ω

R_1 10 k Ω

C_S 0,22 μF

C_1 0,022 μF

NOTE The measuring test circuit of this figure is reproduced from Figure 4 of IEC 60990:2016.

Figure N.2 – Measuring instrument

Electrical measuring instruments shall have adequate bandwidth to provide accurate readings, taking into account all components (alternating current, direct current mains supply frequency, high frequency and harmonic content) of the parameter being measured. If the RMS value is measured, care shall be taken that measuring instruments give true RMS readings of non-sinusoidal waveforms as well as sinusoidal waveforms.

Annex O (informative)

Load monitoring indicators

O.1 General

The implementation of an energy efficiency (EE) approach for AC motor-driven systems (e.g. pumps, compressors) or asset management activities requires load monitoring indicators based on electrical supply quantities.

An example implementation of such load monitoring indicators is to detect sudden changes or drifts in active power or phase current.

O.2 Indicators list

Table O.1 shows the minimum requirements for a proposed set of indicators recommended for EE analysis or asset management.

Trueness and repeatability as stated in Table O.1 apply to the complete monitoring chain, including external sensors if any.

The selection of the indicators within Table O.1 is at the discretion of the manufacturer.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

Table O.1 – AC monitoring indicators list

Indicator name	Definition	Units ^a	Symbol	Minimum range	Trueness ^c	Repeatability ^d
phase <i>x</i> current	the value of the current flowing in phase <i>x</i> of an electrical distribution system	A	I_x	$0,4 \times I_e - 0,7 \times I_e$	± 25 %	2 %
				$0,7 \times I_e - 1,1 \times I_e$	± 10 %	2 %
phase to phase voltage	the voltage between phases	V	U_{pg}	$0,9 \times U_e - 1,1 \times U_e$	± 5 %	2 %
phase to neutral voltage	the voltage between a phase in a polyphase system and the neutral point	V	V_{pN}	$0,9 \times U_e / \sqrt{3} - 1,1 \times U_e / \sqrt{3}$	± 5 %	2 %
total active power	the sum of the active powers in all phases of an electrical distribution system	W	P	PF ≥ 0,9	± 20 %	3 %
total apparent power	the sum of the apparent powers in all phases of an electrical distribution system	VA	S	-	± 25 %	3 %
current imbalance ^b	the ratio between the maximum current deviation of any phase from average current and the average current	%	I_{imb}	70 % to 130 %	± 10 points ^e	± 2 points ^e
power factor	under periodic conditions, ratio of the absolute value of the active power P to the apparent power S : $\lambda = \frac{ P }{S}$	No unit	PF (λ in IEC 60050 series)	0,5 – 1	± 0,3 ^f	± 0,04 ^f
NOTE 1 Unless otherwise stated by manufacturer, ambient air temperature effects are assumed to be compensated. When not, the reference ambient air temperature is specified by the manufacturer.						
NOTE 2 Performances could be referred according to PROFIEnergy classes X to Y, Accuracy domain 2, which combines trueness and repeatability into "accuracy".						
^a Absolute or per unit (ratio to a reference value, e.g. FLA for current). ^b See Annex T of IEC 60947-1:2007/AMD2:2014. ^c Trueness is characterized by the systematic error of the measured value (see 3.3.3 of ISO 3534-2:2006). ^d Repeatability represents the random part of the measurement error. It is a variation parameter characterizing the dispersion of the measurements, taken under the same conditions. This value should be declared together with a time-window or number of measurements (see O.3). ^e "point" is an absolute deviation from a measurement expressed in percent. For example, if the measured imbalance value is 8 %, then the associated repeatability criterion is to measure values between 6 % and 10 %. ^f PF has no unit. Therefore, limit is expressed as an absolute deviation from the measured value.						

The refresh interval is a global requirement, and should not be more than 1 min. It can be defined individually for each indicator. The minimum bandwidth of the measurement should be up to the 7th harmonic of the fundamental frequency.

The values given for trueness and repeatability in Table O.1 are given for the minimum range, and cannot be used to characterize the accuracy of the motor overload protection.

O.3 Uncertainty

Uncertainty of measurement is the combination of systematic error and random error, both referring to the conventional true value which is obtained with a measuring instrument typically 10 times more accurate than the device under test.

The systematic error quantifies the trueness of the measurement, i.e. how close the average measurement results are to the true value. In given conditions, the systematic error results from factors having a fixed impact on the measurement results, such as the imperfect calibration or correction of the measurement chain resulting from temperature effects.

The random error is resulting from factors having an unpredictable impact on the measurement results such as noise in the different parts of the measurement chain, imperfections in the measurement algorithms, crosstalk and other electromagnetic compatibility issues. The random error quantifies the precision or repeatability of the measurement, i.e. how close repeated measurement results are to each other. The most common statistical indicator used is the standard deviation σ . It can be estimated from a series of N measurement results in the same conditions as:

$$\sigma = \sqrt{\frac{\sum_{i=1}^N (x_i - \bar{x})^2}{N-1}} \quad \text{with} \quad \bar{x} = \frac{1}{N} \times \sum_{i=1}^N x_i$$

For load monitoring applications and especially the evaluation of energy efficiency, the systematic error of individual measurements is not relevant because the goal is to detect trends or check the impact of process changes. For example, one might want to check the impact of Energy Efficiency actions or process changes on the average power consumption as shown in Figure O.1.

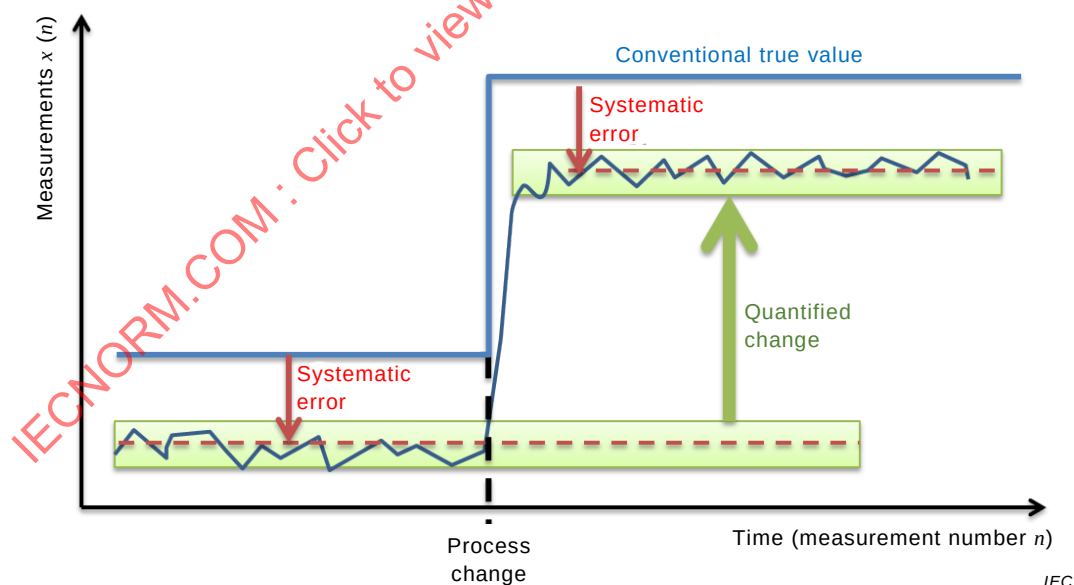


Figure O.1 – Example of quantification of a process change

The systematic error does not matter so much for change detection: as soon as the impact is significantly greater than the random error, it easily shows up on the measurement results and the change will be well quantified. In borderline cases, some averaging may be needed.

Any integrated or subsequent integration or averaging process tends to reduce the random error so that only the systematic error remains significant. Therefore, changes and trends are

easily detected on such integrated/averaged quantities, whatever the uncertainty (trueness and precision) of the measurement device.

O.4 Tests

O.4.1 Routine tests

No routine tests are required.

O.4.2 Type tests

O.4.2.1 General

Various methods for verification (see Table O.2) of indicators performances include:

- verification by measurement;
- verification by simulation, using models for which the validity has to be demonstrated;
- verification by design assessment, i.e. confirmation of the correct application of calculations and design rules, including use of appropriate safety margins.

Table O.2 – Different possibilities authorized for verification of indicators

Indicator	Fundamental	Harmonics	Non-tested phase
phase x current	Measurement	Measurement Simulation Design assessment	Measurement Simulation Design assessment
phase to phase voltage	Measurement	Measurement Simulation Design assessment	Measurement Simulation Design assessment
phase to neutral voltage	Measurement	Measurement Simulation Design assessment	Measurement Simulation Design assessment
total active power	Measurement	Measurement Simulation Design assessment	Not applicable
total apparent power	Measurement	Measurement Simulation Design assessment	Not applicable
current imbalance	Measurement	N/A	Not applicable
Total power factor	Measurement	Measurement Simulation Design assessment	Not applicable

O.4.2.2 Test conditions

When the product has only-one rating, one product sample should be tested. For a product range, the minimum and maximum ratings should be tested.

Test has to be performed under conditions stated in Table O.3.

Table O.3 – Reference for verification conditions

	Value
Current	Minimum value (see Table O.1) ^a
Voltage	Minimum value (see Table O.1) ^a
Power factor	0,7 IND
Frequency	50 Hz or 60 Hz
Ambient temperature ^b	23 °C
^a When manufacturer range specification is different from Table O.1, it has to be tested according to minimum rated voltage/current values.	
^b When not compensated, ambient temperature has to be specified by manufacturer.	

Harmonic levels for verification are given in following Table O.4.

Table O.4 – Harmonic levels

Harmonic	Voltage %	Current %
5 th	12	12
7 th	10	10
NOTE Harmonics are expressed in per-cent of the fundamental value.		

O.4.2.3 Test criteria

Performance evaluation is to be considered as statistical approach. For details, refer to O.3. The coverage factor for assessing repeatability of measured indicator values is equal to two.

Annex P (normative)

Short-circuit breaking tests of MPSD

P.1 General test conditions

For short-circuit breaking capacity tests other than those in an individual enclosure, a wire mesh shall be placed at all points of the MPSD likely to be a source of external phenomena capable of producing a breakdown, in accordance with the arrangements and distances specified by the manufacturer. Details, including distance from the MPSD under test to wire-mesh, shall be stated in the test report. MPSD's intended for use in an individual enclosure shall, in addition, be tested in the smallest of such enclosure stated by the manufacturer.

If a MPSD is fitted with adjustable short-circuit releases, the setting of the releases shall be as specified for each test sequence.

For MPSD having a rated current up to and including 630 A, a cable of maximum length 75 cm, having a cross-section corresponding to the conventional thermal current (see 8.3.3.3.4, Tables 9 and 10 of IEC 60947-1:2007) shall be included as follows:

- approximately 50 cm on the supply side;
- approximately 25 cm on the load side.

The sequence of operations shall be that which is applicable to the test sequence as specified in P.2, P.3 and P.4.

The following symbols are used for defining the sequence of operations:

- O represents a breaking operation;
- CO represents a making operation followed, after the appropriate opening time, by a breaking operation;
- t represents the time interval between two successive short-circuit operations which shall be as short as possible, allowing for the resetting time of the MPSD, but not less than 3 min. The actual value of t shall be stated in the test report.

The maximum resetting time shall be 15 min or such longer time as may be stated by the manufacturer, during which time the MPSD shall not be displaced. Attempts to reclose the MPSD during the resetting time shall be spaced by at least 1 min.

The maximum value of I^2t (see 2.5.18 of IEC 60947-1:2007) during these tests shall be recorded in the test report.

The behaviour of the MPSD during short-circuit tests shall be according to 8.3.4.1.7 of IEC 60947-1:2007 and the interpretation of the test result shall be according to 8.3.4.1.8 of IEC 60947-1:2007.

After the short-circuit tests, the result shall be verified according to 9.3.4.2.4.

P.2 Rated service short-circuit breaking capacity

P.2.1 General

The following tests shall be realised in the following sequence:

- rated service short-circuit breaking capacity (P.2.2);

- verification of operational performance capability (P.2.3);
- verification of dielectric withstand (P.2.4);
- verification of temperature-rise (P.2.5);
- verification of overload releases (P.2.6).

P.2.2 Test of rated service short-circuit breaking capacity

A short-circuit test is made under the general conditions of 9.3.4.1 and P.1 with a value of prospective current equal to the rated service short-circuit breaking capacity I_{CS} , as declared by the manufacturer in accordance with 5.3.6.2.

The power factor for this test shall be according to Table 16 of IEC 60947-1:2007 for the appropriate test current.

The sequence of operations shall be:

O – t – CO – t – CO

t represents the time interval between two successive short-circuit operations which shall be 3 min or the resetting time of the MPSD. The actual value of t shall be stated in the test report.

P.2.3 Verification of operational performance capability

Following the test according to P.2.2, the operational performance capability shall be verified in accordance with 9.3.3.6 except that this verification shall be made at the same rated operational voltage as used for the test of P.2.2, and that the number of operations shall be 5 % of the on-load operations given in Table 10.

Following the test, the dielectric withstand shall be verified according to P.2.4.

P.2.4 Verification of dielectric withstand

P.2.4.1 General

The test shall be performed on the MPSD whilst it remains mounted for the preceding test. If this is not practicable it may be disconnected and removed from the test circuit, although measures shall be taken to ensure that this does not influence the result of the test.

P.2.4.2 Test voltage

Subclause 8.3.3.4.1, item 3) b), of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.

The value of the test voltage shall be $2 U_e$ with a minimum of 1 000 V RMS, or 1 415 V DC if an AC voltage cannot be applied. The value of U_e referred to is that at which the preceding switching and/or short-circuit tests have been performed.

P.2.4.3 Application of the test voltage

The test voltage shall be applied for 60 s in accordance with 8.3.3.4.1, items 2) c) i), ii) and iii), of IEC 60947-1:2007 and, in addition, between the incoming and outgoing terminals of each pole with the MPSD open. The use of the metal foil as specified in 8.3.3.4.1, item 1), of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 is not required. For the purposes of this document, circuits incorporating solid-state devices connected to the main circuit may be disconnected for the tests. The normal positions of operation include the tripped position, if any.

For MPSD suitable for isolation the leakage current shall be measured in accordance with 9.3.3.4.1, fourth item, except that the leakage current shall not exceed 2 mA.

P.2.4.4 Acceptance criteria

Subclause 8.3.3.4.1, item 3) d), of IEC 60947-1:2007 applies.

P.2.5 Verification of temperature-rise

Following the test according to P.2.4, the temperature-rise at the main terminals shall be verified in accordance with 9.3.3.3. The temperature-rise shall not exceed the values given in Table 2 of IEC 60947-1:2007 plus 15 K but not exceeding 80 K.

P.2.6 Verification of overload releases

The operation of overload releases shall be verified in accordance with 9.3.4.2.4 k).

P.3 Rated ultimate short-circuit breaking capacity

P.3.1 General

Where $I_{CS} = I_{CU}$, this test sequence need not to be made, but the following verifications shall additionally be made in the test sequence P.2:

- the verification of P.3.2 at the beginning of the test sequence;
- the verification of P.3.5 at the end of the test sequence.

The following tests shall be realised in the following sequence:

- verification of overload releases (P.3.2);
- test of rated ultimate short-circuit breaking capacity (P.3.3);
- verification of dielectric withstand (P.3.4);
- verification of overload releases (P.3.5).

An additional test with reverse connection is required on a new sample at the highest rated operational voltage applicable U_e in the following cases:

- no information is given with the product on how to connect the line and load phases to the terminals e.g. with marking L and T, or;
- the manufacturer claims the suitability for reverse connection.

P.3.2 Verification of overload releases

The operation of overload releases shall be verified at twice the value of their current setting. This test may be made at any convenient voltage.

If the ambient temperature differs from the reference temperature, the test current shall be corrected in accordance with the manufacturer's temperature/current data, for releases dependent on ambient temperature.

For tests for which the tripping characteristic is independent of the temperature of the terminals (e.g. electronic overload releases, magnetic releases), connection data (type, cross-section, length) may be different from those required in 8.3.3.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014. The connections should be compatible with the test current and induced thermal stresses.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the current setting at the reference temperature.

NOTE This test is performed on all 3 poles together to avoid a trip under phase loss condition.

P.3.3 Test of rated ultimate short-circuit breaking capacity

Following the test according to P.3.2, a short-circuit breaking capacity test is made with a value of prospective current equal to the ultimate rated short-circuit breaking capacity as declared by the manufacturer, under the general conditions according to 9.4.3.1 and P.1.

The sequence of operations shall be:

O – t – CO

P.3.4 Verification of dielectric withstand

Following the test according to P.3.3, the dielectric withstand shall be verified according to P.2.4. For MPSD suitable for isolation, the leakage current shall not exceed 6 mA.

P.3.5 Verification of overload releases

Following the test according to P.3.4, the operation of overload releases shall be verified in accordance with P.3.2, except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature.

NOTE This test is performed on all 3 poles together to avoid a trip under phase loss condition.

P.4 Test of MPSD for IT system

NOTE This test is intended to cover the case of a second fault to earth in presence of a first fault on the opposite side of a MPSD when connected to an electrical installation having all live parts isolated from earth or one point connected to earth through an impedance.

P.4.1 General

This test shall apply to multipole MPSDs for application on IT system, in accordance with IEC 60364-1:2005; it comprises the following test sequence:

- individual pole short-circuit in P.4.2;
- verification of dielectric withstand in P.4.3;
- verification of overload releases in P.4.4.

Additional marking of the MPSD are given in P.4.5.

P.4.2 Individual pole short-circuit

A short-circuit test is made on the individual poles of a multipole MPSD under the general conditions of 9.3.4.1 and P.1, at a value of current I_{IT} equal to 1,2 times the maximum tripping current setting of the short-circuit release but not less than 500 A nor exceeding 50 kA.

NOTE 1 The prospective current of the test circuit can have to be increased to ensure that the test current exceeds the actual short-time or instantaneous tripping current, due to impedance of the MPSD and its connections.

NOTE 2 Values higher than I_{IT} can be required, tested instead and declared by the manufacturer.

The test voltage shall be the phase-to-phase voltage corresponding to the maximum rated operational voltage of the MPSD at which it is suitable for application on IT systems, taking into account the requirements for recovery voltage of 8.3.2.2.3, item a) of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014. The power factor shall be according to Table 16 of

IEC 60947-1:2007. When $I_{IT} = 50$ kA, the short-time or instantaneous tripping current setting shall be adjusted to the nearest setting lower than (50/1,2) kA.

The test circuit shall be according to 8.3.4.1.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 and Figure 9 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, the supply S being derived from two phases of a three-phase supply, the fusible element F being connected to the remaining phase. The remaining pole or poles shall also be connected to this phase via the fusible element F.

The sequence of operations shall be:

O – t – CO

and shall be made on each pole separately, in turn.

P.4.3 Verification of dielectric withstand

The dielectric withstand shall be verified according to P.2.4 except for MPSD suitable for isolation, the leakage current shall not exceed 6 mA.

P.4.4 Verification of overload releases

The operation of overload releases shall be verified in accordance with 9.3.4.2.4 k), except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

P.4.5 Marking

MPSDs for which all values of rated voltage have been tested according to this annex or are covered by such testing require no additional marking.

MPSDs for which all values of rated voltage have not been tested according to this annex or are not covered by such testing shall be identified by the symbol  (IEC 60417-6363 "not suitable for use on IT systems") which shall be marked on the MPSD immediately following these values of rated voltage (see EXAMPLE 1).

Where a MPSD has not been tested according to this annex, a single marking by the symbol  may be used provided it is so placed that it unmistakably covers all voltage ratings (see EXAMPLE 2).

EXAMPLE 1:

690 V 

EXAMPLE 2:

415 V
500 V
690 V } 

Annex Q (normative)

Co-ordination under short-circuit conditions between a MPSD and another short-circuit protective device associated in the same circuit

Q.1 Application

To ensure co-ordination under short-circuit conditions between a MPSD (C_1) and another short-circuit protective device (SCPD) associated with it in the same circuit, it is necessary to consider the characteristics of each of the two devices as well as their behaviour as an association.

NOTE An SCPD can incorporate additional protective means, for example, overload releases.

The SCPD may consist of a fuse (or a set of fuses) – see Figure Q.1 – or of a circuit-breaker (C_2) (see Figure Q.2 to Figure Q.5).

The comparison of the individual operating characteristics of each of the two associated devices may not be sufficient, when reference has to be made to the behaviour of these two devices operating in series, since the impedance of the devices is not always negligible. This should be taken into account. For short-circuit currents it is recommended that reference be made to I^2t instead of time.

C_1 is frequently connected in series with another SCPD for reasons such as the method of power distribution adopted for the installation or because the short-circuit breaking capacity of C_1 alone may be insufficient for the proposed application. In such instances, the SCPD may be mounted in locations remote from C_1 . The SCPD may be protecting a main feeder supplying a number of MPSDs C_1 or just an individual MPSD.

For such applications the user or specifying authority may have to decide, on the basis of a desk study alone, how the optimum level of co-ordination may best be achieved. This annex is intended to give guidance for this decision, and also on the type of information which the MPSD manufacturer should make available to the prospective user.

Guidance is also given on test requirements, where such tests are deemed necessary for the proposed application.

The term "co-ordination" includes consideration of selectivity (see 2.5.23 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 and also 2.17.2 and 2.17.3 of IEC 60947-2:2016).

Consideration of selectivity can in general be carried out by desk study (see Q.5).

When considering short-circuit breaking capacity of SCPD, reference can be made to the rated ultimate short-circuit breaking capacity (I_{cu}), or to the rated service short-circuit breaking capacity (I_{cs}), according to the desired criterion.

Q.2 Object

This annex gives guidance on and requirements for the co-ordination of a MPSD with other SCPDs associated in the same circuit, as regards selectivity.

The object of this annex is to state:

- the general requirements for the co-ordination of a MPSD with another SCPD;

- the methods and the tests (if deemed necessary) intended to verify that the conditions for co-ordination have been met.

Q.3 General requirements for the co-ordination of a MPSD with another SCPD

Q.3.1 General considerations

Ideally, the co-ordination should be such that a MPSD (C_1) alone will operate at all values of over-current up to the limit of its rated short-circuit breaking capacity I_{cu} .

NOTE If the value of the prospective fault current at the point of installation is less than the rated service short-circuit breaking capacity of C_1 , it can be assumed that the SCPD is only in the circuit for considerations other than those of back-up protection.

In practice, the following considerations apply:

- a) if the value of the selectivity limit current I_s (see 2.17.4 of IEC 60947-2:2016) is too low, there is a risk of unnecessary loss of selectivity;
- b) if the value of the prospective fault current at the point of installation exceeds the rated service short-circuit breaking capacity of C_1 , the SCPD shall be so selected that the behaviour of C_1 is in accordance with Q.3.2.

Whenever possible, the SCPD shall be located on the supply side of C_1 . If the SCPD is located on the load side, it is essential that the connection between C_1 and the SCPD be so arranged as to minimize any risk of short-circuit.

Q.3.2 Behaviour of C_1 in association with another SCPD

For all values of over-current up to and including the short-circuit breaking capacity of the association, C_1 shall comply with the requirements of 7.2.5 of IEC 60947-1:2007, and the association shall comply with the requirements of 8.2.1.5.7.

Where tests on combinations of short-circuit protective devices for over-current co-ordination are not performed (2.5.22 of IEC 60947-1:2007), the manufacturer shall provide information (usually curves) showing:

- maximum cut-off (let-through) peak current (2.5.19 of IEC 60947-1:2007) as a function of prospective current (RMS symmetrical);
- I^2t characteristics.

Conformity with this information may be checked during the relevant test of Annex P.

Q.4 Type and characteristics of the associated SCPD

On request, the manufacturer of the MPSD shall provide information on the type and the characteristics of the SCPD to be used with C_1 , and on the maximum prospective short-circuit current for which the association is suitable at the stated operational voltage.

Details of the SCPD used for any tests made in accordance with this annex, i.e. manufacturer's name, type designation, rated voltage, rated current and short-circuit breaking capacity, shall be given in the test report.

The maximum conditional short-circuit current (2.5.29 of IEC 60947-1:2007) shall not exceed the rated ultimate short-circuit breaking capacity of the SCPD or the rated service short-circuit breaking capacity of the SCPD in case of no rated ultimate short-circuit breaking capacity.

If the associated SCPD is a circuit-breaker, it shall meet the requirements of IEC 60947-2, or any other relevant standard. If the associated SCPD is a fuse, it shall be in accordance with the appropriate fuse standard.

Q.5 Verification of selectivity

Q.5.1 General

Selectivity can normally be considered by desk study alone, i.e. by a comparison of the operating characteristics of C_1 and the associated SCPD, for example, when the associated SCPD is a circuit-breaker (C_2) provided with an intentional time-delay.

The manufacturers of both the C_1 and the SCPD shall provide adequate data concerning the relevant operating characteristics so as to permit I_s to be determined for each individual association.

In certain cases, tests at I_s are necessary on the association, for example:

- when C_1 is of the current-limiting type and C_2 is not provided with an intentional time-delay;
- when the opening time of the SCPD is less than that corresponding to one half-cycle.

Selectivity may be partial (see Figure Q.4) or total up to the rated short-circuit breaking capacity I_{cu} of C_1 . For total selectivity, the non-tripping characteristic of C_2 or the pre-arcing characteristic of the fuse shall lie above the tripping (break-time) characteristic of C_1 .

Two illustrations of total selectivity are given in Figure Q.2 and Figure Q.3.

Q.5.2 Consideration of selectivity by desk study

Q.5.2.1 Selectivity in the overload zone

Two cases are considered hereafter, depending on whether the SCPD is a circuit-breaker or a fuse:

- a) MPSP (C_1) and circuit-breakers (C_2) in series – selectivity determination by comparison of characteristics;

Selectivity in the time-delayed over-current zone is verified by comparison of the time-current characteristics. Separation of the characteristics in both the time and current axes ensures selective operation of C_1 with respect to C_2 , in this zone. There will be a tolerance applicable to the characteristics, which should be taken into account. The manufacturer's data should show a tolerance band or otherwise indicate the tolerance applicable, as required by this document.

- b) MPSP (C_1) with fuse as SCPD – selectivity determination by comparison of characteristics.

Selectivity in the overload zone is determined by the comparison of time-current characteristics. Separation of the characteristics in both the time and current axes ensures selective operation of C_1 with respect to the fuse, in this zone. There will be a tolerance applicable to the characteristics, which should be taken into account. The manufacturer's data should show a tolerance band or otherwise indicate the tolerance applicable, as required by the product standards.

Q.5.2.2 Determination of selectivity in the fault current (short-circuit) zone

Determination from time-current characteristics, of selectivity between a MPSP and a circuit-breaker in the fault current (short-circuit) zone (see Figure Q.2), is limited to the case where C_2 has a short-circuit release time-delay function provided by an electronic release.

- a) MPSP (C_1) and circuit-breaker (C_2) in series – selectivity determination by consideration of peak let-through current;

In the case where the instantaneous tripping of C_2 depends on an electromagnetic effect (i.e. thermal/magnetic or magnetic-only circuit-breaker) or in the case of an electronic trip unit with an instantaneous release, the minimum level of selectivity between two circuit-breakers in the fault current zone may be determined as follows:

Selectivity is assured up to the fault current level at which the peak current let-through of C_1 is less than the peak value corresponding to the instantaneous short-circuit current setting (I_i) of C_2 , taking into account the tolerance.

NOTE 1 Example of selectivity calculation

$C_2 = 800$ A MCCB; $I_i = 8$ kA RMS – 12 kA RMS (10 kA setting ± 20 %); $C_1 = 125$ A MCCB.

Minimum tripping level of C_2 is $8 \times 1,414 = 11,3$ kA peak.

Let-through current of C_1 at 15 kA RMS prospective, due to the current limitation of C_1 , is 11 kA peak, from test data.

Therefore, the system is selective to at least 15 kA RMS prospective.

NOTE 2 The selectivity limit obtained by this method will be on the low side and the actual limit determined by test will be significantly higher in most cases.

b) MPD (C₁) with fuse as SCPD.

Selectivity in the fault-current (short-circuit) zone (see Figure Q.1) is determined from the I^2t characteristics. The selectivity limit current I_s is the maximum value at which let-through I^2t of the circuit-breaker is lower than the pre-arcing I^2t of the fuse. In the absence of an actual curve, the manufacturer's quoted I^2t pre-arc value for the fuse is taken.

Q.5.2.3 Determination of selectivity limit current for specific installation conditions

Data on selectivity limits may be supplied in tabulated form, graphically or as software media. Data obtained from either a desk study or tests, to this document, will be based on the prospective fault current level at the incoming device (C_2) and assumes that the coordinated devices are in close proximity. In practice the selectivity limit will be influenced by the impedance between the two devices. Therefore, in the practical situation taking the prospective fault current at the downstream MPD will give a more precise value for the selectivity limit.

Q.5.3 Selectivity determined by test

An example of the circuit diagram for the tests is shown in Figure Q.5, where:

- C_1 is a MPD;
- settings of C_1 and C_2 are adjusted to the maximum instantaneous setting, if applicable.

Tests at other release settings may be made at the discretion of the manufacturer, in which case the settings of the releases shall be recorded in the test report.

The connecting cables shall be included as specified in 9.3.4.1 and P.1 except the total length of the cables may be distributed between the supply side and the load side of C_1 and C_2 as convenient.

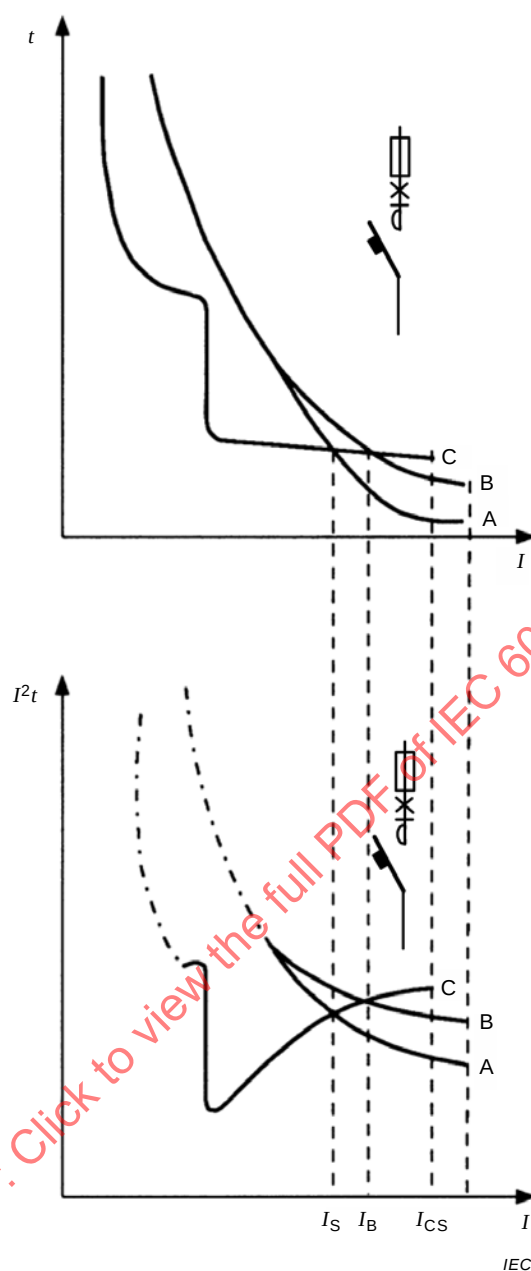
The test shall consist of an O – t – CO operation, the CO operation being made by closing the downstream device C_1 . If the downstream device is a fuse, the operation shall be made by closing C_2 .

The test is made at the level of prospective current for which the association of C_1 and C_2 is declared by the manufacturer to be selective.

Results to be obtained:

- 8.3.4.1.7 of IEC 60947-1:2007 applies;
- during each operation, C_1 shall operate and C_2 shall not trip. If the contacts of C_2 separate momentarily during the operations, the time between the beginning of short-circuit and the end of C_2 contact separation shall be less than or equal to 30 ms. The actual value shall be stated in the test report;
- in addition, it shall be verified that the contacts of C_2 are able to be opened by the normal operating means.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV



I prospective short-circuit current

I_{CS} rated service short-circuit breaking capacity (5.3.6.1)

I_s selectivity limit current (2.17.4 of IEC 60947-2:2016)

I_B take-over current (2.17.5 of IEC 60947-2:2016)

A pre-arcing characteristic of the fuse

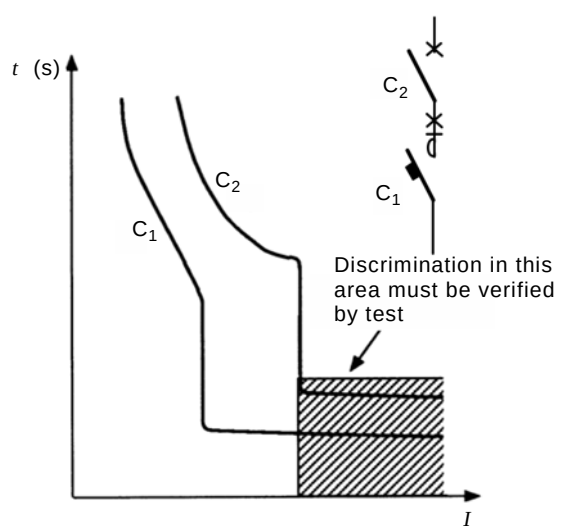
B operating characteristic of the fuse

C operating characteristic of the MPSD (break-time-current and I^2t / current)

NOTE 1 A is deemed to be the lower limit; B and C are deemed to be the upper limits.

NOTE 2 Non-adiabatic zone for I^2t shown chain-dotted.

Figure Q.1 – Over-current co-ordination between a MPSD and a fuse or back-up protection by a fuse: operating characteristics



IEC

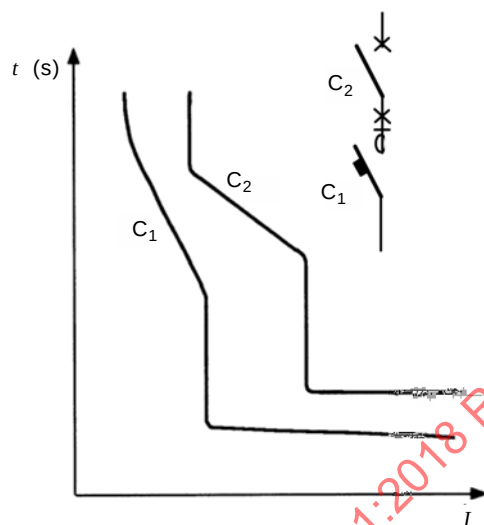
Key

C_1 current-limiting MPSD
(break-time characteristic)

C_2 non-current-limiting circuit-breaker
(tripping characteristic)

Values of I_{cu} (or I_{cs}) are not shown

**Figure Q.2 – Total selectivity between
MPSD and circuit-breakers – Case 1**



IEC

Key

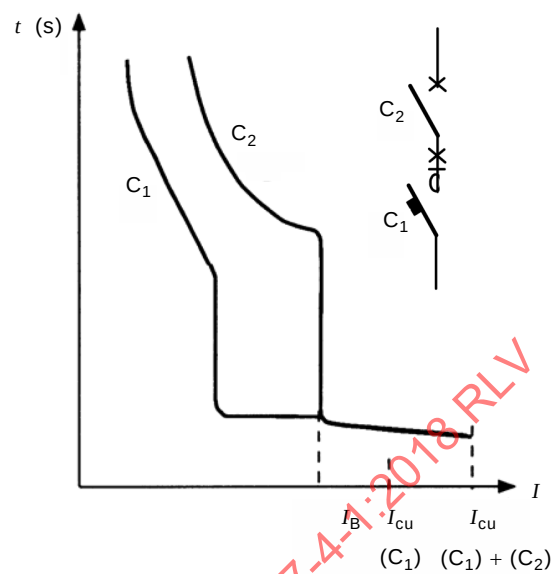
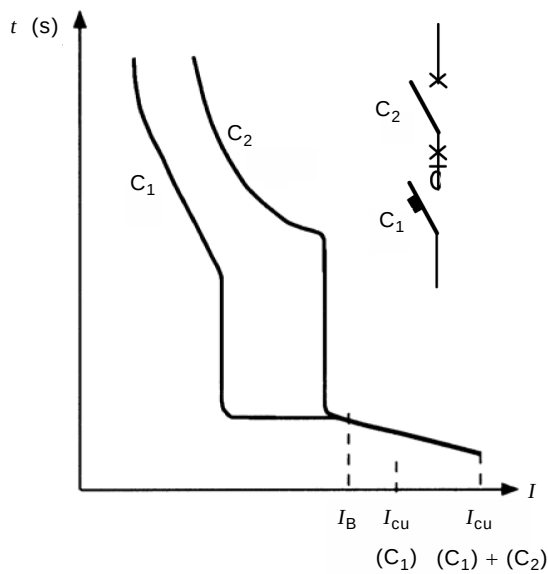
C_1 non-current-limiting MPSD
(break-time characteristic)

C_2 circuit-breaker with intentional short-time
delay (tripping characteristic)

Values of I_{cu} (or I_{cs}) are not shown

**Figure Q.3 – Total selectivity between
MPSD and circuit-breakers – Case 2**

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV



Key

C_1 non current-limiting MPSD/circuit-breaker

C_2 current-limiting circuit-breaker

I_B take-over current

NOTE 1 Where applicable, restoration of supply by C_2 occurs.

NOTE 2 $I_{cu} (C_1 + C_2) \leq I_{cu} (C_2)$.

NOTE 3 For values of $I > I_B$, the curve is that of the association (shown in bold) for which data are obtained by tests.

**Figure Q.4 – Back-up protection
by a circuit-breaker –
Operating characteristics – Case 1**

Key

C_1 non current-limiting MPSD/circuit-breaker

C_2 non current-limiting circuit-breaker

I_B take-over current

NOTE 1 Where applicable, restoration of supply by C_2 occurs.

NOTE 2 $I_{cu} (C_1 + C_2) \leq I_{cu} (C_2)$.

NOTE 3 For values of $I > I_B$, the curve is that of the association (shown in bold) for which data are obtained by tests.

**Figure Q.5 – Back-up protection
by a circuit-breaker –
Operating characteristics – Case 2**

Bibliography

IEC 60050-151:2001, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

IEC 60050-191:1990, *International Electrotechnical Vocabulary – Chapter 191: Dependability and quality of service*

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

IEC 60050-421:1990, *International Electrotechnical Vocabulary. Chapter 421: Power transformers and reactors*

IEC 60050-441:1984, *International Electrotechnical Vocabulary. Switchgear, controlgear and fuses*

IEC 60050-442:1998, *International Electrotechnical Vocabulary – Part 442: Electrical accessories*

IEC 60050-826:2004, *International Electrotechnical Vocabulary – Part 826: Electrical installations*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60072-1:1991, *Dimensions and output series for rotating electrical machines – Part 1: Frame numbers 56 to 400 and flange numbers 55 to 1080*

~~IEC 60076-1:1993, Power transformers – Part 1: General~~

IEC 60079 (all parts), *Explosive atmospheres*

IEC 60079-7, *Explosive atmospheres – Part 7: Equipment protection by increased safety "e"*

IEC 60079-29-3, *Explosive atmospheres – Part 29-3: Gas detectors – Guidance on functional safety of fixed gas detection systems*

IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*

IEC 60269-2:2006 2013, *Low-voltage fuses – Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Examples of standardized systems of fuses A to K*

IEC 60417, *Graphical symbols for use on equipment* (available at <http://www.graphical-symbols.info/equipment>)

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60812:2006, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*

IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

IEC 60947-8, *Low-voltage switchgear and controlgear – Part 8: Control units for built-in thermal protection (PTC) for rotating electrical machines*

IEC 60990:2016, *Methods of measurement of touch current and protective conductor current*

IEC 61000-6-5, *Electromagnetic compatibility (EMC) – Part 6-5: Generic standards – Immunity for equipment used in power station and substation environment*

IEC 61032, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 61095:2009, *Electromechanical contactors for household and similar purposes*

IEC 61508-2, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems* (see <http://www.iec.ch/functionalsafety>)

IEC 61508-3, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 3: Software requirements* (see <http://www.iec.ch/functionalsafety>)

IEC 61508-4:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 4: Definitions and abbreviations* (see <http://www.iec.ch/functionalsafety>)

IEC 61508-6:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 6: Guidelines on the application of IEC 61508-2 and IEC 61508-3* (see <http://www.iec.ch/functionalsafety>)

IEC 61649, *Weibull analysis*

IEC 61915-2:2011, *Low-voltage switchgear and controlgear – Device profiles for networked industrial devices – Part 2: Root device profiles for starters and similar equipment*

IEC 62061, *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*

IEC 62443 (all parts), *Security for industrial automation and control systems*

IEC 62477-1:2012, *Safety requirements for power electronic converter systems and equipment – Part 1: General*

IEC 62683-1, *Low-voltage switchgear and controlgear – Product data and properties for information exchange – Part 1: Catalogue data*

IEC TR 63054, *Low-voltage switchgear and controlgear – Fire risk analysis and risk reduction measures*

IEC TS 63058, *Environmental aspects for low-voltage switchgear and controlgear and their assemblies²*

IEC Guide 104:2010, *The preparation of safety publications and the use of basic safety publications and group safety publications*

² Under preparation. Stage at the time of publication: IEC/ACD TS 63058:2018.

ISO/IEC 80079-34, *Explosive atmospheres – Part 34: Application of quality systems for equipment manufacture*

ISO/IEC 82079-1, *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*

ISO/IEC Guide 51:2014, *Safety aspects – Guideline for their inclusion in standards*

ISO 3534-2:2006, *Statistics – Vocabulary and symbols – Part 2: Applied statistics*

CSA C22.1, *Canadian Electrical Code*

EN 50495, *Safety devices required for the safe functioning of equipment with respect to explosion risks*

NFPA 70, *National Electrical Code®*

PROFIEnergy profile test specification V1.1:2014

UL 508:2013, *Industrial control equipment* ~~(available in English only)~~

UL 60947-1, *Low-Voltage Switchgear and Controlgear – Part 1: General rules*

UL 60947-4-1 *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor starters*

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Low-voltage switchgear and controlgear –
Part 4-1: Contactors and motor-starters – Electromechanical contactors and
motor-starters**

**Appareillage à basse tension –
Partie 4-1: Contacteurs et démarreurs de moteurs – Contacteurs et démarreurs
électromécaniques**

INTERNATIONAL ELECTROTECHNICAL COMMISSION

IEC 60947-4-1
Edition 4.0 2018-10

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

**Part 4-1: Contactors and motor-starters –
Electromechanical contactors and motor-starters**

INTERPRETATION SHEET 1

This interpretation sheet 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.

The text of this interpretation sheet is based on the following documents:

DISH	Report on voting
121A/336/DISH	121A/342/RVDISH

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

Interpretation of the first paragraph of 6.2

The reference to 5.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 is intended to cover the whole subclause where its first paragraph can be discarded.

In particular, the third paragraph of this Subclause 5.2 requiring the marking on the equipment of manufacturer's name or trademark and type designation or serial number is covering items a) and b) of 6.1.1 of IEC 60947-4-1:2018.

Interpretation of footnotes ⁿ and ^o of Table 7

The standard making conditions for the utilization category AC-3e are defined by the ratio I / I_e equal to 12 with the corresponding value of $\cos \phi$ in footnote ^o.

Footnote ⁿ provides the possibility to select an alternate value of the ratio I / I_e between 12 and 13, and gives the corresponding equations to determine the value of $\cos \phi$.

Interpretation of the rated operational current of Table 13 and Table 14

Tables 13 and 14 are intended to be used for contactors and starters specified for motor loads. If the contactor or starter is specified with more than one motor load utilization category (AC-2, AC-3, AC-3e or AC-4), the rated operational current I_e corresponding to the utilization category AC-3 is preferred for determining the prospective current “ r ” for the test.

The utilization category AC-3 is considered as the most representative use case and is deemed to cover the other motor utilization categories.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

CONTENTS

FOREWORD.....	10
INTRODUCTION.....	13
1 Scope.....	14
2 Normative references	15
3 Terms, definitions, symbols and abbreviated terms.....	16
3.1 General.....	16
3.2 Alphabetical index of terms	16
3.3 Terms and definitions concerning contactors	18
3.4 Terms and definitions concerning starters	19
3.5 Terms and definitions concerning characteristic quantities	25
3.6 Terms and definitions concerning safety aspects	26
3.7 Symbols and abbreviated terms	27
4 Classification	28
5 Characteristics of contactors and starters	28
5.1 Summary of characteristics	28
5.2 Type of equipment	29
5.2.1 Kind of equipment.....	29
5.2.2 Number of poles	29
5.2.3 Kind of current (AC or DC).....	29
5.2.4 Interrupting medium (air, oil, gas, vacuum, etc.)	29
5.2.5 Operating conditions of the equipment.....	29
5.3 Rated and limiting values for main circuits	29
5.3.1 Rated voltages	29
5.3.2 Currents or powers	31
5.3.3 Rated frequency	32
5.3.4 Rated duties	32
5.3.5 Normal load and overload characteristics	33
5.3.6 Short-circuit characteristics	35
5.3.7 Pole impedance of a contactor (Z)	36
5.4 Utilization category	36
5.4.1 General	36
5.4.2 Assignment of utilization categories based on the results of tests	36
5.5 Control circuits.....	38
5.6 Auxiliary circuits.....	39
5.7 Characteristics of relay and release of overload relays and motor protective switching device (MPSD)	39
5.7.1 Summary of characteristics.....	39
5.7.2 Types of relay or release	39
5.7.3 Characteristic values	39
5.7.4 Designation and current settings of overload relays	41
5.7.5 Time-current characteristics of overload relays	41
5.7.6 Influence of ambient air temperature.....	42
5.8 Co-ordination with short-circuit protective devices.....	42
5.9 Void	42
5.10 Types and characteristics of automatic change-over devices and automatic acceleration control devices	42

5.10.1	Types	42
5.10.2	Characteristics.....	42
5.11	Types and characteristics of auto-transformers for two-step auto-transformer starters	43
5.12	Types and characteristics of starting resistors for rheostatic rotor starters	43
6	Product information	43
6.1	Nature of information	43
6.1.1	Identification.....	43
6.1.2	Characteristics, basic rated values and utilization	43
6.2	Marking.....	44
6.3	Instructions for installation, operation, maintenance, decommissioning and dismantling	46
6.4	Environmental information	46
7	Normal service, mounting and transport conditions.....	46
8	Constructional and performance requirements	47
8.1	Constructional requirements	47
8.1.1	General	47
8.1.2	Materials	47
8.1.3	Current-carrying parts and their connections	48
8.1.4	Clearances and creepage distances	48
8.1.5	Actuator.....	48
8.1.6	Indication of the contact position	49
8.1.7	Additional requirements for equipment suitable for isolation.....	49
8.1.8	Terminals	49
8.1.9	Additional requirements for equipment provided with a neutral pole	49
8.1.10	Provisions for protective earthing.....	49
8.1.11	Enclosures for equipment	49
8.1.12	Degrees of protection of enclosed equipment	50
8.1.13	Conduit pull-out torque and bending with metallic conduits	50
8.1.14	Limited energy source	50
8.1.15	Stored charge energy circuit.....	52
8.1.16	Fault and abnormal conditions.....	52
8.1.17	Short-circuit and overload protection of ports.....	53
8.2	Performance requirements	53
8.2.1	Operating conditions.....	53
8.2.2	Temperature-rise	59
8.2.3	Dielectric properties.....	61
8.2.4	Normal load and overload performance requirements	62
8.2.5	Co-ordination with short-circuit protective devices	68
8.3	Electromagnetic compatibility (EMC).....	71
8.3.1	General	71
8.3.2	Immunity.....	71
8.3.3	Emission.....	72
9	Tests	72
9.1	Kinds of test.....	72
9.1.1	General	72
9.1.2	Type tests.....	73
9.1.3	Routine tests	73

9.1.4	Sampling tests	73
9.1.5	Special tests	74
9.2	Compliance with constructional requirements	75
9.2.1	General	75
9.2.2	Electrical performance of screwless-type clamping units	75
9.2.3	Ageing test for screwless-type clamping units	75
9.2.4	Limited energy source test	76
9.2.5	Breakdown of components	76
9.3	Compliance with performance requirements	77
9.3.1	Test sequences	77
9.3.2	General test conditions	78
9.3.3	Performance under no load, normal load and overload conditions	78
9.3.4	Performance under short-circuit conditions	90
9.3.5	Overload current withstand capability of contactors	95
9.3.6	Routine tests and sampling tests	95
9.4	EMC tests	97
9.4.1	General	97
9.4.2	Immunity	97
9.4.3	Emission	99
Annex A (normative)	Marking and identification of terminals of contactors, starters and associated overload relays	101
A.1	General	101
A.2	Marking and identification of terminals of main circuits	101
A.3	Marking and identification of terminals of overload relays	101
Annex B (normative)	Special tests	103
B.1	General	103
B.2	Mechanical durability	103
B.2.1	General	103
B.2.2	Verification of mechanical durability	103
B.3	Electrical durability	105
B.3.1	General	105
B.3.2	Results to be obtained	106
B.3.3	Statistical analysis of test results for contactors or starters	106
B.4	Coordination at the crossover current between the starter and associated SCPD	107
B.4.1	General and definitions	107
B.4.2	Condition for the test for the verification of co-ordination at the crossover current by a direct method	108
B.4.3	Test currents and test circuits	108
B.4.4	Test procedure and results to be obtained	108
B.4.5	Verification of co-ordination at the crossover current by an indirect method	108
Annex C (informative)	Typical characteristics of starters	111
Annex D (informative)	Items subject to agreement between manufacturer and user	118
Annex E (Void)		119
Annex F (normative)	Requirements for auxiliary contact linked with power contact (mirror contact)	120
F.1	Application and object	120
F.1.1	Application	120

F.1.2	Object.....	120
F.2	Terms and definitions.....	120
F.3	Characteristics.....	120
F.4	Product information.....	120
F.5	Normal service, mounting and transport conditions	121
F.6	Constructional and performance requirements	121
F.7	Tests	121
F.7.1	General	121
F.7.2	Tests on products in a new condition	121
F.7.3	Test after conventional operational performance (defined under Table 13).....	122
Annex G (informative)	Rated operational currents and rated operational powers of switching devices for electrical motors	123
G.1	General.....	123
G.2	Rated operational powers and rated operational currents.....	123
Annex H (normative)	Extended functions to electronic overload relays.....	127
H.1	General.....	127
H.2	Terms and definitions.....	127
H.3	Limits of operation of control functions	127
H.3.1	General	127
H.3.2	Limits of electronic overload relay with main circuit under-voltage restarting function.....	127
H.4	Test of the control functions	128
Annex I (informative)	AC-1 contactors for use with semiconductor controlled motor load	129
Annex J (Void)		130
Annex K (normative)	Procedure to determine data for electromechanical contactors used in functional safety applications.....	131
K.1	General.....	131
K.2	Test requirements	131
K.3	Characterization of a failure mode	131
K.4	Failure ratios of a contactor	131
Annex L (normative)	Assessment procedure for electromechanical overload protection used in safety applications and especially in explosive atmospheres	133
L.1	Application and object.....	133
L.1.1	Application.....	133
L.1.2	Object.....	133
L.2	Terms, definitions and symbols	133
L.2.1	Terms and definitions	133
L.2.2	Symbols and abbreviations	134
L.3	Procedure	135
L.3.1	General	135
L.3.2	Safety design process	135
L.4	Requirements	136
L.4.1	General	136
L.4.2	Safety plan	136
L.4.3	Design	137
L.4.4	Failure mode and effects analysis of the safety function	137
L.4.5	Design plan	138

L.4.6	Verification	138
L.4.7	Function assessed	138
L.5	Documentation	138
L.5.1	Technical safety documentation	138
L.5.2	Safety instructions	138
L.6	Example	139
L.6.1	architecture description	139
L.6.2	FMEA	140
Annex M (normative)	DC contactors for use in photovoltaic (PV) applications	148
M.1	Application	148
M.2	Object	148
M.3	Terms and definitions	148
M.4	Classification	149
M.5	Characteristics	149
M.5.1	General	149
M.5.2	Rated impulse withstand voltage	149
M.5.3	Utilization category	149
M.6	Product information	150
M.7	Normal service, mounting and transport conditions	150
M.7.1	General	150
M.7.2	Ambient air temperature	150
M.7.3	Altitude	150
M.8	Constructional and performance requirements	151
M.8.1	Constructional requirements	151
M.8.2	Performance requirements	151
M.8.3	Electromagnetic compatibility (EMC)	152
M.9	Tests	152
M.9.1	General	152
M.9.2	Type tests	152
M.9.3	Making and breaking capacities and conventional operational performance	153
M.9.4	Thermal cycling test	153
M.9.5	Climatic test	153
M.9.6	Dielectric test	153
M.9.7	Critical load current test	154
M.9.8	Mechanical properties	155
M.9.9	Degree of protection of enclosed contactors	156
M.9.10	EMC	156
M.9.11	Clearance and creepage distances	156
Annex N (normative)	Additional requirements and tests for equipment with protective separation	157
N.1	General	157
N.2	Definitions	157
N.3	Requirements	157
N.3.1	Test method for implementing protective impedance	157
N.3.2	Touch current measurement	158
Annex O (informative)	Load monitoring indicators	160
O.1	General	160
O.2	Indicators list	160

O.3	Uncertainty	162
O.4	Tests	163
O.4.1	Routine tests	163
O.4.2	Type tests.....	163
Annex P (normative)	Short-circuit breaking tests of MPSD	165
P.1	General test conditions	165
P.2	Rated service short-circuit breaking capacity	165
P.2.1	General	165
P.2.2	Test of rated service short-circuit breaking capacity.....	166
P.2.3	Verification of operational performance capability	166
P.2.4	Verification of dielectric withstand.....	166
P.2.5	Verification of temperature-rise.....	167
P.2.6	Verification of overload releases	167
P.3	Rated ultimate short-circuit breaking capacity	167
P.3.1	General	167
P.3.2	Verification of overload releases	167
P.3.3	Test of rated ultimate short-circuit breaking capacity	168
P.3.4	Verification of dielectric withstand.....	168
P.3.5	Verification of overload releases	168
P.4	Test of MPSD for IT system	168
P.4.1	General	168
P.4.2	Individual pole short-circuit	168
P.4.3	Verification of dielectric withstand.....	169
P.4.4	Verification of overload releases	169
P.4.5	Marking	169
Annex Q (normative)	Co-ordination under short-circuit conditions between a MPSD and another short-circuit protective device associated in the same circuit.....	170
Q.1	Application	170
Q.2	Object.....	170
Q.3	General requirements for the co-ordination of a MPSD with another SCPD	171
Q.3.1	General considerations	171
Q.3.2	Behaviour of C_1 in association with another SCPD	171
Q.4	Type and characteristics of the associated SCPD	171
Q.5	Verification of selectivity	172
Q.5.1	General	172
Q.5.2	Consideration of selectivity by desk study.....	172
Q.5.3	Selectivity determined by test	173
Bibliography.....		178
Figure 1	Multiple of current setting limits for ambient air temperature compensated time-delay overload relays	56
Figure 2	Thermal memory test	57
Figure 3	Examples of co-ordination characteristics of a starter.....	70
Figure 4	Voltage drop measurement at contact point of the clamping terminal	75
Figure 5	Example of a pole impedance measurement for a 3 pole contactor	81
Figure A.1	Main circuit	101
Figure A.2	Overload relays	102

Figure B.1 – Examples of time-current withstand characteristic.....	110
Figure C.1 – Typical curves of currents and torques during a star-delta start (see 3.4.4.1)	111
Figure C.2 – Typical curves of currents and torques during an auto-transformer start (see 3.4.4.2)	112
Figure C.3 – Typical variants of protected starters, combination starters, protected switching devices and combination switching devices	113
Figure C.4 – Example of three-phase diagram of a rheostatic rotor starter with three starting steps and one direction of rotation (in the case when all the mechanical switching devices are contactors)	114
Figure C.5 – Typical methods and diagrams of starting alternating-current induction motors by means of auto-transformers	116
Figure C.6 – Examples of speed/time curves corresponding to cases a), b), c), d), e) and f) of 5.3.5.6.1	117
Figure F.1 – Mirror contact.....	121
Figure L.1 – Safety design process	136
Figure L.2 – Typical structure of a thermal overload relay	139
Figure L.3 – typical structure of MPSD	140
Figure M.1 – Critical current.....	154
Figure N.1 – Protection by means of protective impedance.....	158
Figure N.2 – Measuring instrument	159
Figure O.1 – Example of quantification of a process change	162
Figure Q.1 – Over-current co-ordination between a MPSD and a fuse or back-up protection by a fuse: operating characteristics	175
Figure Q.2 – Total selectivity between MPSD and circuit-breakers – Case 1	176
Figure Q.3 – Total selectivity between MPSD and circuit-breakers – Case 2	176
Figure Q.4 – Back-up protection by a circuit-breaker – Operating characteristics – Case 1	177
Figure Q.5 – Back-up protection by a circuit-breaker – Operating characteristics – Case 2	177
Table 1 – Utilization categories	38
Table 2 – Trip classes of overload relays	41
Table 3 – Limits of operation of time-delay overload relays when energized on all poles.....	55
Table 4 – Limits of operation of three-pole time-delay overload relays when energized on two poles only	58
Table 5 – Temperature-rise limits for insulated coils in air and in oil	60
Table 6 – Intermittent duty test cycle data.....	61
Table 7 – Making and breaking capacities – Making and breaking conditions according to utilization category	63
Table 8 – Relationship between the test current and off-time for the verification of rated making and breaking capacities	65
Table 9 – Operational current determination for utilization categories AC-6a and AC-6b when derived from AC-3 ratings	65
Table 10 – Conventional operational performance – Making and breaking conditions according to utilization category	66
Table 11 – Overload current withstand requirements	68

Table 12 – Specific acceptance criteria for immunity tests	72
Table 13 – Value of the prospective test current according to the rated operational current	92
Table 14 – Value of the prospective test current according to the rated operational current (harmonized table)	92
Table 15 – Test conditions for I_{cd}	70
Table 16 – EMC immunity tests	97
Table 17 – Terminal disturbance voltage limits for conducted radio-frequency emission (for mains ports)	99
Table 18 – Radiated emission test limits	100
Table 19 – Limits for limited energy sources without an over-current protective device	51
Table 20 – Limits for limited energy sources with an over-current protective device	51
Table 21 – Limits for limited energy source with current limiting impedance	52
Table B.1 – Verification of the number of on-load operating cycles – Conditions for making and breaking corresponding to the several utilization categories	106
Table B.2 – Test conditions	109
Table F.1 – Test voltage according to altitude	122
Table G.1 – Rated operational powers and rated operational currents of motors	124
Table K.1 – Failure mode of contactors	131
Table K.2 – Typical failure ratios for normally open contactors	132
Table L.1 – Severity	140
Table L.2 – Occurrence	141
Table L.3 – Detection levels	141
Table L.4 – Conclusion	142
Table L.5 – Example of failure mode and effects analysis for thermal overload relay	143
Table M.1 – Rated impulse voltage levels for PV contactors	149
Table M.2 – Utilization categories	149
Table M.3 – Ambient air temperature conditions	150
Table M.4 – Verification of rated making and breaking capacities – Conditions for making and breaking corresponding to the DC-PV category	151
Table M.5 – Conventional operational performance – Making and breaking condition corresponding to the DC-PV category	152
Table M.6 – Overall scheme of test sequences	153
Table M.7 – Number of operating cycles corresponding to the critical load current	155
Table M.8 – Critical load current performance	155
Table O.1 – AC monitoring indicators list	161
Table O.2 – Different possibilities authorized for verification of indicators	163
Table O.3 – Reference for verification conditions	164
Table O.4 – Harmonic levels	164

INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters

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 60947-4-1 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 fourth edition cancels and replaces the third edition published in 2009 and its Amendment 1:2012. This edition constitutes a technical revision.

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

- Scope structure and exclusions
- Editorial correction of notes and hanging paragraphs
- Reference to IEC 62683-1
- Motor protective switching device (MPSD) with its requirements

- Safety aspects related to:
 - General aspects;
 - Limited energy circuits;
 - Electronic circuits;
 - Assessment procedure for electromechanical overload protection used in safety - applications (new Annex L)
- Introduction of provisions covering the impact of higher locked rotor current to achieve high efficiency class
- Mention of dedicated wiring accessories
- Pickup power measurement
- Alignment to IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, and IEC 60947-1:2007/AMD2:2014
- Direct current requirements for covering photovoltaic application (new Annex M)
- Load monitoring indicators (new Annex O)
- Short-circuit breaking tests of MPSD (new Annex P)
- Co-ordination under short-circuit conditions between a MPSD and another short-circuit protective device associated in the same circuit (new Annex Q)

The text of this International Standard is based on the following documents:

FDIS	Report on voting
121A/224/FDIS	121A/233/RVD

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

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

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

This document shall be read in conjunction with IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014, *Low voltage switchgear and controlgear – Part 1: General rules*. The provisions of the general rules are applicable to this document, where specifically called for.

The provisions of the general rules dealt with IEC 60947-1 are applicable to this part of IEC 60947 series where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, and IEC 60947-1:2007/AMD2:2014. For example, 4.3.4.1 of IEC 60947-1:2007, Table 4 of IEC 60947-1:2007, or Annex A of IEC 60947-1:2007.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

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

The contents of the interpretation sheet of March 2020 have been included in this copy.

The contents of the corrigenda 1 (2020-04) and 2 (2021-04) have been included in this copy.

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.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 R1-V

INTRODUCTION

This document introduces the requirements for motor protection switching devices (MPSD).

MPSDs have been available on the market for many years. They are introduced in this document for covering the minimum safety and performance requirements of a manual motor starter with integral electromechanical or electronic short-circuit protection. This device fulfils all requirements of a starter and specific requirements of a circuit-breaker according to IEC 60947-2, mainly I_{cu} and I_{cs} , for protecting the motor and its circuit with control devices e.g. a contactor. An MPSD is not intended to support neutral pole, DC ratings, rated uninterrupted current I_u , backup protection, short-circuit tripping time-delay, selectivity category, withdrawable capability, RCD, recloser, EMC requirements of IEC 60947-2, etc.

Circuit-breakers according to Annex O of IEC 60947-2:2016 with motor overload protection characteristic according to this document but without starter ratings e.g. AC-3 are also available on the market. These devices are not covered by this document.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 REV

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters

1 Scope

This part of IEC 60947 is applicable to the following equipment:

- electromechanical contactors and starters including motor protective switching device (MPSD);
- actuators of contactor relays;
- contacts dedicated exclusively to the coil circuit of this contactor or this contactor relay;
- dedicated accessories (e.g. dedicated wiring, dedicated latch accessory);

intended to be connected to distribution circuits, motors circuits and other load circuits, the rated voltage of which does not exceed 1 000 V AC or 1 500 V DC.

This document covers also the assessment procedure for electromechanical overload protection used in safety applications such as protecting a motor located in explosive atmosphere from the outside atmosphere: See Annex L.

This document does not apply to:

- starters for DC motors¹;
NOTE 1 The requirements for DC motor starters are under consideration for the next maintenance cycle.
- auxiliary contacts of contactors and contacts of contactor relays. These are covered by IEC 60947-5-1;
- starter used downstream to frequency drive¹;
NOTE 2 Additional requirements for starter used downstream to frequency drive are under consideration for the next maintenance cycle.
- short-circuit protective device integrated within starters other than MPSDs. This is covered by IEC 60947-2 and IEC 60947-3;
- the use of the product with additional measure within explosive atmospheres. These are given in IEC 60079 series;
- embedded software design rules¹;
- cyber security aspects. These are covered by IEC 62443 series.

The objective of this document is to state:

- a) the characteristics of the equipment;
- b) the conditions applicable to the equipment with reference to:
 - 1) its operation and behaviour,
 - 2) its dielectric properties,
 - 3) its degree of protection,

¹ For this subject the manufacturer is responsible for taking additional safety measures.

- 4) its construction including safety measures against electric shock, fire hazard and mechanical hazard;
- c) the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests;
- d) the information to be given with the equipment or in the manufacturer's literature.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60034-1:2017, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-12:2016, *Rotating electrical machines – Part 12: Starting performance of single-speed three-phase cage induction motors*

IEC 60034-30-1, *Rotating electrical machines – Part 30-1: Efficiency classes of line operated AC motors (IE code)*

IEC 60038, *IEC standard voltages*

IEC 60068-2-14:2009, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60079-14, *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*

IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*

IEC 60364-1:2005, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC 60364-7-712, *Low voltage electrical installations – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*

IEC 60715:2017, *Dimensions of low-voltage switchgear and controlgear – Standardized mounting on rails for mechanical support of switchgear, controlgear and accessories*

IEC 60730-1, *Automatic electrical controls – Part 1: General requirements*

IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 60947-1:2007/AMD1:2010

IEC 60947-1:2007/AMD2:2014

IEC 60947-2:2016, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*

IEC 60947-5-1:2016, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

IEC 61051-2, *Varistors for use in electronic equipment – Part 2: Sectional specification for surge suppression varistors*

IEC 61140:2016, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61439 (all parts), *Low-voltage switchgear and controlgear assemblies*

IEC 61810-1, *Electromechanical elementary relays – Part 1: General and safety requirements*

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

CISPR 11:2015/AMD1:2016

ISO 2859-1:1999, *Sampling procedures for inspection by attributes – Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

ISO 3864-2, *Graphical symbols – Safety colours and safety signs – Part 2: Design principles for product safety labels*

3 Terms, definitions, symbols and abbreviated terms

3.1 General

For the purposes of this document, the terms and definitions of Clause 2 of IEC 60947-1:2007/AMD1:2010/AMD2:2014, as well as the following terms, definitions, symbol and abbreviations apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.2 Alphabetical index of terms

	Reference
A	
abnormal operating condition	3.6.1
accessible part	3.6.2
auto-transformer starter	3.4.4.2
auto-transformer	3.4.4.3
C	
closed transition (with an auto-transformer starter or star-delta starter)	3.4.22
combination starter	3.4.7
combination switching device	3.4.26
CO operation	3.5.2
contactor (mechanical)	3.3.1
D	
dedicated wiring accessory	3.4.32
direct-on-line starter	3.4.2

E

electromagnetic contactor	3.3.2
electromagnetic starter	3.4.9
electronically controlled electromagnet	3.3.8
electro-pneumatic contactor	3.3.4
electro-pneumatic starter	3.4.12

G

galvanic opening (of a circuit)	3.5.9
galvanic separation	3.5.10

H

hazardous-live-part	3.6.3
holding power (of a contactor)	3.3.9

I

I^2t characteristic of a circuit-breaker or a MPSD	3.5.6
I_{cd} current	3.5.4
inching (jogging)	3.4.23
inhibit time	3.4.29

J

jam relay (or release)	3.4.28

L

latch accessory	3.4.33
latched contactor	3.3.5
limited energy source	3.6.4

M

manual starter	3.4.8
mirror contact	F.2.1
motor management starter	3.4.30
motor-operated starter	3.4.10
motor protective switching device (abbreviation: MPSD)	3.4.31
motor starter	3.4.1

N

n -step starter	3.4.15

O

O operation	3.5.3
open transition (with an auto-transformer starter or star-delta starter)	3.4.21
overload current setting (abbreviation: I_r)	3.5.8

P

phase loss sensitive overload relay or release	3.4.16
pick-up power (of a contactor)	3.3.10
plugging	3.4.24
pneumatic contactor	3.3.3
pneumatic starter	3.4.11
position of rest (of a contactor)	3.3.7
protected starter	3.4.6
protected switching device	3.4.25
protective impedance	3.6.5

R

rated instantaneous short-circuit current setting (abbreviation: I_i)	3.5.7
reasonably foreseeable misuse	3.6.6
reduced voltage starter	3.4.4
resetting time	3.5.5
reversing starter	3.4.3
rheostatic rotor starter	3.4.5.2
rheostatic starter	3.4.5
rheostatic stator starter	3.4.5.1

S

single fault condition	3.6.7
single-step starter	3.4.13
stall relay (or release)	3.4.27
star-delta starter	3.4.4.1
starting time (of a rheostatic starter)	3.4.19
starting time (of an auto-transformer starter)	3.4.20

T

transient recovery voltage (abbreviation: TRV)	3.5.1
two-step starter	3.4.14

U

under-current relay or release	3.4.17
under-voltage relay or release	3.4.18

V

vacuum contactor (or starter)	3.3.6

3.3 Terms and definitions concerning contactors

3.3.1

(mechanical) contactor

mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions

Note 1 to entry: Mechanical contactors may be designated according to the method by which the force for closing the main contacts is provided.

Note 2 to entry: The term "operated otherwise than by hand" means that the device is intended to be controlled and kept in working position from one or more external supplies.

Note 3 to entry: In French, a contactor the main contacts of which are closed in the position of rest is usually called a "rupteur". The word "rupteur" has no equivalent in the English language.

Note 4 to entry: A contactor is usually intended to operate frequently.

Note 5 to entry: A mechanical contactor can provide a galvanic opening (3.5.9) but is not suitable for isolation unless the additional requirements defined under 8.1.7 are fulfilled. In this case the equipment can be marked in accordance with IEC 60417-6169-1 "Disconnecter; isolator".

[SOURCE: IEC 60050-441:2000, 441-14-33, modified – Term "mechanical" in bracket; "may" replaced by "can" in Note 1 to entry; Notes to entry 2 to 5 have been added]

3.3.2

electromagnetic contactor

contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by an electromagnet

Note 1 to entry: The electromagnet may be electronically controlled.

3.3.3**pneumatic contactor**

contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by a device using compressed air, without the use of electrical means

3.3.4**electro-pneumatic contactor**

contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by a device using compressed air under the control of electrically operated valves

3.3.5**latched contactor**

contactor, the moving elements of which are prevented by means of a latching arrangement from returning to the position of rest when the operating means are de-energized

Note 1 to entry: The latching, and the release of the latching, can be mechanical, electromagnetic, pneumatic, etc.

Note 2 to entry: Because of the latching, the latched contactor actually acquires a second position of rest and, according to the definition of a contactor, it is not, strictly speaking, a contactor. However, since the latched contactor in both its utilization and its design is more closely related to contactors in general than to any other classification of switching device, it is considered proper to require that it complies with the specifications for contactors wherever they are appropriate.

[SOURCE: IEC 60050-441:2000, 441-14-34, modified – “may” replaced by “can” in Note 1 to entry]

3.3.6**vacuum contactor (or starter)**

contactor (or starter) in which the main contacts open and close within a highly evacuated envelope

3.3.7**position of rest (of a contactor)**

position which the moving elements of the contactor take up when its electromagnet or its compressed-air device is not energized

[SOURCE: IEC 60050-441:2000, 441-16-24]

3.3.8**electronically controlled electromagnet**

electromagnet in which the coil is controlled by a circuit with active electronic elements

3.3.9**holding power (of a contactor)**

power needed to maintain the operation of the electromagnet

3.3.10**pick-up power (of a contactor)**

power needed to operate the contactor from the de-energized state to the energized state

3.4 Terms and definitions concerning starters**3.4.1****motor starter**

combination of all the switching means necessary to start and stop a motor in combination with suitable overload protection

[SOURCE: IEC 60050-441:2000, 441-14-38, modified – “Motor” added to the term and Note 1 to entry has been deleted]

3.4.2

direct-on-line starter

starter which connects the line voltage across the motor terminals in one step

[SOURCE: IEC 60050-441:2000, 441-14-40]

3.4.3

reversing starter

starter intended to cause the motor to reverse the direction of rotation by reversing the motor primary connections when the motor is not running

Note 1 to entry: An application where reversing the motor primary connections while the motor is running is called plugging (see 3.4.24).

3.4.4

reduced voltage starter

starter which connects the line voltage across the motor terminals in more than one step or by gradually increasing the voltage applied to the terminals

3.4.4.1

star-delta starter

starter for a three-phase induction motor such that in the starting position the stator windings are connected in star and in the final running position they are connected in delta

Note 1 to entry: A star-delta starter is not intended for reversing motor running and, therefore, utilization category AC-4 does not apply.

Note 2 to entry: In the star connection, the starting current in the line and the torque of the motor are about one-third of the corresponding values for delta connection. Therefore, star-delta starters are used when the inrush current due to the starting is to be limited, or when the driven machine needs a limited torque for starting. See Figure C.1a) and Figure C.1b)).

[SOURCE: IEC 60050-441:2000, 441-14-44, modified – Notes to entry have been added]

3.4.4.2

auto-transformer starter

starter for an induction motor which uses for starting one or more reduced voltages derived from an auto-transformer

Note 1 to entry: The auto-transformer starter is not intended for inching duty or reversing running motors and, therefore, utilization category AC-4 does not apply.

Note 2 to entry: In the starting position, the current in the line and the torque of the motor related to the motor starting with rated voltage are reduced approximately as the square of the ratio (starting voltage)/(rated voltage). Therefore, auto-transformer starters are used when the inrush current due to the starting is to be limited or when the driven machine needs a limited torque for starting. See Figure C.2a) and Figure C.2b)).

[SOURCE: IEC 60050-441:2000, 441-14-45, modified – Notes to entry have been added]

3.4.4.3

auto-transformer

transformer in which at least two windings have a common part

[SOURCE: IEC 60050-421:1990, 421-01-11]

3.4.5

rheostatic starter

starter utilizing one or several resistors for obtaining, during starting, stated motor torque characteristics and for limiting the current

Note 1 to entry: A rheostatic starter generally consists of three basic parts which may be supplied either as a composite unit or as separate units to be connected at the place of utilization:

- the mechanical switching devices for supplying the stator (generally associated with an overload protective device);
- the resistor(s) inserted in the stator or rotor circuit;
- the mechanical switching devices for cutting out the resistor(s) successively.

Note 2 to entry: It applies also to starters for two directions of rotation when reversal of connections is made with the motor stopped.

[SOURCE: IEC 60050-441:2000, 441-14-42, modified – Notes to entry have been added]

3.4.5.1

rheostatic stator starter

rheostatic starter for a squirrel cage motor which, during the starting period, cuts out successively one or several resistors previously provided in the stator circuit

3.4.5.2

rheostatic rotor starter

rheostatic starter for an asynchronous wound-rotor motor which, during the starting period, cuts out successively one or several resistors previously provided in the rotor circuit

[SOURCE: IEC 60050-441: 2000, 441-14-43]

3.4.6

protected starter

equipment consisting of a starter, a manually-operated switching device and a short-circuit protective device, rated as a unit by the manufacturer

Note 1 to entry: The protected starter may or may not be enclosed.

Note 2 to entry: In the context of this document, the term "manufacturer" means any person, company or organization with ultimate responsibility as follows:

- to verify compliance with the appropriate standard;
- to provide the product information according to Clause 6.

Note 3 to entry: A manually protected starter as one unit can be a MPSP.

3.4.7

combination starter

equipment consisting of a protected starter incorporating an isolating function

Note 1 to entry: Also called "combination motor controller".

Note 2 to entry: See Figure C.3.

3.4.8

manual starter

starter in which the force for closing the main contacts is provided exclusively by manual energy

[SOURCE: IEC 60050-441:2000, 441-14-39]

3.4.9

electromagnetic starter

starter in which the force for closing the main contacts is provided by an electromagnet

3.4.10

motor-operated starter

starter in which the force for closing the main contacts is provided by an electric motor

3.4.11

pneumatic starter

starter in which the force for closing the main contacts is provided by using compressed air, without the use of electrical means

3.4.12

electro-pneumatic starter

starter in which the force for closing the main contacts is provided by using compressed air under the control of electrically operated valves

3.4.13

single-step starter

starter in which there is no intermediate accelerating position between the OFF and ON positions

Note 1 to entry: This starter is a direct-on-line starter.

3.4.14

two-step starter

starter in which there is only one intermediate accelerating position between the OFF and ON positions

EXAMPLE A star-delta starter is a two-step starter.

3.4.15

***n*-step starter**

starter in which there are (*n*-1) intermediate accelerating positions between the OFF and full ON positions

Note 1 to entry: See Figure C.4.

EXAMPLE A three-step rheostatic starter has two sections of resistors used for starting.

[SOURCE: IEC 60050-441:2000, 441-14-41, modified – “OFF” and “ON” in capital; Example and Note 1 to entry are added]

3.4.16

phase loss sensitive overload relay or release

multipole overload relay or release which operates in the case of overload and also in case of loss of phase in accordance with specified requirements

3.4.17

under-current relay or release

measuring relay or release which operates automatically when the current through it is reduced below a predetermined value

3.4.18

under-voltage relay or release

measuring relay or release which operates automatically when the voltage applied to it is reduced below a predetermined value

3.4.19**starting time (of a rheostatic starter)**

period of time during which the starting resistors or parts of them carry current

Note 1 to entry: The starting time of a starter is shorter than the total starting time of the motor which also takes into account the last period of acceleration following the switching operation to the ON position.

3.4.20**starting time (of an auto-transformer starter)**

period of time during which the auto-transformer carries current

Note 1 to entry: The starting time of a starter is shorter than the total starting time of the motor which also takes into account the last period of acceleration following the switching operation to the ON position.

3.4.21**open transition (with an auto-transformer starter or star-delta starter)**

circuit arrangement such that the supply to the motor is interrupted and reconnected when changing over from one step to another

Note 1 to entry: The transition stage is not considered as an additional step.

3.4.22**closed transition (with an auto-transformer starter or star-delta starter)**

circuit arrangement such that the supply to the motor is not interrupted (even momentarily) when changing over from one step to another

Note 1 to entry: The transition stage is not considered as an additional step.

3.4.23**inching (jogging)**

energizing a motor or solenoid repeatedly for short periods to obtain small movements of the driven mechanism

3.4.24**plugging**

stopping or reversing a motor rapidly by reversing the motor primary connections while the motor is running

3.4.25**protected switching device**

equipment (for non-motor loads) consisting of a contactor or a semiconductor controller, overload protection, a manually operated switching device and a short-circuit protective device, rated as a unit by the manufacturer

Note 1 to entry: The protected switching device may or may not be enclosed.

Note 2 to entry: In the context of this document, the term "manufacturer" means any person, company or organization with ultimate responsibility as follows:

- to verify compliance with the appropriate standard;
- to provide the product information according to Clause 6.

Note 3 to entry: The manually operated switching device and the short-circuit protective device may be just one device and may incorporate the overload protection as well.

3.4.26**combination switching device**

equipment consisting of a protected switching device incorporating an isolating function

3.4.27

stall relay (or release)

electronic overload relay or release which operates when the current has not decreased below a predetermined value for a specific period of time during start-up or when the relay or the release receives the input indicating there is no rotation of the motor after a predetermined time in accordance with specified requirements

Note 1 to entry: Explanation of stall: rotor locked during start.

Note 2 to entry: With appropriate adjustment of the current and starting time settings, such relay or release can be used to detect starts requiring longer than specified times.

3.4.28

jam relay (or release)

electronic overload relay or release which operates in the case of overload and also when the current has increased above a predetermined value for a specific period of time during operation, in accordance with specified requirements

Note 1 to entry: A jam is a high overload occurring after the completion of starting which causes the current to reach the locked rotor current value of the motor being controlled.

3.4.29

inhibit time

time-delay period during which the tripping function of the relay is inhibited (may be adjustable)

3.4.30

motor management starter

starter including extended functions with communication ability

Note 1 to entry: Interoperable device profiles for motor management starter are defined by IEC 61915-2:2011.

3.4.31

motor protective switching device

MPSD

manually operated motor starter additionally providing resettable short-circuit protection to the motor and the circuit

Note 1 to entry: A MPSD can also be used as a manual starter, a protected starter or a combination starter.

Note 2 to entry: A MPSD can be used as a SCPD within the motor branch.

Note 3 to entry: In North America, this device is called manual motor controller suitable for tap conductor protection.

3.4.32

dedicated wiring accessory

prefabricated connection wiring system specifically intended for identified switchgear or controlgear

Note 1 to entry: A dedicated wiring accessory can be integrated in the switchgear or controlgear or delivered separately.

Note 2 to entry: A typical dedicated wiring accessory is for example a connection link.

3.4.33

latch accessory

mechanical device attached to a contactor, the moving elements of which are prevented from returning to the position of rest when the operating means are de-energized

Note 1 to entry: The latching, and the release of the latching, can be mechanical, electromagnetic, pneumatic, etc.

[SOURCE: IEC 60050-441:2000, 441-14-34, modified – Adapted to accessories, and Note 2 to entry deleted]

3.5 Terms and definitions concerning characteristic quantities

3.5.1

transient recovery voltage

TRV

recovery voltage during the time in which it has a significant transient character

Note 1 to entry: In a vacuum contactor or starter, the highest transient recovery voltage can occur on another pole than the first pole to clear.

[SOURCE: IEC 60947-1:2007, 2.5.34, modified – Note 1 to entry has been modified]

3.5.2

CO operation

breaking of the circuit by the SCPD resulting from closing the circuit by the equipment under test

3.5.3

O operation

breaking of the circuit by the SCPD resulting from closing the circuit on the equipment under test which is in the closed position

Note 1 to entry: The SCPD is normally in the closed position prior closing the circuit; in some cases, the SCPD has to close the circuit (see 9.3.4.2.2, item b).

3.5.4

I_{cd} current

current representing a fault current equal to or higher than the current corresponding to the crossover point of the mean value of the published curves representing the time-current characteristics of the overload relay and the SCPD respectively

3.5.5

resetting time

time elapsed between a circuit-breaker (MPSD) tripping due to an over-current and subsequently reaching a condition where it can be reclosed

[SOURCE: IEC 60947-2:2016, 2.19, modified – Insertion of “(MPSD)” in definition]

3.5.6

I^2t characteristic of a circuit-breaker or a MPSD

information (usually a curve) giving the maximum values of I^2t related to break time as a function of prospective current (r.m.s. symmetrical for a.c.) up to the maximum prospective current corresponding to the rated service short-circuit breaking capacity and associated voltage

[SOURCE: IEC 60947-2:2016, 2.18, modified – “or a MPSD” inserted in term]

3.5.7

rated instantaneous short-circuit current setting

I_i

rated value of the current causing the operation of a release without any intentional time-delay

[SOURCE: IEC 60947-2:2016, 2.20]

3.5.8 overload current setting

I_r
current setting of an adjustable overload release

[SOURCE: IEC 60947-2:2016, 2.21, modified – Note 1 to entry has been deleted]

3.5.9 galvanic opening (of a circuit)

prevention of electric conduction within an electric circuit intended to provide power and/or signals

Note 1 to entry: Galvanic opening can be provided e.g. by a switch or a contactor.

3.5.10 galvanic separation

prevention of electric conduction between two electric circuits intended to exchange power and/or signals

Note 1 to entry: Galvanic separation can be provided e.g. by an isolating transformer or an opto-coupler.

[SOURCE: IEC 60050-151:2001, 151-12-26]

3.6 Terms and definitions concerning safety aspects

3.6.1 abnormal operating condition

temporary operating condition that is not a normal operating condition and is not a single fault condition of the equipment itself

Note 1 to entry: An abnormal operating condition is a temporary condition which may be introduced by the equipment or by a person and may result in a failure of a component, a device or a safeguard.

Note 2 to entry: This definition is used in the context of component failure risk analysis.

3.6.2 accessible part

part which can be touched by means of the standard test finger

[SOURCE: IEC 60050-442:1998, 442-01-15]

3.6.3 hazardous-live-part

live part which, under certain conditions, can give a harmful electric shock

[SOURCE: IEC 60050-195:1998, 195-06-05]

3.6.4 limited energy source

source that is designed and protected that, under both normal operating conditions and single fault conditions, the current that can be delivered is not hazardous with respect to fire hazard

3.6.5 protective impedance

impedance connected between hazardous-live-parts and accessible conductive parts, of such value that the current, in normal use and under likely fault conditions, is limited to a safe value, and which is so constructed that its ability is maintained throughout the life of the equipment

[SOURCE: IEC 62477-1:2012, 3.42]

3.6.6

reasonably foreseeable misuse

use of a product or system in a way not intended by the supplier, but which can result from readily predictable human behaviour

[SOURCE: ISO/IEC Guide 51:2014, 3.7, modified – Notes to entry have been removed]

3.6.7

single fault condition

condition in which there is a fault of a single protection (but not a reinforced protection) or of a single component or a device

Note 1 to entry: If a single fault condition results in one or more other fault conditions, all are considered as one single fault condition.

[SOURCE: IEC Guide 104:2010, 3.8]

3.7 Symbols and abbreviated terms

AQL	Acceptable quality level
EMC	Electromagnetic compatibility
SCPD	Short-circuit protective device
$\hat{I}$	Maximum peak value of the pick-up current of an electronically controlled electromagnet
I_c	Current made and broken (Table 7)
I_{cs}	Rated service short-circuit breaking capacity (5.3.6.2)
I_{cu}	Rated ultimate short-circuit breaking capacity (5.3.6.1)
I_e	Rated operational current (5.3.2.5)
I_{er}	Rated rotor operational current (5.3.2.7)
I_{es}	Rated stator operational current (5.3.2.6)
I_i	Instantaneous short-circuit current setting
I_{IT}	Short-circuit test current for IT system
I_q	Maximum conditional short-circuit test current
I_{th}	Conventional free air thermal current (5.3.2.1)
I_{the}	Conventional enclosed thermal current (5.3.2.2)
I_{thr}	Conventional rotor thermal current (5.3.2.4)
I_{ths}	Conventional stator thermal current (5.3.2.3)
I_u	Rated uninterrupted current (5.3.2.8)
P_c	Nominal holding/pickup power of a conventional direct current controlled electromagnet, or the holding power for an electronically direct current controlled electromagnet
P_p	Pick-up power of a direct current controlled contactor with separate pick-up and hold-on windings
"r"	Minimum short-circuit test current
S_h	Holding power of an alternating current controlled electromagnet
S_p	Pick-up power of an alternating current controlled electromagnet
T_p	Tripping time (Table 2)
U_c	Rated control circuit voltage (5.5)

U_d	Voltage drop of a contactor pole
U_e	Rated operational voltage (5.3.1.1)
U_{er}	Rated rotor operational voltage (5.3.1.1.3)
U_{es}	Rated stator operational voltage (5.3.1.1.2)
U_i	Rated insulation voltage (5.3.1.2)
U_{imp}	Rated impulse (withstand) voltage (5.3.1.3)
U_{ir}	Rated rotor insulation voltage (5.3.1.2.3)
U_{is}	Rated stator insulation voltage (5.3.1.2.2)
U_r	Power frequency or DC recovery voltage (Table 7)
U_s	Rated control circuit supply voltage (5.5)
Z	Pole impedance of a contactor (5.3.7)

4 Classification

Subclause 5.2 gives all the data which may be used as criteria for classification.

5 Characteristics of contactors and starters

5.1 Summary of characteristics

The characteristics of a contactor or starter shall be stated in the following terms, where such terms are applicable:

- type of equipment (5.2);
- rated and limiting values for main circuits (5.3);

NOTE 1 The rated values established for a rheostatic rotor starter are stated in accordance with 5.3.1.1.2, 5.3.1.1.3, 5.3.1.2.2, 5.3.1.2.3, 5.3.2.3, 5.3.2.4, 5.3.2.6, 5.3.2.7 and 5.3.5.6 but it is not necessary to specify all the values listed.

- utilization category (5.4);
- control circuits (5.5);
- auxiliary circuits (5.6);
- types and characteristics of relays and releases (5.7);
- co-ordination with short-circuit protective devices (5.8);
- types and characteristics of automatic change-over devices and automatic acceleration control devices (5.10);
- types and characteristics of auto-transformers for two-step auto-transformer starters (5.11);
- types and characteristics of starting resistors for rheostatic rotor starters (5.12);
- items subject to agreement between manufacturer and user; see Annex D.

For information exchange in electronic format, e.g. electronic catalogue, IEC 62683-1 gives the data format of the essential characteristics of motor starters, contactors and their accessories.

NOTE 2 In the case of a star-delta starter, the currents relate to the delta connection and, in the case of a two-step auto-transformer or rheostatic rotor starter, to the ON position.

5.2 Type of equipment

5.2.1 Kind of equipment

- contactor;
- direct-on-line AC starter;
- star-delta starter;
- two-step auto-transformer starter;
- rheostatic rotor starter;
- combination or protected starter.

5.2.2 Number of poles

5.2.3 Kind of current (AC or DC)

5.2.4 Interrupting medium (air, oil, gas, vacuum, etc.)

5.2.5 Operating conditions of the equipment

5.2.5.1 Method of operation

For example: manual, electromagnetic, motor-operated, pneumatic, electro-pneumatic.

5.2.5.2 Method of control

For example:

- automatic (by pilot switch or sequence control);
- non-automatic (such as by hand operation or by push-buttons);
- semi-automatic (i.e. partly automatic, partly non-automatic).

5.2.5.3 Method of change-over for particular types of starters

The change-over for star-delta starters, rheostatic rotor starters or auto-transformer starters may be automatic, non-automatic or semi-automatic (see Figure C.4 and Figure C.5).

5.2.5.4 Method of connecting for particular types of starters

For example: open transition starter, closed transition starter (see Figure C.5).

5.3 Rated and limiting values for main circuits

5.3.1 Rated voltages

5.3.1.1 Rated operational voltage (U_e)

5.3.1.1.1 General

Subclause 4.3.1.1 of IEC 60947-1:2007 applies.

The value of the rated operational voltage shall clearly indicate for which 3 phase system (star or delta) it is valid, according to IEC 60038, e.g. 230/400 V or 400 V (50 Hz), 277/480 V or 480 V (60 Hz). When given in the form X/Y V, the lower value is the voltage RMS to neutral and the higher value is the voltage RMS between phases. When one value only is indicated, it refers to the voltage RMS between phases and to neutral.

5.3.1.1.2 Rated stator operational voltage (U_{es})

For rheostatic rotor starters, a rated stator operational voltage is a value of voltage which, when combined with a rated stator operational current, determines the application of the stator circuit including its mechanical switching devices and to which are referred the making and breaking capacities, the type of duty and the starting characteristics. In no case shall the maximum rated operational voltage exceed the corresponding rated insulation voltage.

NOTE The rated stator operational voltage is expressed as the voltage between phases.

5.3.1.1.3 Rated rotor operational voltage (U_{er})

For rheostatic rotor starters, the value of rated rotor operational voltage is that of the voltage which, when combined with a rated rotor operational current, determines the application of the rotor circuit including its mechanical switching devices and to which are referred the making and breaking capacities, the type of duty and the starting characteristics.

This voltage is taken as equal to the voltage measured between slip-rings, with the motor stopped and the rotor open-circuited, when the stator is supplied at its rated voltage.

The rated insulation voltage of the switching devices inserted in the rotor circuit shall be at least 50 % of the highest voltage between open slip-rings.

NOTE Electrical stresses are lower and shorter in the rotor than in the stator.

The rated rotor operational voltage is only applied for a short duration during the starting period. For this reason, it is permissible that the rated rotor operational voltage exceeds the rated rotor insulation voltage by 100 %.

The maximum voltage between the different live parts (e.g. switching devices, resistors, connecting parts, etc.) of the rotor circuit of the starter will vary and account may be taken of this fact in choosing the equipment and its disposition.

5.3.1.2 Rated insulation voltage (U_i)

5.3.1.2.1 General

Subclause 4.3.1.2 of IEC 60947-1:2007 applies.

5.3.1.2.2 Rated stator insulation voltage (U_{is})

For rheostatic rotor starters, the rated stator insulation voltage is the value of voltage which is designated for the devices inserted in the stator supply, as well as the unit they are part of, and to which dielectric tests and creepage distances are referred.

Unless otherwise stated, the rated stator insulation voltage is the value of the maximum rated stator operational voltage of the starter.

5.3.1.2.3 Rated rotor insulation voltage (U_{ir})

For rheostatic rotor starters, the rated rotor insulation voltage is the value of voltage which is designated to the devices inserted in the rotor circuit, as well as the unit they are part of (connecting links, resistors, enclosure), and to which dielectric tests and creepage distances are referred.

5.3.1.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1:2007 applies.

5.3.1.4 Rated starting voltage of an auto-transformer starter

The rated starting voltage of an auto-transformer starter is the reduced voltage derived from the transformer.

Preferred values of rated starting voltage are 50 %, 65 % or 80 % of the rated operational voltage.

5.3.2 Currents or powers

5.3.2.1 Conventional free air thermal current (I_{th})

Subclause 4.3.2.1 of IEC 60947-1:2007 applies.

5.3.2.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of IEC 60947-1:2007 applies.

5.3.2.3 Conventional stator thermal current (I_{ths})

The conventional stator thermal current of a starter may be either free air current I_{ths} or enclosed current I_{thes} , in line with 5.3.2.1 and 5.3.2.2.

For a rheostatic rotor starter, the stator thermal current is the maximum current it can carry on eight-hour duty (see 5.3.4.1) without the temperature-rise of its several parts exceeding the limits specified in 8.2.2 when tested in accordance with 9.3.3.3.

5.3.2.4 Conventional rotor thermal current (I_{thr})

The conventional rotor thermal current of a starter may be either free air current I_{thr} or enclosed current I_{ther} , in line with 5.3.2.1 and 5.3.2.2.

For rheostatic rotor starters, the rotor thermal current is the maximum current that those parts of the starter through which the rotor current flows in the ON position, precisely after cutting out resistors, can carry on eight-hour duty (see 5.3.4.1) without their temperature-rise exceeding the limits specified in 8.2.2 when tested in accordance with 9.3.3.3.

NOTE 1 For those elements (switching devices, connecting links, resistors) through which a current of practically no value flows in the ON position, it can be verified that, for the rated duties (see 5.3.4) stated by the manufacturer, the value of integral

$$\int_0^t i^2 dt$$

does not lead to temperature-rises higher than those appearing in 8.2.2.

NOTE 2 When resistors are built-in into the starter, the temperature-rise can be taken into account.

5.3.2.5 Rated operational currents (I_e) or rated operational powers

A rated operational current of a contactor or a starter is stated by the manufacturer and takes into account the rated operational voltage (see 5.3.1.1), the conventional free air or enclosed thermal current, the rated current of the overload relay, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the utilization category (see 5.4) and the type of protective enclosure, if any.

In the case of equipment for direct switching of individual motors, the indication of a rated operational current may be replaced or supplemented by an indication of the maximum rated power output, at the rated operational voltage considered, of the motor for which the

equipment is intended. The manufacturer shall be prepared to state the relationship assumed between the current and the power.

NOTE Annex G gives values concerning the relationship between rated operational currents and rated operational powers.

For starters, the rated operational current (I_e) is the current in the ON position of the starter.

5.3.2.6 Rated stator operational current (I_{es}) or rated stator operational power

For rheostatic rotor starters, a rated stator operational current is stated by the manufacturer and takes into account the rated current of the overload relay installed in this starter, the rated stator operational voltage (see 5.3.1.1.1), the conventional free air or enclosed thermal current, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the starting characteristics (see 5.3.5.6) and the type of protective enclosure.

The indication of a rated stator operational current may be replaced by the indication of the maximum rated power output, at the rated stator operational voltage considered, of the motor for which the stator elements of the starter are intended. The manufacturer shall be prepared to state the relationship assumed between the motor power and the stator current.

5.3.2.7 Rated rotor operational current (I_{er})

For rheostatic rotor starters, a rated rotor operational current is stated by the manufacturer and takes into account the rated rotor operational voltage (see 5.3.1.1.2), the conventional free air or enclosed rotor thermal current, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the starting characteristics (see 5.3.5.6) and the type of protective enclosure.

It is taken as equal to the current flowing in the connections to the rotor when the latter is short-circuited and the motor is running at full load and the stator is supplied at its rated voltage and rated frequency.

When the rotor part of a rheostatic rotor starter is rated separately, the indication of a rated rotor operational current may be supplemented by the maximum rated power output, for motors having the rated rotor operational voltage considered, of the motor for which that part of the starter (switching devices, connecting links, relays, resistors) is intended. This power varies in particular with the breakaway torque foreseen and consequently takes into account the starting characteristics (see 5.3.5.6).

5.3.2.8 Rated uninterrupted current (I_u)

Subclause 4.3.2.4 of IEC 60947-1:2007 applies.

5.3.3 Rated frequency

Subclause 4.3.3 of IEC 60947-1:2007 applies.

5.3.4 Rated duties

5.3.4.1 Eight-hour duty (continuous duty)

Subclause 4.3.4.1 of IEC 60947-1:2007 applies with the following addition.

For a star-delta starter, a two-step auto-transformer starter or a rheostatic rotor-starter, the continuous duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it, which are closed in this position, remain closed while each of them carries a steady current long enough for the starter to reach thermal equilibrium, but not for more than 8 h without interruption.

5.3.4.2 Uninterrupted duty

Subclause 4.3.4.2 of IEC 60947-1:2007 applies with the following addition.

For a star-delta starter, a two-step auto-transformer starter or a rheostatic rotor starter, the uninterrupted duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it, which are closed in this position, remain closed without interruption while each of them carries a steady current for periods of more than 8 h (weeks, months or even years).

5.3.4.3 Intermittent periodic duty or intermittent duty

Subclause 4.3.4.3 of IEC 60947-1:2007 applies with the following addition.

For a reduced voltage starter, the intermittent duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it remain closed for periods bearing a definite relation to the no-load periods, both periods being too short to allow the starter to reach thermal equilibrium.

Preferred classes of intermittent duty are:

- for contactors: 1, 3, 12, 30, 120, 300 and 1 200 (operating cycles per hour);
- for starters: 1, 3, 12 and 30 (operating cycles per hour).

It is recalled that an operating cycle is a complete working cycle comprising one closing operation and one opening operation.

For starters, an operating cycle comprises starting, running to full speed and switching off the supply from the motor.

NOTE In the case of starters for intermittent duty, the difference between the thermal time-constant of the overload relay and that of the motor can render a thermal relay unsuited for overload protection. For installations intended for intermittent duty, the question of overload protection is subject to agreement between manufacturer and user.

5.3.4.4 Temporary duty

Subclause 4.3.4.4 of IEC 60947-1:2007 applies.

5.3.4.5 Periodic duty

Subclause 4.3.4.5 of IEC 60947-1:2007 applies.

5.3.5 Normal load and overload characteristics

5.3.5.1 General

Subclause 4.3.5 of IEC 60947-1:2007 applies with the following additions.

5.3.5.2 Ability to withstand motor switching overload currents

Requirements to meet these conditions are given for contactors in 8.2.4.4.

5.3.5.3 Rated making capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.1. The rated making and breaking capacities are only valid when the contactor or the starter is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.5.4 Rated breaking capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.1. The rated making and breaking capacities are only valid when the contactor or the starter is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.5.5 Conventional operational performance

This performance is specified as a series of making and breaking operations in 8.2.4.2.

5.3.5.6 Starting and stopping characteristics of starters (see Figure C.6)

5.3.5.6.1 General

Typical service conditions for starters are:

- one direction of rotation with the motor being switched off during running in normal service conditions (utilization categories AC-2, AC-3 and AC-3e);
- two directions of rotation, but the running in the second direction is realized after the starter has been switched off and the motor has completely stopped (utilization categories AC-2, AC-3 and AC-3e);
- one direction of rotation, or two directions of rotation as in item b), but with the possibility of infrequent inching (jogging). For this service condition, direct-on-line starters are usually employed (utilization category AC-3 and AC-3e);
- one direction of rotation with frequent inching (jogging). Usually direct-on-line starters (utilization category AC-4) are used for this duty;
- one or two directions of rotation, but with the possibility of infrequent plugging for stopping the motor, plugging being associated, if so provided, with rotor resistor braking (reversing starter with braking). Usually a rheostatic rotor starter is used for this duty condition (utilization category AC-2);
- two directions of rotation, but with the possibility of reversing the supply connections to the motor while it is running in the first direction (plugging), in order to obtain its rotation in the other direction, with switching off the motor running in normal service conditions. Usually a direct-on-line reversing starter while running is used for this duty condition (utilization category AC-4).

Unless otherwise stated, starters are designed on the basis of the starting characteristics of the motors compatible with the making capacities of Table 7. These making capacities cover both the transient and steady-state starting currents of the great majority of standard motors. However, the starting currents for some large motors may attain peak values corresponding to power factors considerably lower than those specified for the test circuit in Table 7. In these cases, the operational current of the contactor or starter should be decreased to a value lower than its rated value such that the making capacity of the contactor or starter is not exceeded.

5.3.5.6.2 Starting characteristics of rheostatic rotor starters

A distinction shall be drawn between the currents and voltages in the stator and rotor circuits of slip-ring motors. However, the changes of the current values in stator and rotor circuits, caused by the various steps of the starting process, are nearly proportional under normal operating conditions.

The following definitions deal mainly with the characteristics of the rotor circuit:

U_{er} is the rated rotor operational voltage;

I_{er} is the rated rotor operational current;

Z_r is the characteristic impedance of the rotor of an AC slip-ring induction motor;

where

$$Z_r = \frac{U_{er}}{\sqrt{3} \times I_{er}};$$

I_1 is the current in the rotor circuit immediately before shorting out a resistor section;

I_2 is the current in the rotor circuit immediately after shorting out a resistor section;

$I_m = 1/2 (I_1 + I_2)$;

T_e is the rated motor operational torque;

t_s is the starting time;

k is the severity of start = $\frac{I_m}{I_{er}}$.

It is recognized that many rheostatic rotor starter applications have very specific starting requirements which may result not only in a different number of starting steps and different values of I_1 and I_2 , but also in the values of I_1 and I_2 being different for individual resistor sections. Therefore, no attempt has been made to lay down standard parameters, but the following factors should be taken into consideration:

- for most applications, between two and six starting steps are adequate depending upon load torque, inertia and the severity of start required;
- the resistor sections should be designed to have adequate thermal ratings bearing in mind the starting time of the drive, which will be dependent upon load torque and load inertia.

5.3.5.6.3 Standard conditions for making and breaking corresponding to the starting characteristics for rheostatic rotor starters

These conditions are given in Table 7 and apply to starting with high torque (for the designation of the mechanical switching devices, see Figure C.4).

The conditions for making and breaking as given in Table 7 for AC-2 utilization category are considered as standard.

The starter circuit shall be designed to open all rotor resistor switching devices before or approximately simultaneously with the opening of the stator switching device. Otherwise, the stator switching device shall comply with AC-3 and AC-3e requirements.

5.3.5.6.4 Starting characteristics for two-step auto-transformer starters

Unless otherwise stated, the auto-transformer starters and specifically the auto-transformers are designed on the condition that the starting time for all classes of duty (see 5.3.4) shall not exceed 15 s. The number of starting cycles per hour assumes equal periods between starts except that, in the event of two operating cycles being made in rapid succession, the starter and the auto-transformer shall be allowed to cool to ambient air temperature before a further start is made.

When a starting time in excess of 15 s is required, this shall be the subject of agreement between manufacturer and user.

5.3.6 Short-circuit characteristics

5.3.6.1 Rated ultimate short-circuit breaking capacity of a MPSD (I_{cu})

The rated ultimate short-circuit breaking capacity of a MPSD is the value of ultimate short-circuit breaking capacity assigned to that MPSD by the manufacturer for the corresponding rated operational voltage, under the conditions specified in P.3. It is expressed as the value of

the prospective breaking current, in kA (RMS value of the AC component in the case of alternating current).

5.3.6.2 Rated service short-circuit breaking capacity of a MPSD (I_{cs})

The rated service short-circuit breaking capacity of a MPSD is the value of service short-circuit breaking capacity assigned to that MPSD by the manufacturer for the corresponding rated operational voltage U_e , under the conditions specified in P.2. It is expressed as a value of prospective breaking current, in kA, or as a % of I_{cu} (for example $I_{cs} = 25 \% I_{cu}$).

I_{cs} shall be at least equal to 25 % of I_{cu} .

5.3.6.3 Rated conditional short-circuit current

Subclause 4.3.6.4 of IEC 60947-1:2007/AMD2:2014 applies.

5.3.7 Pole impedance of a contactor (Z)

The pole impedance may be stated by the manufacturer and is determined by measuring the voltage drop resulting of the current flowing through the pole.

5.4 Utilization category

5.4.1 General

Subclause 4.4 of IEC 60947-1:2007 applies with the following additions.

For contactors and starters, the utilization categories as given in Table 1 are considered standard. Any other type of utilization shall be based on agreement between manufacturer and user, but information given in the manufacturer's catalogue or tender may constitute such an agreement.

Each utilization category is characterized by the values of the currents, voltages, power-factors or time-constants and other data of Table 7 and Table 10, and by the test conditions specified in this document.

For contactors or starters defined by their utilization category, it is therefore unnecessary to specify separately the rated making and breaking capacities as these values depend directly on the utilization category as shown in Table 7.

The voltage for all utilization categories is the rated operational voltage of a contactor or a starter other than a rheostatic rotor starter, and the rated stator operational voltage for a rheostatic rotor starter.

All direct-on-line starters belong to one or more of the following utilization categories: AC-3, AC-3e, AC-4, AC-7b, AC-8a and AC-8b.

All star-delta and two-step auto-transformer starters belong to utilization category AC-3 or AC-3e.

Rheostatic rotor starters belong to utilization category AC-2.

5.4.2 Assignment of utilization categories based on the results of tests

- a) A contactor or starter which has been tested for one utilization category or at any combination of parameters (such as highest operational voltage and current, etc.) can be assigned other utilization categories without testing, provided that the test currents, voltages, power-factors or time-constants, number of operating cycles, on and off times

given in Table 7 and Table 10, and the test circuit for the assigned utilization categories are not more severe than those at which the contactor or starter has been tested and the temperature-rise has been verified at a current not less than the highest assigned rated operational current in continuous duty.

For example, when tested for utilization category AC-4, a contactor may be assigned utilization category AC-3 provided I_e for AC-3 is not higher than $1,2 I_e$ for AC-4 at the same rated operational voltage.

- b) DC-3 and DC-5 contactors are assumed to be capable of opening and closing loads other than those on which they have been tested provided that:
- the voltage and current do not exceed the specified values of U_e and I_e ;
 - the energy J stored in the actual load is equal to or less than the energy J_c stored in the load with which they were tested.

The values of the energy stored in the test circuit are as follows:

Utilization category	Stored energy J_c
DC-3	$0,005\ 25 \times U_e \times I_e$
DC-5	$0,031\ 5 \times U_e \times I_e$

The values of the constants 0,005 25 and 0,031 5 are derived from:

$$J_c = 1/2 LI^2$$

where the time-constant has been replaced by:

$2,5 \times 10^{-3}$ s (DC-3) and:

15×10^{-3} s (DC-5)

and where $U = 1,05 U_e$, $I = 4 I_e$ and L is the inductance of the test circuit (see Table 7).

Table 1 – Utilization categories

Kind of current	Utilization categories	Additional category designation	Typical load
AC	AC-1	General use	Non-inductive or slightly inductive loads
	AC-2		Slip-ring motors or mixed resistive and inductive loads, including moderate overloads
	AC-3		Squirrel-cage motors ^d : starting, switching off motors during running, reversing ^a
	AC-3e ^e		Squirrel-cage motors with higher locked rotor current ^e : starting, switching off motors during running, reversing ^a
	AC-4	Ballast Incandescent	Squirrel-cage motors ^d : starting, plugging, inching
	AC-5a		Discharge lamps
	AC-5b		AC incandescent lamps
	AC-6a		Transformers
	AC-6b		Capacitor banks
	AC-7a ^c		Slightly inductive loads for household appliances and similar applications
	AC-7b ^c		Motor-loads for household applications
	AC-8a		Hermetic refrigerant compressor motor ^b control with manual resetting of overload releases
AC-8b	Hermetic refrigerant compressor motor ^b control with automatic resetting of overload releases		
DC	DC-1	Incandescent	Non-inductive or slightly inductive loads
	DC-3		Shunt-motors: starting, plugging, inching, dynamic breaking of DC motors
	DC-5		Series-motors: starting, plugging, inching, dynamic breaking of DC motors
	DC-6		DC incandescent lamps
^a AC-3 category may be used for occasional inching (jogging) or plugging for limited time periods such as machine set-up; during such limited time periods, the number of such operations should not exceed five per minute or more than ten in a 10-min period.			
^b A hermetic refrigerant compressor motor is a combination consisting of a compressor and a motor, both of which are enclosed in the same housing, with no external shaft or shaft seals, the motor operating in the refrigerant.			
^c For AC-7a and AC-7b, see IEC 61095.			
^d Asynchronous motor of design N and H according to IEC 60034-12:2016.			
^e Asynchronous motor of design NE and HE, according to IEC 60034-12:2016, having extended / higher locked rotor apparent power and current than design N and H respectively, to achieve a higher efficiency class according to IEC 60034-30-1.			

5.5 Control circuits

Subclause 4.5 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies with the following additions.

The list of characteristics given in 4.5.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 shall be completed by:

- limited energy (if the source is in accordance with 8.1.14);
- SELV (PELV) supply (in accordance with Annex N of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014);

- the power consumption of the electromagnet of a contactor, necessary for determining the characteristics of the power supply of the control circuit, which is given by:
 - holding power,
 - pick-up power.

NOTE In the USA and Canada, control circuits are characterised as Class 2 sources as defined in NFPA 70, National Electrical Code and CSA C22.1, Canadian Electrical Code (CE Code) in lieu of or in addition to SELV (PELV) sources.

5.6 Auxiliary circuits

Subclause 4.6 of IEC 60947-1:2007 applies.

Digital inputs and/or digital outputs contained in contactors and motor-starters, and intended to be compatible with PLCs shall fulfil the requirements of Annex S of IEC 60947-1:2007.

5.7 Characteristics of relay and release of overload relays and motor protective switching device (MPSD)

NOTE In the remainder of this document, the words "overload relay" will be taken to apply equally to an overload relay or an overload release, as appropriate.

5.7.1 Summary of characteristics

The characteristics of relays and releases shall be stated in the following terms, whenever applicable:

- types of relay or release (see 5.7.2);
- characteristic values (see 5.7.3);
- designation and current settings of overload relays (see 5.7.4);
- time-current characteristics of overload relays (see 5.7.5);
- influence of ambient air temperature (see 5.7.6);
- extended functions as given in Annex H;
- load monitoring indicators as given in Annex O.

5.7.2 Types of relay or release

- a) Release with shunt-coil (shunt trip).
- b) Under-voltage and under-current opening relay or release.
- c) Overload time-delay relay the time-lag of which is:
 - 1) substantially independent of previous load;
 - 2) dependent on previous load;
 - 3) dependent on previous load and also phase loss sensitive overload relay or release.
- d) Instantaneous overload relay or release;
- e) Instantaneous short-circuit relays or releases.

NOTE A MPSD has a combination of relays or releases from c) and e) above.

- f) Stall relay or release.
- g) Other relays or releases (e.g. control relay associated with devices for the thermal protection of the motor).

5.7.3 Characteristic values

- a) Release with shunt-coil, under-voltage (under-current), over-voltage (instantaneous over current), current or voltage imbalance and phase reversal opening relay or release:
 - rated voltage (current);

- rated frequency;
 - operating voltage (current);
 - operating time (when applicable);
 - inhibit time (when applicable).
- b) Overload relay and release (including the overload function of MPSD):
- designation and current settings (see 5.7.4);
 - rated frequency, when necessary (for example in the case of a current transformer operated overload relay);
 - time-current characteristics (or range of characteristics), when necessary;
 - trip class according to classification in Table 2, or the value of the maximum tripping time, in seconds, under the conditions specified in 8.2.1.5.1, Table 3, column D, when this time exceeds 40 s;
 - nature of the relay: thermal, magnetic, electronic or electronic without thermal memory (electronic relay not fulfilling the thermal memory test verification according 8.2.1.5.1.2 shall be marked ~~Thm~~);
 - nature of the reset: in case of manual/automatic, the set position shall be indicated;
 - tripping time of overload relays class 10A if longer than 2 min at –5 °C or below (see 8.2.1.5.1.1, item c).
- c) Release with residual current sensing relay:
- rated current;
 - operating current;
 - operating time or time-current characteristic according to Table T.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010;
 - inhibit time (when applicable);
 - type designation (see Annex T of IEC 60947-1: 2007, IEC 60947-1:2007/AMD1:2010).
- d) Short-circuit release of an MPSD:
- rated operational currents (I_e) or rated operational powers;
 - rated frequency;
 - current setting (or range of settings) if applicable.

Table 2 – Trip classes of overload relays

Trip class	Tripping time T_p under the conditions specified in 8.2.1.5.1, Table 3, column D ^a	Tripping time T_p under the conditions specified in 8.2.1.5.1, Table 3, column D for tighter tolerances (tolerance band E) ^a
	s	S
2	–	$T_p \leq 2$
3	–	$2 < T_p \leq 3$
5	$0,5 < T_p \leq 5$	$3 < T_p \leq 5$
10A	$2 < T_p \leq 10$	–
10	$4 < T_p \leq 10$	$5 < T_p \leq 10$
20	$6 < T_p \leq 20$	$10 < T_p \leq 20$
30	$9 < T_p \leq 30$	$20 < T_p \leq 30$
40	–	$30 < T_p \leq 40$
NOTE 1 Depending on the nature of the relay, the tripping conditions are given in 8.2.1.5. NOTE 2 In the case of a rheostatic rotor starter, the overload relay is commonly inserted in the stator circuit. As a result, it cannot efficiently protect the rotor circuit and more particularly the resistors (generally more easily damageable than the rotor itself or the switching devices in case of a faulty start); protection of the rotor circuit is the subject of a specific agreement between manufacturer and user (see, inter alia, 8.2.1.1.3). NOTE 3 In the case of a two-step auto-transformer starter, the starting auto-transformer is normally designed for use during the starting period only: as a result, it cannot be efficiently protected by the overload relay in the event of faulty starting. Protection of the auto-transformer is the subject of specific agreement between manufacturer and user (see 8.2.1.1.4). NOTE 4 The lower limiting values of T_p are selected to allow for differing heater characteristics and manufacturing tolerances.		
^a The manufacturer shall add the letter E to trip classes to indicate compliance with the band E.		

5.7.4 Designation and current settings of overload relays

Overload relays are designated by their current setting (or the upper and lower limits of the current setting range, if adjustable) and their trip class.

The current setting (or current setting range) shall be marked on the relays.

However, if the current setting is influenced by the conditions of use or other factors which cannot readily be marked on the relay, then the relay or any interchangeable parts thereof (e.g. heaters, operating coils or current transformers) shall carry a number or an identifying mark which makes it possible to obtain the relevant information from the manufacturer or his catalogue or, preferably, from data furnished with the starter.

In the case of current transformer operated overload relays, the marking may refer either to the primary current of the current transformer through which they are supplied or to the current setting of the overload relays. In either case, the ratio of the current transformer shall be stated.

5.7.5 Time-current characteristics of overload relays

Typical time-current characteristics shall be given in the form of curves supplied by the manufacturer. These curves shall indicate how the tripping time, starting from the cold state (see 5.7.6), varies with the current up to a value of at least eight times the full-load current of the motor with which it is intended that the relay be used. The manufacturer shall be prepared to indicate, by suitable means, the general tolerances applicable to these curves and the conductor cross-sections used for establishing these curves (see 9.3.3.2.2, item c)).

NOTE The current is plotted as abscissa and the time as ordinates, using logarithmic scales. The current is plotted as multiples of the setting current I_r and the time in seconds on the standard graph sheet detailed in 5.6.1 and Figure 1 of IEC 60269-1:2006 and in Figure 104, Figure 504 and Figure 505 of IEC 60269-2:2013.

5.7.6 Influence of ambient air temperature

The time-current characteristics (see 5.7.5) refer to a stated value of ambient air temperature, and are based on no previous loading of the overload relay (i.e. from an initial cold state). This value of the ambient air temperature shall be clearly given on the time curves; the preferred values are +20 °C or +40 °C.

The overload relays shall be able to operate within the ambient air temperature range of –5 °C to +40 °C, and the manufacturer shall be prepared to state the effect of variation in ambient air temperature on the characteristics of overload relays.

5.8 Co-ordination with short-circuit protective devices

The co-ordination of contactors and starters is characterized by the type, ratings and characteristics of the short-circuit protective devices (SCPD) that provide protection of the contactor and starter against short-circuit currents. Requirements are given in 8.2.5.1 and 8.2.5.2 of this document, and in 4.8 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010.

Requirements for AC-3e rated starters with type 2 coordination are given in 8.2.5.3.

When a MPSD is used as a manual starter without associated contactor, it does not need to be tested according to this subclause.

5.9 Void

5.10 Types and characteristics of automatic change-over devices and automatic acceleration control devices

5.10.1 Types

- a) Time-delay devices, e.g. time-delay contactor relays according to IEC 60947-5-1 applicable to control-circuit devices or specified-time all-or-nothing relays according to IEC 61810-1.
- b) Undercurrent devices (undercurrent relays).
- c) Other devices for automatic acceleration control:
 - devices dependent on voltage;
 - devices dependent on power;
 - devices dependent on speed.

5.10.2 Characteristics

- a) The characteristics of time-delay devices are:
 - the rated time-delay or its range, if adjustable;
 - for time-delay devices fitted with a coil, the rated voltage, when it differs from the starter line voltage.
- b) The characteristics of the undercurrent devices are:
 - the rated current (thermal current and/or rated short-time withstand current, according to the indications given by the manufacturer);
 - the current setting or its range, if adjustable.
- c) The characteristics of the other devices shall be determined by agreement between manufacturer and user.

5.11 Types and characteristics of auto-transformers for two-step auto-transformer starters

Account being taken of the starting characteristics (see 5.3.5.6.3), starting auto-transformers shall be characterized by:

- the rated voltage of the auto-transformer;
- the number of taps available for adjusting the starting torque and current;
- the starting voltage, i.e. the voltage at the tapping terminals, as a percentage of the rated voltage of the auto-transformer;
- the current they can carry for a specified duration;
- the rated duty (see 5.3.4);
- the method of cooling $\left\{ \begin{array}{l} \text{air-cooling;} \\ \text{oil-cooling.} \end{array} \right.$

The auto-transformer can be:

- either built-in into the starter, in which case the resulting temperature-rise has to be taken into account in determining the ratings of the starter;
- or provided separately, in which case the nature and dimensions of the connecting links have to be specified by agreement between the manufacturer of the transformer and the manufacturer of the starter.

5.12 Types and characteristics of starting resistors for rheostatic rotor starters

Account being taken of the starting characteristics (see 5.3.5.6.2), the starting resistors shall be characterized by:

- the rated rotor insulation voltage (U_{ir});
- their resistance value;
- the mean thermal current, defined by the value of steady current they can carry for a specified duration;
- the rated duty (see 5.3.4);
- the method of cooling $\left\{ \begin{array}{l} \text{free air;} \\ \text{forced air;} \\ \text{oil-immersion.} \end{array} \right.$

They can be:

- either built-in into the starter, in which case the resulting temperature-rise has to be limited in order not to cause any damage to the other parts of the starter;
- or provided separately, in which case the nature and dimensions of the connecting links have to be specified by agreement between the manufacturer of the resistors and the manufacturer of the starter.

6 Product information

6.1 Nature of information

6.1.1 Identification

- a) manufacturer's name or trade mark;
- b) type designation or serial number;
- c) number of this document, if the manufacturer claims compliance.

6.1.2 Characteristics, basic rated values and utilization

Characteristics:

- d) rated operational voltages (see 5.3.1.1);
- e) polarity of terminals, if applicable;
- f) utilization category and rated operational currents (or rated powers), at the rated operational voltages of the equipment (see 5.3.2.5 and 5.4);
- g) either the value of the rated frequency 50/60 Hz or the symbol **==** (IEC 60417-5031), or other rated frequencies e.g. 16 2/3 Hz, 400 Hz;
- h) rated duty with the indication of the class of intermittent duty, if any (see 5.3.4), and the off time as specified in footnote d) of Table 10, if necessary;
- i) pole impedance of the switching device (Z);
- j) material declaration according to Annex W of IEC 60947-1:2007/AMD2:2014;

Associated values:

- k) rated making and breaking capacities. These indications may be replaced, where applicable, by the indication of the utilization category in Table 7 and in Table M.2.

Safety and installation:

- l) rated insulation voltage (see 5.3.1.2);
- m) rated impulse withstand voltage (see 5.3.1.3);
- n1) IP code according to Annex C of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010;
- n2) pollution degree (see Clause 7);
- o) short-circuit rating:
 - for contactor or starter: rated conditional short-circuit current (see 5.3.6) and type of co-ordination (see 8.2.5.1) and type, current rating and characteristics of the associated SCPD;
 - for combination starter, combination switching device, protected starter or protected switching device: rated conditional short-circuit current (see 5.3.6) and type of co-ordination (see 8.2.5.1);
 - for MPD, rated ultimate short-circuit breaking capacity (I_{cu}) and rated service short-circuit breaking capacity (I_{cs}) (see 8.2.4.7).
- p1) maximum permissible altitude of the site of installation, if greater than 2 000 m.
- p2) conductor connection on terminal:
 - length of insulation to be removed before insertion of the conductor into the terminal;
 - maximum number of conductors which may be clamped.

For non-universal screwless terminals:

- “s” or “sol” for terminals declared for rigid-solid conductors;
- “r” for terminals declared for rigid (solid and stranded) conductors;
- “f” for terminals declared for flexible conductors.
- q) reference of dedicated wiring accessories which can be used for wiring the starter or the combination of contactors;

Control circuits:

The following information concerning control circuits shall be placed either on the coil or on the equipment:

r) rated control circuit voltage (U_c), nature of current and rated frequency;

NOTE 1 Other information such as the holding or pick-up power could be given e.g. in the product literature.

s) if necessary, nature of current, rated frequency and rated control circuit supply voltage;

In the case of electronically controlled electromagnets, other information may also be necessary, for example control circuit configuration (see 5.5 of this document and Annex U of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014).

Air supply systems for starters or contactors operated by compressed air:

t) rated supply pressure of the compressed air and limits of variation of this pressure, if they are different from those specified in 8.2.1.2.

Auxiliary circuits:

u) ratings of auxiliary circuits (see 5.6).

Over-current relays and releases:

v1) characteristics according to 5.7.2, 5.7.5 and 5.7.6;

v2) characteristics according to 5.7.3 and 5.7.4.

Additional information for certain types of contactor and starter:

Rheostatic rotor starters:

w) circuit diagram;

x) severity of start (see 5.3.5.6.1);

y) starting time (see 5.3.5.6.1).

Auto-transformer starters:

z) rated starting voltage(s), i.e. voltage(s) at the tapping terminals.

NOTE 2 This value can be expressed as a percentage of the rated operational voltage of the starter.

EMC:

aa) environment A or B; see 7.3.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010;

ab) special requirements, if applicable, for example shielded or twisted conductors.

NOTE 3 Unshielded or untwisted conductors are considered as normal installation conditions.

6.2 Marking

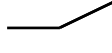
Subclause 5.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies to contactors, starters and overload relays with the following additions.

Data under items d) to ab) in 6.1.2 shall be included on the nameplate or on the equipment or in the manufacturer's published literature.

Data under items c) in 6.1.1, e), n) (if the degree of protection is different than IP00) and v2) in 6.1.2 shall be marked on the equipment; time-current characteristics (or range of characteristics) may be provided in the manufacturer's published literature.

NOTE In the USA and Canada, on multiple equipment, the additional category designation given in Table 1 is marked on the product.

MPSD shall be marked in addition, in a place such that they are visible and legible when the MPSD is installed, for the:

- suitability for isolation, if applicable, with the symbol  (IEC 60617- S00287 "Circuit breaker" combined with IEC 60417-6169-1 "Disconnecter; isolator");
- indication of the open and closed positions, with  (IEC 60417-5008 "OFF" (power)) and  (IEC 60417-5007 "ON" (power)) respectively, if symbols are used (see 7.1.6.1 of IEC 60947-1:2007);

The following data shall be marked externally on the MPSD in a place such they may be visible and legible when the MPSD is installed:

- range of the rated instantaneous short-circuit current setting (I_i), for adjustable releases.

For dedicated accessories used for wiring the starter or the combination of contactors, data under 6.1.1 c), 6.1.2 l) and the current I_{th} , if applicable, shall be provided in the manufacturer's published literature.

6.3 Instructions for installation, operation, maintenance, decommissioning and dismantling

Subclause 5.3 of IEC 60947-1:2007 and IEC 60947-1:2007/AMD2:2014 applies with the following addition.

The instructions shall also cover the dedicated wiring accessories.

Additional information for the decommissioning and dismantling of the device shall be maintained available to the user in case of foreseeable hazardous condition of the device, for example due to stored energy, instability or falling of objects, etc.

In the case of protected starters, the manufacturer shall also provide the necessary mounting and wiring instructions.

The manufacturer of a starter incorporating an automatic reset overload relay capable of being connected to enable automatic restarting, shall provide, with the starter, that information necessary to alert the user to the possibility of automatic restarting.

If the construction requires energization by an external source that is not a limited energy source as defined in 8.1.14, the manufacturer shall provide the appropriate information for short-circuit and overcurrent protection of the ports.

For each relevant potential hazard, the manufacturer shall provide safety signs, graphical symbols or safety notes of the hazard for example by using e.g. IEC 60417-5036. Signal words shall be defined according to ISO 3864-2.

NOTE ISO/IEC 82079-1 provide guidance for developing safety instructions.

6.4 Environmental information

Subclause 5.4 of IEC 60947-1:2007/AMD2:2014 applies.

NOTE Future publication IEC TS 63058 will give the method for assessing the environmental impact of switchgear and controlgear.

7 Normal service, mounting and transport conditions

Clause 6 of IEC 60947-1:2007 applies with the following addition.

Unless otherwise stated by the manufacturer, a contactor or a starter is for use in pollution degree 3 environmental conditions, as defined in 6.1.3.2 of IEC 60947-1:2007. However, other pollution degrees may be considered to apply, depending upon the micro-environment.

Rail mounting shall be specified according to IEC 60715:2017, when relevant.

Standard conditions of vibration are defined in footnote ^b of Table Q.1 of IEC 60947-1:2007/AMD2:2014.

Altitude above 2 000 m are subjected to agreement between manufacturer and user.

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 General

Subclause 7.1.1 of IEC 60947-1:2007 applies with the following addition.

Measures shall be provided to reduce the likelihood of injury and property damage, under installation, maintenance, normal operation conditions, abnormal operation conditions and reasonably foreseeable misuses. The requirements of this document are generically providing these measures.

Protection against hazards caused by the electronic circuits shall be maintained under normal and single fault conditions, as specified in this document.

The risk assessment method of electromechanical overload protection function used in safety application is given in Annex L.

Components used in the construction of the equipment, compliant with a relevant IEC product standard do not require separate evaluation. Components or assemblies of components, for which no relevant product standard exists, shall be tested according to the requirements of this document.

Where the product is intended to be used together with specific auxiliary equipment and dedicated wiring accessories, the safety evaluation and test shall include this auxiliary equipment and accessories unless it can be shown that it does not affect the safety of any equipment.

The accessible part of the device and especially the operating means shall not present sharp edges and corners which can injure the operator.

Annex O of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 should be considered carefully especially for substitution or reduction in use of hazardous substances or if not possible for providing measures to prevent emission and contact with them.

8.1.2 Materials

8.1.2.1 General materials requirements

Subclause 7.1.2.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies with the following additions.

NOTE Fire hazard aspects are detailed in IEC TR 63054.

Parts of insulating materials located in electrical circuits sourced from limited energy sources according to 8.1.14 are not required to comply with the requirements of this subclause.

8.1.2.2 Glow wire testing

Subclause 7.1.2.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies with the following addition.

When tests on the equipment or on sections taken from the equipment are used, parts of insulating materials necessary to retain current-carrying parts in position shall conform to the glow-wire tests of 8.2.1.1.1 of IEC 60947-1:2007 at a test temperature of 850 °C.

8.1.2.3 Test based on flammability category

Subclause 7.1.2.3 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.

8.1.3 Current-carrying parts and their connections

Subclause 7.1.3 of IEC 60947-1:2007 applies.

8.1.4 Clearances and creepage distances

Subclause 7.1.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies with the following additions.

Clearance and creepage distances within the circuits sourced from limited energy sources as defined in 8.1.14 are not required to comply with the requirements of this subclause.

Clearance and creepage distances on printed wiring boards (PWBs) including components mounted on PWBs, for functional, basic, supplementary and reinforced insulation, designed according to 8.1.14, are considered to meet these requirements and do not need any further investigation.

Where SELV and PELV circuits are accessible, they shall be separated from other hazardous-live-part according to the requirements of Annex N for protective impedance in addition to Annex N of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014.

NOTE If some circuits are only accessible under maintenance or similar conditions, they can, depending on the risk level (severity of harm and the probability of occurrence), be considered under normal service conditions (see 6.1), and use only basic insulation. Accessible parts can be determined using test probes according to IEC 61032.

8.1.5 Actuator

8.1.5.1 Insulation

Subclause 7.1.5.1 of IEC 60947-1:2007 applies.

8.1.5.2 Direction of movement

Subclause 7.1.5.2 of IEC 60947-1:2007 applies.

8.1.5.3 Mounting

Actuators mounted on removable panels or opening doors shall be so designed that, when the panels are replaced or the doors closed, the actuator will engage correctly with the associated mechanism.

8.1.5.4 Protection

There shall be no path or opening which allows incandescent particles to be discharged from the area of the manual operating means.

8.1.6 Indication of the contact position

8.1.6.1 Indicating means

Subclause 7.1.6.1 of IEC 60947-1:2007 applies to manually operated starters.

8.1.6.2 Indication by the actuator

Subclause 7.1.6.2 of IEC 60947-1:2007 applies.

8.1.7 Additional requirements for equipment suitable for isolation

Subclause 7.1.7 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with the following additions:

If the tripped position of the MPSD is not the indicated open position, it should be clearly visible that it is not the open position. The verification of the main contact position for a manual starter and a MPSD suitable for isolation shall be tested according to 9.3.3.2.3.

MPSDs and manual motor starter suitable for isolation shall be provided with means for locking in the open position.

8.1.8 Terminals

8.1.8.1 General

Subclause 7.1.8 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with the following additions.

8.1.8.2 Terminal identification and marking

Subclause 7.1.8.4 of IEC 60947-1:2007 applies with additional requirements as given in Annex A.

8.1.9 Additional requirements for equipment provided with a neutral pole

Subclause 7.1.9 of IEC 60947-1:2007 applies.

8.1.10 Provisions for protective earthing

Subclause 7.1.10 of IEC 60947-1:2007 applies.

8.1.11 Enclosures for equipment

8.1.11.1 Design

Subclause 7.1.11.1 of IEC 60947-1:2007 applies with the following additions.

Starting resistors mounted within an enclosure shall be so located or guarded that issuing heat is not detrimental to other apparatus and materials within the enclosure.

For the specific case of combination starters, the cover or door shall be interlocked so that it cannot be opened without the manually operated switching device being in the open position.

However, provision may be made to open the door or cover with the manually operated switching device in the ON position by the use of a tool.

8.1.11.2 Insulation

Subclause 7.1.11.2 of IEC 60947-1:2007 applies.

8.1.12 Degrees of protection of enclosed equipment

Subclause 7.1.12 of IEC 60947-1:2007 applies.

8.1.13 Conduit pull-out, torque and bending with metallic conduits

Subclause 7.1.13 of IEC 60947-1:2007 applies.

8.1.14 Limited energy source

8.1.14.1 General

A limited energy source can be implemented as a secondary circuit derived from circuits connected to the hazardous-live-part with the following separation means:

- a) galvanic separation;
- b) current limiting impedance.

NOTE Class 2 sources as defined in NFPA 70, National Electrical Code and CSA C22.1 Canadian Electrical Code (CE Code) have the same electrical output characteristics as limited energy sources with galvanic separation.

8.1.14.2 Limited energy source with galvanic separation

A limited energy source with galvanic separation incorporates an isolating component such as a transformer between the primary circuit and the limited energy output. It shall comply with one of the following requirements:

- a) the output is inherently limited in compliance with Table 19; or
- b) a linear or non-linear impedance limits the output in compliance with Table 19. If a positive temperature coefficient device (e.g. PTC) is used, it shall pass the applicable tests specified in IEC 60730-1; or
- c) a regulating network limits the output in compliance with Table 19, both with and without a single fault in the regulating network; or
- d) an over-current protective device is used and the output is limited in compliance with Table 20.

Where an over-current protective device is used, it shall be a fuse or non-adjustable electromechanical device.

Compliance to determine the maximum available power is checked by test of 9.2.4.

In case of external power supply without over-current protective devices, it shall not exceed the values given in Table 19. In case of external power supply with over-current protective devices, it shall not exceed the values given in Table 20.

Table 19 – Limits for limited energy sources without an over-current protective device

Output voltage ^a		Output current ^{b, d} I_{sc} A	Maximum power ^c S VA
V AC	V DC		
≤ 30 RMS	≤ 30 V	≤ 8	100
-	$30 < U_{oc} \leq 60$ ^e	$\leq \frac{150}{U_{oc}}$	100

NOTE This table will be moved into the future revision of IEC 60947-1 and is therefore numbered differently to the other tables in this document.

^a U_{oc} : Output voltage measured in accordance with all load circuits disconnected. Voltages are for substantially sinusoidal alternating current and ripple-free direct current. For non-sinusoidal alternating current and direct current with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V.

^b I_{sc} : Maximum output current with any non-capacitive load, including a short-circuit.

^c S (VA): Maximum output apparent power in VA with any non-capacitive load as determined by 9.2.4.

^d Measurement of I_{sc} is made 5 s after application of the load if protection is by an electronic circuit or a positive temperature coefficient device (e.g. PTC), and 60 s in other cases.

^e In the USA, the limit is 60 V DC continuous or direct current switching outside of 10 Hz to 200 Hz, 24,8 V DC switching at 10 Hz to 200 Hz.

Table 20 – Limits for limited energy sources with an over-current protective device

Output voltage ^a		Output current ^{b, d} I_{sc} A	Maximum power ^{c, d} S VA	Current rating of over-current protective device ^e A
V AC	V DC			
≤ 20	≤ 20	$\leq \frac{1000}{U_{oc}}$	250	$\leq 5,0$
$20 < U_{oc} \leq 30$	$20 < U_{oc} \leq 30$ ^f			$\leq \frac{100}{U_{oc}}$
-	$30 < U_{oc} \leq 60$ ^f			$\leq \frac{100}{U_{oc}}$

NOTE 1 The reason for making measurements with over-current protective devices bypassed is to determine the amount of energy that is available to cause possible overheating during the operating time of the over-current protective devices.

NOTE 2 This table will be moved into the future revision of IEC 60947-1 and is therefore numbered differently to the other tables in this document.

^a U_{oc} : Output voltage measured with all load circuits disconnected. Voltages are for substantially sinusoidal alternating current and ripple free direct current. For non-sinusoidal alternating current and for direct current with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V.

^b I_{sc} : Maximum output current with any non-capacitive load, including a short-circuit, measured 60 s after application of the load.

^c S (VA): Maximum output VA with any non-capacitive load measured 60 s after application of the load as determined by 9.2.4.

^d Current limiting impedances remain in the circuit during measurement, but over-current protective devices are bypassed.

^e The current ratings of over-current protective devices that break the circuit within 120 s with a current equal to 210 % of the current rating specified in the table.

^f In the USA, the limit is 60 V DC continuous or direct current switching outside of 10 Hz to 200 Hz, 24,8 V DC switching at 10 Hz to 200 Hz.

8.1.14.3 Limited energy source with current limiting impedance

A limited energy source with current limiting impedance has the following characteristics:

- a) the output voltage is limited in compliance with Table 21 and
- b) a linear or non-linear impedance limits the output in compliance with Table 21 both with and without a single fault.

A limited energy source with current limiting impedance may be derived from either mains or from a galvanically separated circuit e.g. the secondary of a transformer.

Table 21 – Limits for limited energy source with current limiting impedance

Output voltage ^a		Output current ^{b, d}	Maximum power ^c
V AC	V DC		
≤ 30 V RMS	≤ 30 V	I_{sc} A	S VA
		0,5	15
NOTE This table will be moved into the future revision of IEC 60947-1 and is therefore numbered differently to the other tables in this document. ^a U_{oc}: Output voltage measured in accordance with all load circuits disconnected. Voltages are for substantially sinusoidal alternating current and ripple-free direct current. For non-sinusoidal alternating current and direct current with ripple greater than 10 % of the peak, the peak voltage shall not exceed 42,4 V. ^b I_{sc}: Maximum output current measured across the output of the limited energy source. ^c S (VA): Maximum output apparent power in VA as determined by 9.2.4. ^d Measurement of I_{sc} is made 5 s after application of the short-circuit.			

8.1.15 Stored charge energy circuit

Parts including stored charge (capacitors) that are removable for servicing (such as coil replacement), installation, or disconnection shall present no risk of electric energy hazard after disconnection.

Capacitors connected to accessible hazardous live parts shall be discharged to an energy level less than 0.5 mJ within 5 s after the removal of power. Otherwise, a readily visible warning notice shall be provided on the product, indicating the time of discharge to the limit values or a preferable method how to discharge the capacitor before touching the connecting parts.

8.1.16 Fault and abnormal conditions

The product shall be designed to avoid operating modes or sequences that can cause a fault condition or component failure leading to a hazard, unless other measures to prevent the hazard are provided by the installation and are described in the installation information provided with the product. The requirements in this clause also apply to abnormal operating conditions as applicable.

Circuit analysis or testing shall be performed to determine whether or not failure of a particular component (including insulation systems) would result in hazard.

This analysis shall include situations where a failure of the component or the insulation (basic and supplementary) would result in:

- an impact on the risk of electric shock;
- a risk of degradation resulting in emission of flame, burning particles or molten metal.

The analysis or testing shall include the effect of short-circuit and open-circuit conditions of the component. Testing is necessary unless analysis can conclusively show that, in short-circuit and open circuit conditions, no shock and fire hazard will result from failure of the component. Compliance shall be checked by test of 9.2.5.

Components evaluated for their reliability according to relevant product standards are considered to meet these requirements and do not need any further investigation, if tested under conditions that fulfil the conditions for which the product is designed.

8.1.17 Short-circuit and overload protection of ports

Where the power source for a signal port or power port that is external to the device does not comply with the requirements for limited energy sources in 8.1.14, the product shall not present a hazard under short-circuit or overload conditions. Instructions for the installation of external overcurrent protection shall be made available in accordance with 6.3.

Compliance shall be checked by inspection and where necessary, by simulation of single fault conditions.

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 General

8.2.1.1.1 General conditions

Subclause 7.2.1.1 of IEC 60947-1:2007 applies with the following additions.

The requirements for the short-circuit protective device of a combination starter or a protected starter are given by IEC 60947-2 for circuit-breaker, by IEC 60947-3 for fuse-combination unit and by this document for MPSP.

Requirements concerning normal load and overload characteristics according to 5.3.5 are given in 8.2.4.1, 8.2.4.2 and 8.2.4.4.

The requirements apply to the product as well as to the dedicated wiring accessories.

If there is no distinction between U_s and U_c , requirements apply with U_c .

8.2.1.1.2 General conditions A

Starters shall be so constructed that they:

- a) are trip free;
- b) can be caused to open their contacts by the means provided when running and at any time during the starting sequence;
- c) will not function in other than the correct starting sequence.

8.2.1.1.3 General conditions B

Starters employing contactors shall not trip due to the shocks caused by operation of the contactors when tested according to 9.3.3.1, after the starter has carried its rated full load current at the reference ambient temperature (i.e. +20 °C) and has reached thermal equilibrium at both minimum and maximum settings of the overload relay, if adjustable.

8.2.1.1.4 General conditions C

For rheostatic starters, the overload relay shall be connected in the stator circuit. Special arrangements may be made to protect the rotor contactors and resistors against overheating, if requested by the user.

8.2.1.1.5 General conditions D

When starters are used in conditions in which the overheating of the starting resistors or transformers would represent an exceptional hazard, it is recommended that a suitable device be fitted to switch off the starter automatically before a dangerous temperature is reached.

8.2.1.1.6 General conditions E

The moving contacts of multipole equipment intended to make and break together shall be so coupled that all poles make and break substantially together, whether operated manually or automatically.

8.2.1.2 Limits of operation of contactors and power-operated starters

Subclause 7.2.1.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with following additions:

For latched contactors, the device shall drop out and open fully when a de-latching voltage between 85 % and 110 % of the rated de-latching voltage is applied.

8.2.1.3 Limits of operation of under-voltage relays and releases

Subclause 7.2.1.3 of IEC 60947-1:2007 applies with the following addition: tests are specified in 9.3.3.2.2 of this document.

8.2.1.4 Limits of operation of shunt-coil operated releases (shunt trip)

Subclause 7.2.1.4 of IEC 60947-1, IEC 60947-1:2007/AMD2:2014 applies with the following addition: tests are specified in 9.3.3.2.2 of this document.

8.2.1.5 Limits of operation of current sensing relays and releases

8.2.1.5.1 Limits of operation of time-delay overload relays when all poles are energized

8.2.1.5.1.1 General tripping requirements of overload relays

NOTE 1 The thermal protection of motors in the presence of harmonics in the supply voltage is under consideration.

The relays shall comply with the requirements of Table 3 when tested as follows:

- with the overload relay or starter in its enclosure, if normally fitted, and at A times the current setting, tripping shall not occur in less than 2 h starting from the cold state, at the value of reference ambient air temperature stated in Table 3. However, when the overload relay terminals have reached thermal equilibrium at the test current in less than 2 h, the test duration can be the time needed to reach such thermal equilibrium;
- when the current is subsequently raised to B times the current setting, tripping shall occur in less than 2 h;
- for class 2, 3, 5 and 10A overload relays energized at C times the current setting, tripping shall occur in less than 2 min starting from thermal equilibrium, at the current setting, in accordance with 9.3.3 of IEC 60034-1:2017; for class 10A overload relays, for ambient air temperature $-5\text{ }^{\circ}\text{C}$ or below, the manufacturer may declare a longer tripping time but not longer than 4 min;

NOTE 2 Subclause 9.3.3 of IEC 60034-1:2017 states: "Polyphase motors having rated outputs not exceeding 315 kW and rated voltages not exceeding 1 kV shall be capable of withstanding a current equal to 1,5 times the rated current for not less than 2 min".

- d) for class 10, 20, 30 and 40 overload relays energized at *C* times the current setting, tripping shall occur in less than 4 min, 8 min, 12 min or 16 min respectively, starting from thermal equilibrium, at the current setting;
- e) at *D* times the current setting, tripping shall occur within the limits given in Table 2 for the appropriate trip class and tolerance band, starting from the cold state.

In the case of overload relays having a current setting range, the limits of operation shall apply when the relay is carrying the current associated with the maximum setting and also when the relay is carrying the current associated with the minimum setting.

For non-compensated overload relays, the current multiple/ambient temperature characteristic shall not be greater than 1,2 %/K.

NOTE 3 1,2 %/K is the derating characteristic of PVC-insulated conductors.

An overload relay is regarded as compensated if it complies with the relevant requirements of Table 3 at +20 °C and is within the limits shown in Table 3 at other temperatures (see Figure 1).

Table 3 – Limits of operation of time-delay overload relays when energized on all poles

Type of overload relay	Multiples of current setting				Ambient air temperature values
	A	B	C	D	
Thermal type not compensated for ambient air temperature variations	1,0	1,2 ^b	1,5	7,2	+40 °C
Thermal type compensated for ambient air temperature variations	c	c	–	–	less than -5 °C ^d
	1,05	1,3	1,5	–	-5 °C
	1,05	1,2 ^b	1,5	7,2	+20 °C
	1,0	1,2 ^b	1,5	–	+40 °C
	c	c	–	–	more than +40 °C ^d
Electronic type ^a	1,05	1,2 ^b	1,5	7,2	0 °C, +20 °C and +40 °C
^a This test shall only be done at 20 °C for A, B and D multiples of current setting. ^b If specified by the manufacturer, the tripping current could be different from 120 % but shall not exceed 125 %. In this case the test current value shall be equal to this tripping current value. In this case, the tripping current value shall be marked on the device. ^c Multiples of current setting should be declared by the manufacturer. ^d See 9.3.3.2.2 for tests outside the -5 °C +40 °C range.					

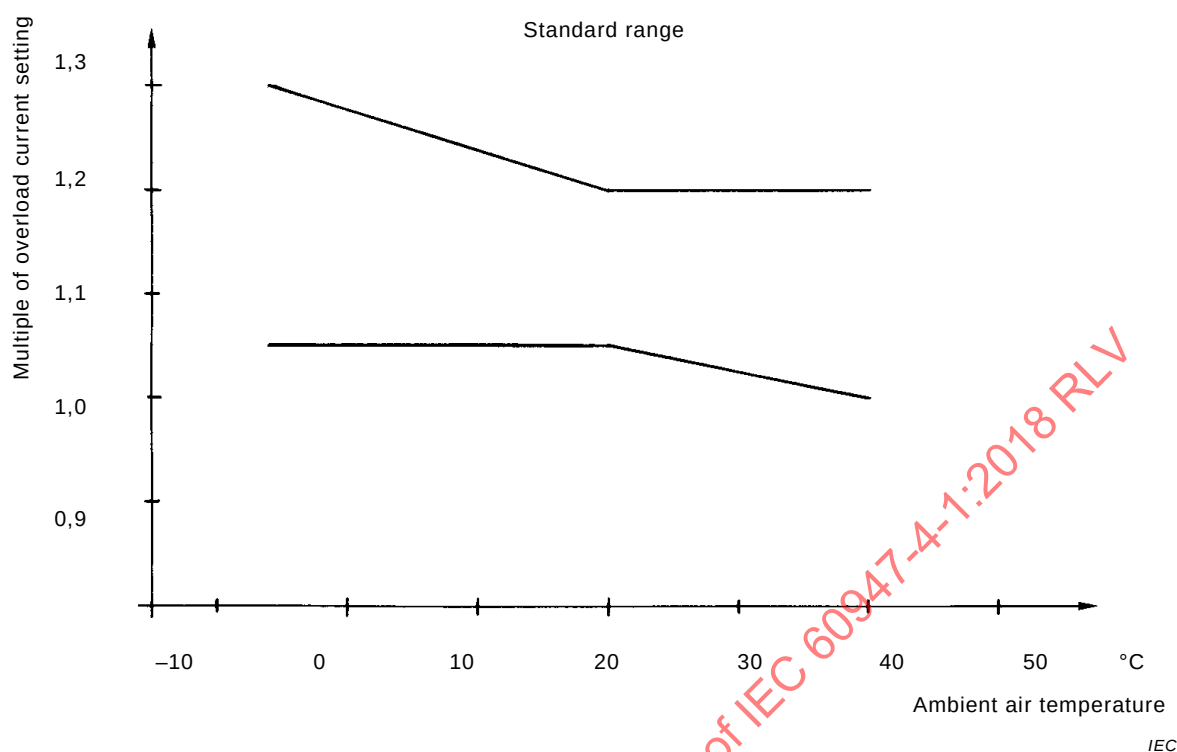


Figure 1 – Multiple of current setting limits for ambient air temperature compensated time-delay overload relays

8.2.1.5.1.2 Thermal memory test verification

Unless the manufacturer has specified that the device does not contain thermal memory, electronic overload relays shall fulfil the following requirements (see Figure 2):

- apply a current equal to I_e until the device has reached the thermal equilibrium;
- interrupt the current for a duration of $2 \times T_p$ (see Table 2) with a relative tolerance of $\pm 10\%$ (where T_p is the time measured at the D current according to Table 3);
- apply a current equal to $7,2 \times I_e$;
- the relay shall trip within 50 % of the time T_p .

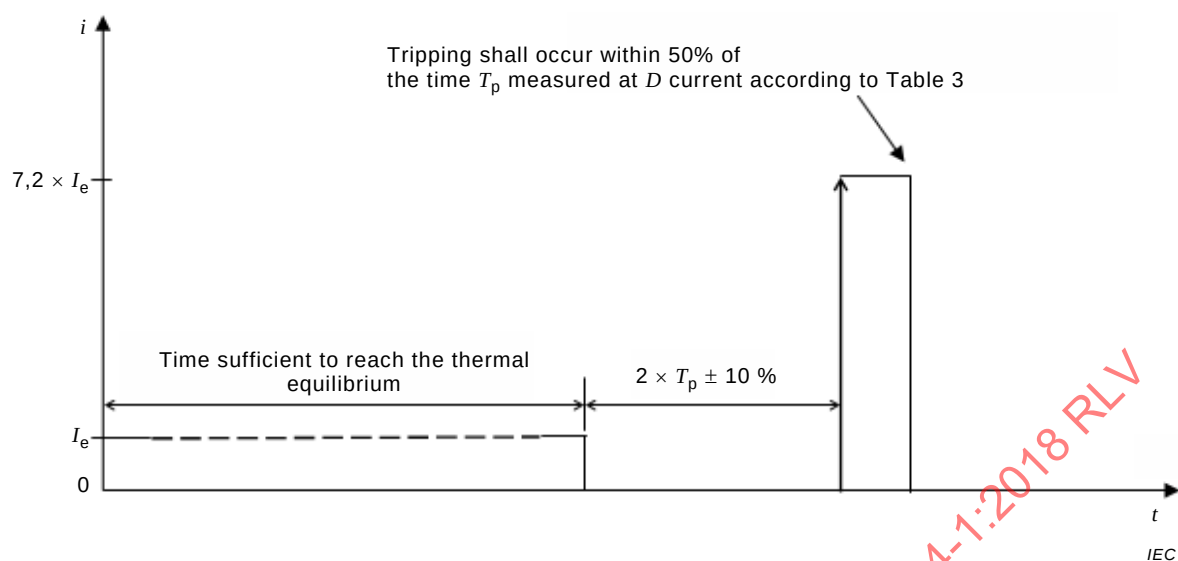


Figure 2 – Thermal memory test

8.2.1.5.2 Limits of operation of three-pole time-delay overload relays energized on two poles

With reference to Table 4:

The overload relay or starter shall be tested in its enclosure if normally fitted. With the relay energized on three poles, at A times the current setting, tripping shall not occur in less than 2 h, starting from the cold state, at the value of the ambient air temperature stated in Table 4.

Moreover, when the value of the current flowing in two poles (in phase loss sensitive overload relay or release, those carrying the higher current) is increased to B times the current setting, and the third pole de-energized, tripping shall occur in less than 2 h.

The values shall apply to all combinations of poles.

In the case of overload relays having an adjustable current setting, the characteristics shall apply both when the relay is carrying the current associated with the maximum setting and when the relay is carrying the current associated with the minimum setting.

Table 4 – Limits of operation of three-pole time-delay overload relays when energized on two poles only

Type of overload relay	Multiples of current setting		Reference ambient air temperature
	A	B	
Thermal, compensated for ambient air temperature variations or electronic Not phase loss sensitive	3 poles 1,0	2 poles 1,32 1 pole 0	+20 °C
Thermal, not compensated for ambient air temperature variations Not phase loss sensitive	3 poles 1,0	2 poles 1,25 1 pole 0	+40 °C
Thermal, compensated for ambient air temperature variations or electronic Phase loss sensitive	2 poles 1,0 1 pole 0,9	2 poles 1,15 1 pole 0	+20 °C

8.2.1.5.3 Limits of operation of instantaneous magnetic overload relays

For all values of the current setting, instantaneous magnetic overload relays shall trip with an accuracy of $\pm 10\%$ of the value of the published current value corresponding to the current setting.

NOTE Magnetic instantaneous overload relays covered by this document are not intended for short-circuit protection.

8.2.1.5.4 Limits of operation of under-current relays and releases for automatic change over

8.2.1.5.4.1 Limits of operation of under-current relays

An under-current relay or release, when associated with a switching device, shall operate to open the switching device within 80 % to 120 % of the set time, when the current during operation is below 0,9 times the under current setting in all poles. When the operating time is below 1 s, a different tolerance may be given by the manufacturer but the upper limit shall not exceed 1,2 s.

NOTE The tolerance depends on the sensing technology.

8.2.1.5.4.2 Limits of operation of automatic change over by under-current relays

This subclause applies to:

- star-delta starters from star to delta, and
- auto-transformer starters from the starting to the ON position.

The lowest drop-out current of an under-current relay shall be not greater than 1,5 times the actual current setting of the overload relay which is active in the starting or star connection. The under-current relay shall be able to carry any value of current, from its lowest current setting to the stalled current in the starting position or the star connection, for the tripping times determined by the overload relay at its highest current setting.

8.2.1.5.5 Limits of operation of stall relays

A stall relay, when associated with a switching device, shall operate to open the switching device within 80 % to 120 % of the set time (stall inhibit time) or within the accuracy specified by the manufacturer, when:

- a) current sensing relays: the current is 20 % higher than the set stall current value;

EXAMPLE Set current of the stall relay: 100 A; set time: 6 s; accuracy: $\pm 10\%$, the relay shall trip within 5,4 s and 6,6 s when the current is equal to or greater than $100\text{ A} \times 1,2 = 120\text{ A}$.

- b) rotation sensing relays: an input signal indicating no motor rotation exists.

8.2.1.5.6 Limits of operation of jam relays and releases

A jam relay or release, when associated with a switching device, shall operate to open the switching device within 80 % to 120 % of the set time (jam inhibit time) or within the accuracy specified by the manufacturer, when the current is above 1,2 times the set current value of the jam relay, during running after completion of the starting.

8.2.1.5.7 Limits of operation of the short-circuit release of a MPSD

The operation of short-circuit release of a MPSD shall cause its tripping with an accuracy of $\pm 20\%$ of the tripping current value of the current setting for all values of the current setting of the short-circuit release when adjustable.

8.2.2 Temperature-rise

8.2.2.1 General

The requirements of 7.2.2 of IEC 60947-1:2007 apply to contactors and starters in a clean, new condition.

NOTE 1 Contact resistance due to oxidation can impact the temperature-rise test at test voltages below 100 V. In the case of conducting the test at a voltage below 100 V, such devices can have the contacts cleaned either by any nonabrasive method or by carrying out 10 operating cycles under the conditions of Table 10 for any applicable utilization category at any voltage.

The temperature-rises of the several parts of the contactor or starter measured during a test carried out under the conditions specified in 9.3.3 shall not exceed the limiting values stated in Table 5 of this document and in 7.2.2.1 and 7.2.2.2 of IEC 60947-1:2007.

In the case of an electronically controlled electromagnet, coil temperature measuring by variation of resistance may be impracticable; in such a case, other methods are permitted, e.g. thermocouples or other suitable methods.

Table 5 – Temperature-rise limits for insulated coils in air and in oil

Class of insulating material (according to IEC 60085:2007)	Temperature-rise limit (measured by resistance variation) K	
	Coils in air	Coils in oil
A	85	60
E	100	60
B	110	60
F	135	–
H	160	–

Because, in an auto-transformer starter, the auto-transformer is energized only intermittently, a maximum temperature-rise of 15 K greater than the figures in Table 5 is permissible for the windings of the transformer when the starter is operated according to the requirements of 5.3.4 and 5.3.5.6.4.

NOTE 2 The temperature-rise limits given in Table 5 of this document and in 7.2.2.2 of IEC 60947-1:2007 are applicable only if the ambient air temperature remains within the limits -5°C , $+40^{\circ}\text{C}$.

8.2.2.2 Terminals

Subclause 7.2.2.1 of IEC 60947-1:2007 applies.

8.2.2.3 Accessible parts

Subclause 7.2.2.2 of IEC 60947-1:2007 applies.

8.2.2.4 Ambient air temperature

Subclause 7.2.2.3 of IEC 60947-1:2007 applies.

8.2.2.5 Main circuit

The main circuit of a contactor or a starter which carries current in the ON position, including the over-current releases which may be associated with it, shall be capable of carrying, without the temperature-rises exceeding the limits specified in 7.2.2.1 of IEC 60947-1:2007 when tested in accordance with 9.3.3.3.4:

- for a contactor or starter intended for continuous duty: its conventional thermal current (see 5.3.2.1 and/or 5.3.2.2);
- for a contactor or starter intended for uninterrupted duty, intermittent duty or temporary duty: its relevant rated operational current (see 5.3.2.5).

8.2.2.6 Control circuits

Subclause 7.2.2.5 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies.

8.2.2.7 Windings of coils and electromagnets

8.2.2.7.1 Uninterrupted and eight-hour duty windings

With the maximum value of current according to 8.2.2.5 flowing through the main circuit, the windings of the coils, including those of electrically operated valves of electro-pneumatic contactors or starters, shall withstand, under continuous load and at the rated frequency, if applicable, their maximum rated control circuit supply voltage without the temperature-rise exceeding the limits specified in Table 5 of this document and in 7.2.2.6 of IEC 60947-1:2007.

NOTE Depending on the technology, e.g. for some kinds of electronically controlled electromagnets, the control supply voltage cannot be directly applied on the coil winding when connected as in normal service.

8.2.2.7.2 Intermittent duty windings

With no current flowing through the main circuit, the windings of the coils shall withstand, at the rated frequency, if applicable, their maximum rated control circuit supply voltage applied as detailed in Table 6 according to their intermittent duty class, without the temperature-rise exceeding the limits specified in Table 5 of this document and in 7.2.2.2 of IEC 60947-1:2007.

NOTE Depending on the technology, e.g. for some kind of electronically controlled electromagnet, the control supply voltage cannot be directly applied on the coil winding when connected as in normal service.

Table 6 – Intermittent duty test cycle data

Intermittent duty class		One close-open operating cycle every	Interval of time during which the supply to the control coil is maintained
Contactors	Starters		
1	1	3 600 s	"ON" time should correspond to the on-load factor specified by the manufacturer
3	3	1 200 s	
12	12	300 s	
30	30	120 s	
120		30 s	
300		12 s	
1 200		3 s	

8.2.2.7.3 Specially rated (temporary or periodic duty) windings

Specially rated windings shall be tested under operating conditions corresponding to the most severe duty for which they are intended and their ratings shall be stated by the manufacturer.

NOTE Specially rated windings can include coils of starters which are energized during the starting period only, trip coils of latched contactors and certain magnetic valve coils for interlocking pneumatic contactors or starters.

8.2.2.8 Auxiliary circuits

Subclause 7.2.2.7 of IEC 60947-1:2007 applies.

8.2.2.9 Other parts

Subclause 7.2.2.8 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies, replacing words "plastics and insulating materials" with "insulating parts".

8.2.3 Dielectric properties

8.2.3.1 General

Subclause 7.2.3 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with the following additions:

8.2.3.2 Voltage limiting components between circuits

General requirements for device including voltage limiting components inserted between circuits not connected to the ground/earth to be tested according to the dielectric test are described as follows.

These voltage limiting components called varistors used in order to protect electronic parts from surges within the device shall comply with IEC 61051-2. In this clause, the intent is not

to reduce the clearances. For the type test of the device the voltage limiting components may be disconnected.

IEC 61051-2 applies as follows:

a) Preferred climatic categories of the varistor:

- maximum lower temperature: -10 °C;
- minimum upper temperature: +85 °C.

The device manufacturer has to verify that the varistor is suitable for use in the extended ambient temperature if any.

b) The minimum rated voltage of the varistor shall be 1,2 times the maximum peak voltage where the varistor is connected.

c) When connected to the mains, varistors shall withstand the surge test according to 9.4.2.5.

NOTE 1 With the verification of the varistors above, it is assumed that a fuse protecting the varistor is not necessary.

NOTE 2 The possibility given in 8.3.3.4.1 item 1) of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 of disconnecting circuits between poles can be not appropriate in the routine test, because the products are completed and it is not appropriate to reopen and manipulate them. The main purpose of this test is to identify the proper operation of the voltage limiting component.

8.2.4 Normal load and overload performance requirements

8.2.4.1 Making and breaking capacities

Contactors or starters shall be capable of making and breaking currents without failure under the conditions stated in Table 7 for the required utilization categories and the number of operations indicated, as specified in 9.3.3.5.

The off-time and on-time values given in Table 7 and Table 8 shall not be exceeded.

These capacities correspond to the normal load characteristics given in 5.3.5.3 and 5.3.5.4.

MPSD shall be tested under the conditions stated in Table 7 with following exceptions:

- If the overload release trips during the test, the off-time may be extended up to the point where no tripping occurs.
- If the short-circuit release trips during the test, the instantaneous short-circuit release shall be inhibited. If the instantaneous short-circuit current rating is lower than the test current, the test current may be reduced to the value of the rated instantaneous short-circuit current setting (I_i) plus 20 % if the manufacturer is not giving a lower tolerance. In case of an adjustable instantaneous tripping unit the trip setting has to be set to the maximum value of the setting.

- a $\cos \phi = 0,45$ for $I_e \leq 100$ A; $0,35$ for $I_e > 100$ A.
- b The time may be less than 0,05 s, provided that contacts are allowed to become properly seated before re-opening. For testing feasibility reason, in agreement with the manufacturer, a longer on-time time may be defined.
- c Tests to be carried out with an incandescent light load.
- d If polarity not marked on the device, 25 operating cycles with one polarity and 25 operating cycles with reverse polarity.
- e The load shall consist of commercially available capacitor combinations to obtain a steady-state reactive current I_e calculated according to 9.3.3.3.4. Alternatively, capacitive ratings may be derived by capacitor switching tests or assigned on the basis of established practice and experience. As a guide, reference may be made to the formula given in Table 9 which does not take into account the thermal effects due to harmonic currents. The available current capacity at the test terminals shall not be less than the prospective current "r". It can be determined by analytical evaluation.
- f Maximum off-time given in Table 8 which can be reduced in agreement with the manufacturer.
- g For U / U_e , a tolerance of ± 20 % is accepted.
- h The values shown are for stator contactors. For rotor contactors, the test shall be made with a current of four times the rated rotor operational current and a power factor of 0,95.
- i The make conditions for utilization categories AC-3, AC-3e and AC-4 shall also be verified. The verification may be made during the make and break test, but only with the manufacturer's agreement. In this case, the making current multiples shall be as shown for I / I_e and the breaking current as shown for I_c / I_e . 25 operating cycles shall be made at a control supply voltage equal to 110 % of the rated control circuit supply voltage U_s and 25 operating cycles at 85 % of U_s .
- j The manufacturer shall verify the AC-6a rating by testing with a transformer or may derive the rating from the values for AC-3 according to Table 9.
- k A lower ratio of I_c / I_e (locked rotor to full load current) may be used if specified by the manufacturer.
- l The on time shall be long enough in order to reach the stabilized current.
- m Off-time according to Table 8. The value of a discharge resistor shall be determined to reach less than 50 V at the end of off-time.
- n As an alternative the factor I / I_e can be selected at the manufacturer discretion between 12 and 13. In this case the power factor is given by the following formulas:

$$I_e \leq 100 \text{ A: } \cos \phi = 0,1 \times I / I_e - 0,85$$

$$I_e > 100 \text{ A: } \cos \phi = 0,1 \times I / I_e - 0,95$$
- o $\cos \phi = 0,35$ for $I_e \leq 100$ A; $\cos \phi = 0,25$ for $I_e > 100$ A

Table 8 – Relationship between the test current and off-time for the verification of rated making and breaking capacities

Test current <i>I</i> A	Off-time s
$I \leq 100$	10
$100 < I \leq 200$	20
$200 < I \leq 300$	30
$300 < I \leq 400$	40
$400 < I \leq 600$	60
$600 < I \leq 800$	80
$800 < I \leq 1\,000$	100
$1\,000 < I \leq 1\,300$	140
$1\,300 < I \leq 1\,600$	180
$1\,600 < I \leq 2\,500$	240
$2\,500 < I$	agreement between user and manufacturer

The off-time values may be reduced if agreed by the manufacturer.

Table 9 – Operational current determination for utilization categories AC-6a and AC-6b when derived from AC-3 ratings

Rated operational current	Determination from making current for utilization category AC-3
I_e (AC-6a) for switching of transformers having inrush current peaks of not more than 30 times peak of rated current	$0,45 I_e$ (AC-3)
I_e (AC-6b) for switching of single capacitor banks in circuits having a prospective short-circuit current i_k at the location of the capacitor bank	$i_k \frac{x^2}{(x-1)^2}$ with $x = 13,3 \times \frac{I_e \text{ (AC-3)}}{i_k}$ and for $i_k > 205 I_e \text{ (AC-3)}$
The expression for the operational current I_e (AC-6b) emanates from the formula for the highest inrush current peak: $I_{pmax} = \frac{U_e \times \sqrt{2}}{\sqrt{3}} \times \frac{1 + \sqrt{\frac{X_C}{X_L}}}{X_L - X_C}$ where U_e is the rated operational voltage; X_L is the short-circuit impedance of the circuit; X_C is the reactance of the capacitor bank. This formula is valid on condition that capacitance on the supply side of the contactor or starter can be neglected and that there is no initial charge on the capacitor.	

Subclause 7.2.4.2 of IEC 60947-1:2007 applies with the following addition.

Contractors or starters shall be capable of making and breaking currents without failure under the conventional conditions stated in Table 10 for the required utilization categories and the number of operating cycles indicated as specified in 9.3.3.6. MPSP shall be tested under the same conditions stated in Table 10 with following exceptions:

If the overload release trips during the test, the off-time may be extended up to the point where no tripping occurs.

Table 10 – Conventional operational performance – Making and breaking conditions according to utilization category

Utilization category	Make and break test conditions					
	I_c / I_e	U_r / U_e	$\cos \phi$	On-time s	Off-time s	Number of operating cycles
AC-1	1,0	1,05	0,80	0,05 ^b	^c	6 000 ⁱ
AC-2	2,0	1,05	0,65	0,05 ^b	^c	6 000 ⁱ
AC-3, AC-3e	2,0	1,05	^a	0,05 ^b	^c	6 000 ⁱ
AC-4	6,0	1,05	^a	0,05 ^b	^c	6 000 ⁱ
AC-5a	2,0	1,05	0,45	0,05 ^b	^c	6 000 ⁱ
AC-5b	1,0 ^e	1,05	^e	0,05 ^b	60	6 000 ⁱ
AC-6a	^g	^g	^g	^g	^g	^g
AC-6b	1 ^k	1,05		^l	^m	6 000
AC-8a	1,0	1,05	0,80	0,05 ^b	^c	30 000
AC-8b ^{h, j}	6,0	1,05	^a	1	9	5 900
				10	90 ^d	100
Utilization category	I_c / I_e	U_r / U_e	L / R ms	On-time s	Off-time s	Number of operating cycles
DC-1	1,0	1,05	1,0	0,05 ^b	^c	6 000 ^f
DC-3	2,5	1,05	2,0	0,05 ^b	^c	6 000 ^f
DC-5	2,5	1,05	7,5	0,05 ^b	^c	6 000 ^f
DC-6	1,0 ^e	1,05	^e	0,05 ^b	60	6 000 ^f

I_c = current made or broken. Except for AC-5b, AC-6 or DC-6 categories, the making current is expressed in direct current or alternating current RMS symmetrical values but it is understood that for alternating current the actual peak value during the making operation may assume a higher value than the symmetrical peak value.

I_e = rated operational current

U_r = power frequency or direct current recovery voltage

U_e = rated operational voltage

$\cos \phi$ = power factor of test circuit

L / R = time-constant of test circuit

^a $\cos \phi = 0,45$ for $I_e \leq 100$ A; $0,35$ for $I_e > 100$ A.

^b The time may be less than 0,05 s, provided that contacts are allowed to become properly seated before re-opening. For testing feasibility reason, in agreement with the manufacturer, a longer on-time time may be defined.

^c These off-times shall be not greater than the values specified in Table 8.

^d The manufacturer may choose any value for the off-time up to 200 s.

- ^e Tests to be carried out with an incandescent light load.
- ^f If polarity not marked on the device, 3 000 operating cycles with one polarity and 3 000 operating cycles with reverse polarity.
- ^g The manufacturer shall verify the AC-6a rating by testing with a transformer or may derive the rating from the values for AC-3 according to Table 9.
- ^h Tests for category AC-8b shall be accompanied by tests for category AC-8a. The tests may be made on different samples.
- ⁱ For manually operated switching devices, the number of operating cycles shall be 1 000 on-load, followed by 5 000 off-load.
- ^j A lower ratio of I_c / I_e (locked rotor to full load current) may be used if specified by the manufacturer.
- ^k The load shall consist of commercially available capacitor combinations to obtain a steady-state reactive current I_e calculated according to 9.3.3.3.4. Alternatively, capacitive ratings may be derived by capacitor switching tests or assigned on the basis of established practice and experience. As a guide, reference may be made to the formula given in Table 9 which does not take into account the thermal effects due to harmonic currents. The available current capacity at the test terminals shall not be less than the prospective current "r". It can be determined by analytical evaluation.
- ^l The on time shall be long enough in order to reach the stabilized current.
- ^m Off-time according to Table 8. The value of a discharge resistor shall be determined to reach less than 50 V at the end of off-time.

8.2.4.3 Durability

8.2.4.3.1 Mechanical durability

Subclause 7.2.4.3.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with the following addition:

The mechanical durability of a contactor or starter is verified by a special test conducted at the discretion of the manufacturer. Recommendations for conducting this test are given in Annex B.

8.2.4.3.2 Electrical durability

Subclause 7.2.4.3.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with the following addition:

Electrical durability of a contactor or starter is verified by a special test conducted at the discretion of the manufacturer. Recommendations for conducting this test are given in Annex B.

8.2.4.4 Overload current withstand capability of contactors

Contactors with utilization categories AC-3, AC-3e or AC-4 shall withstand the overload currents given in Table 11, as specified in 9.3.5.

Table 11 – Overload current withstand requirements

Rated operational current	Test current ^c	Duration of test ^a
≤ 630 A	$8 \times I_e \text{ max/AC-3}$ $8 \times I_e \text{ max/AC-3e}$	10 s
> 630 A	$6 \times I_e \text{ max/AC-3}^b$ $6 \times I_e \text{ max/AC-3e}$	10 s
^a For starter with class 20 overload protection and above, the choice of the contactor is subject to agreement between the manufacturer and the user. ^b With a minimum value of 5 040 A. ^c This test also covers duties where the current is lower and the test duration is longer, provided that the tested value of I^2t is not exceeded.		

NOTE For coordination purposes, especially for AC-3e, a higher factor of I_e can be used (see B.4).

8.2.4.5 Coil power consumption

The power consumption of the electromagnet of a contactor characterises the power supplying its coil necessary for holding and pick up operations.

Where the power consumption of the electromagnet is given, it shall be tested according to 9.3.3.2.1.2.

8.2.4.6 Pole impedance

Where the pole impedance is given, it shall be tested according to 9.3.3.2.1.3.

8.2.4.7 Ability of a MPSD to make and break under short-circuit conditions

Subclause 7.2.5 of IEC 60947-1:2007 applies with the following additions:

The ability of the MPSD to make, carry and break short-circuit currents is stated in terms of the following:

- Rated ultimate short-circuit breaking capacity I_{cu} (see 5.3.6.1);
- Rated service short-circuit breaking capacity I_{cs} (see 5.3.6.2).

The short-circuit tests shall be in accordance with Annex P.

NOTE A MPSD alone cannot be coordinated with itself. Consequently, it does not require a rated conditional short-circuit current nor to be submitted to test current “r”.

8.2.5 Co-ordination with short-circuit protective devices

8.2.5.1 Performance under short-circuit conditions (rated conditional short-circuit current)

The rated conditional short-circuit current of contactors and starters backed up by short-circuit protective device(s) (SCPD(s) or MPSD), combination starters, combination switching devices, protected starters and protected switching devices shall be verified by short-circuit tests as specified in 9.3.4. If a combination starter, combination switching device, protected starter and protected switching device is fulfilling the requirements of 8.2.4.7, it is considered as a MPSD. In this case, no co-ordination test is required unless it is combined with an additional switching device.

These tests are mandatory:

- a) at the appropriate value of prospective current shown in Table 14 or Table 13 (test current " r "), and
- b) at the rated conditional short-circuit current I_{cs} , if higher than test current " r ".

The rating of the SCPD shall be adequate for any given rated operational current, rated operational voltage and the corresponding utilization category.

Two types of co-ordination are permissible, "1" or "2". The test conditions for both are given in 9.3.4.2.1 and 9.3.4.2.2.

Type "1" co-ordination requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons or installation and may not be suitable for further service without repair and replacement of parts.

Type "2" co-ordination requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons or installation and shall be suitable for further use. The risk of contact welding is recognized, in which case the manufacturer shall indicate the measures to be taken as regards the maintenance of the equipment.

NOTE Use of an SCPD not in compliance with the manufacturer's recommendations can invalidate the co-ordination.

These tests are applicable to AC motor ratings only.

8.2.5.2 Co-ordination at the crossover current between starter and associated SCPD

Co-ordination at the crossover current between the starter and the SCPD is a special test. The way to verify it is described in B.4.

8.2.5.3 Co-ordination test between AC-3e rated starter and associated SCPD

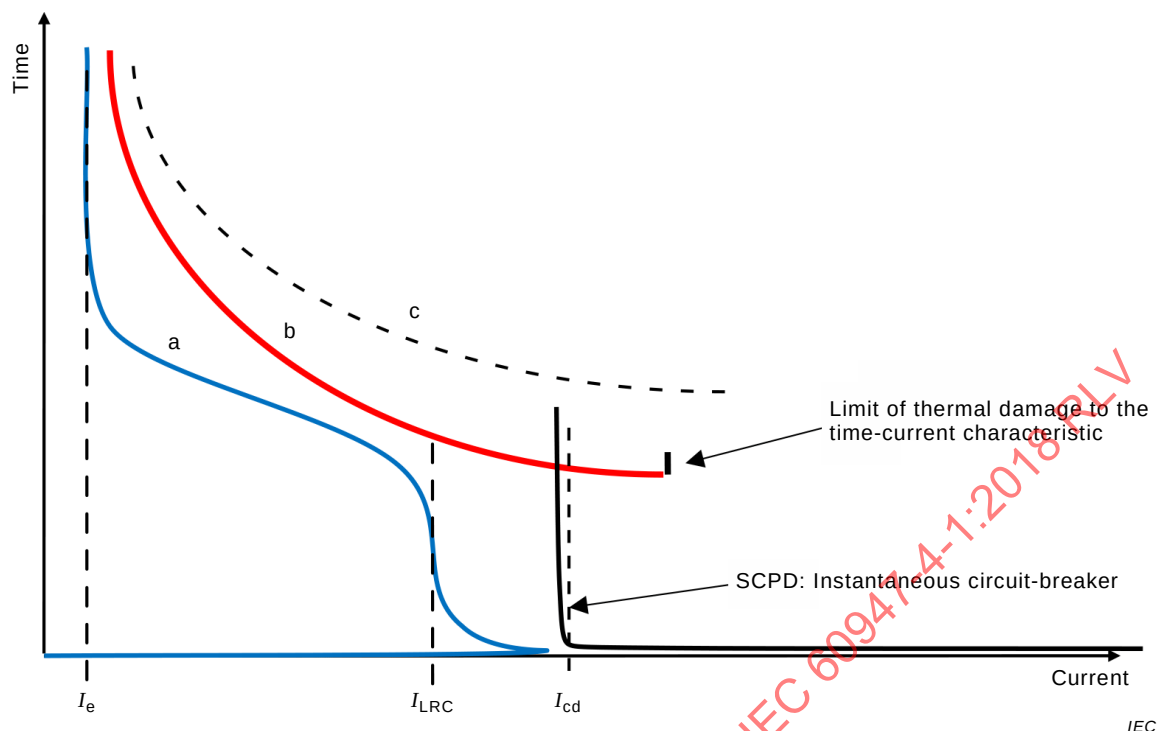
8.2.5.3.1 General

For AC-3e rated starter with type 2 co-ordination, the co-ordination test of 8.2.5.3.2 shall be performed.

This test is intended to verify the co-ordination of the AC-3e rated starter, and the associated SCPD (instantaneous circuit-breaker), in which the overload protection of the starter is operating the contactor in case of short-circuit of fault currents below the tripping current of the SCPD (instantaneous circuit-breaker). The test is performed at a simulated fault current I_{cd} just above the tripping current of the SCPD.

The current I_{cd} is determined by the manufacturer based on the characteristics of the associated SCPD given in item p) of 6.1.2 in order to ensure the co-ordination described in Figure 3 with a power factor given by Table 16 of IEC 60947-1:2007. This test is not necessary if the determined fault current I_{cd} is lower or equal than the tested make and break current for AC-3e.

NOTE Asynchronous motor of design NE or HE can have a higher inrush current and implies a higher setting of the SCPD tripping current. As a consequence, the breaking capacity of the contactor is verified at a higher value than the make and break capacity of Table 7.

**Key**

- a typical motor starting current
- b mean overload relay time-current characteristic from cold state
- c time-current characteristic withstand capability of contactor according to 9.3.5

Figure 3 – Examples of co-ordination characteristics of a starter**8.2.5.3.2 AC-3e co-ordination test procedure**

Test conditions in 8.3.3.5 of IEC 60947-1:2007 apply with the following additions.

- Test procedure: the contactor or starter shall break the test current (I_{cd}) for the number of operating cycles given in Table 15. This is made without the SCPD in the circuit.

Table 15 – Test conditions for I_{cd}

	U_r/U_e	$\cos \phi$	On-time ^b s	Off-time s	Number of operations
I_{cd}	1,05	a	0,05	c	3

NOTE For the next edition, this table will be moved with the current subclause to the end of 9.3.4 and is therefore numbered differently to the other tables in this document.

^a Power factor to be selected according to Table 16 of IEC 60947-1:2007.

^b Time may be less than 0,05 s provided that contacts are allowed to become properly seated before re-opening.

^c See Table 8.

- Behaviour of contactors or starters during and after the I_{cd} test:
 - a) during the test, there shall be no permanent arcing, no flash-over between poles, no blowing of the fusible element in the earth circuit (see 9.3.3.5.2) and no welding of contacts;
 - b) after the test:

- 1) the contacts shall operate correctly when the contactor or starter is switched by the applicable method of control;
- 2) the dielectric properties of the contactors and starters shall be verified by a dielectric test on the contactor or starter using an essentially sinusoidal test voltage of twice the rated operational voltage U_e used for the I_{cd} test, with a minimum of 1 000 V. The test voltage shall be applied as specified in 8.3.3.4.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014, items 4.

8.2.5.4 Co-ordination between a MPSD and another short-circuit protective device

For the co-ordination between a MPSD and another short-circuit protective device, see Annex Q.

8.3 Electromagnetic compatibility (EMC)

8.3.1 General

Subclause 7.3.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with the following addition.

Power frequency magnetic field tests are not required because the devices are naturally submitted to such fields. Immunity is demonstrated by the successful completion of the operational performance capability tests (see 9.3.3.5 and 9.3.3.6).

This equipment is inherently sensitive to voltage dips and short time interruptions on the control supply; it shall react within the limits of 8.2.1.2 and this is verified by the operating limits tests given in 9.3.3.2.

The immunity test levels of this document, based on the requirements of IEC 60947-1, correspond to the severe industrial environment defined in IEC 61000-6-2. Higher immunity test levels may be necessary especially for outdoor high voltage substation as defined by IEC 61000-6-5.

8.3.2 Immunity

8.3.2.1 Equipment not incorporating electronic circuits

Subclause 7.3.2.1 of IEC 60947-1:2007 applies.

8.3.2.2 Equipment incorporating electronic circuits

Subclause 7.3.2.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies with the following addition.

The test results are specified using the performance criteria given in Table 12.

Table 12 – Specific acceptance criteria for immunity tests

Item	Acceptance criteria		
	A	B	C
General	Normal performance within the specified limits	Temporary degradation or loss of function or performance which is self-recoverable	Temporary degradation or loss of function or performance which requires operator's intervention or system reset. There shall not be any damaged component
Operation of power and control circuits	No unwanted operation – the contactor shall remain in the expected position – the overload relay shall not trip	Temporary unwanted operation which cannot cause tripping Unintentional opening or closing of contacts is not accepted Self-recoverable	Tripping of overload relay Unintentional opening or closing of contacts Not self-recoverable
Operation of displays and auxiliary circuits	No changes to visible display information Only slight light intensity fluctuations of LEDs or movement of characters No unwanted operation of auxiliary contacts	Temporary visible changes, for example unwanted LED illumination Unintentional opening or closing of auxiliary contacts is not accepted.	Permanent loss of display information Unintentional opening or closing of auxiliary contacts is not accepted.
Information processing and sensing functions	Communication and data interchange to external devices without unwanted action or erroneous information	Temporarily disturbed communication with possible external impacts, but self-recoverable	Erroneous processing of information Loss of data and/or information Not self-recoverable

8.3.3 Emission

The level of severity required for environment B covers those required for environment A.

The devices covered by this document do not generate significant levels of harmonics and therefore no harmonic tests are required.

8.3.3.1 Equipment not incorporating electronic circuits

Subclause 7.3.3.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies with the following addition.

Equipment incorporating only components such as diodes, varistors, resistors or capacitors is not required to be tested (e.g. in surge suppressors).

8.3.3.2 Equipment incorporating electronic circuits

Subclause 7.3.3.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies.

9 Tests

9.1 Kinds of test

9.1.1 General

Subclause 8.1.1 of IEC 60947-1:2007 applies.

If there is no distinction between U_s and U_c , requirements apply with U_c .

9.1.2 Type tests

Type tests are intended to verify compliance of the design of contactors and starters of all types and their dedicated wiring accessories with this document. They comprise the verification of:

- a) Temperature-rise limits (see 9.3.3.3);
- b) dielectric properties (see 9.3.3.4);
- c) rated making and breaking capacities (see 9.3.3.5);
- d) change-over ability and reversibility, where applicable (see 9.3.3.5);
- e) conventional operational performance (see 9.3.3.6);
- f) operation and operating limits (see 9.3.3.1 and 9.3.3.2);
- g) ability of contactors to withstand overload current (see 9.3.5);
- h) performance under short-circuit conditions (see 9.3.4);
- i) mechanical properties of terminals (see 8.2.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014);
- j) degrees of protection of the equipment (see Annex C of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010);
- k) EMC tests, where applicable (see 9.4).

9.1.3 Routine tests

Subclause 8.1.3 of IEC 60947-1:2007 applies where sampling tests (see 9.1.4) are not made.

Routine tests for contactors and starters comprise:

- operation and operating limits (see 9.3.6.2);
- dielectric tests (see 9.3.6.3).

For dedicated wiring purpose accessories delivered separately, only dielectric test applies.

9.1.4 Sampling tests

Sampling tests for contactors and starters comprise:

- operation and operating limits (see 9.3.6.2)
- dielectric tests (see 9.3.6.3).

Subclause 8.1.4 of IEC 60947-1:2007 applies with the following additions.

A manufacturer may use sampling tests instead of routine tests at his own discretion. Sampling shall meet or exceed the following requirements as specified in Table 2-A: Single sampling plans for normal inspection of ISO 2859-1:1999:

- sampling based on $AQL \leq 1$;
- acceptance number $A_c = 0$ (no defect accepted);
- rejection number $R_e = 1$ (if 1 defect, the entire lot shall be tested).

Sampling shall be made at regular intervals for each specific lot.

Alternative statistical methods that ensure compliance with the above ISO 2859-1:1999 requirements can be used, e.g. statistical methods controlling continuous manufacturing or process control with capability index.

Sampling tests for clearance verification shall be performed according to 8.3.3.4.3 of IEC 60947-1:2007.

9.1.5 Special tests

9.1.5.1 General

The conducting of special test is at the discretion of the manufacturer.

Special tests include:

- environment tests according to 9.1.5.2;
- mechanical and electrical durability tests according to B.2 and B.3. The test results can be used to obtain data needed for functional safety applications (see Annex K);
- verification of co-ordination at the crossover current between the starter and the SCPD according to B.4.

9.1.5.2 Environment tests

For these special tests, Annex Q of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with the following additions.

Where Table Q.1 of IEC 60947-1:2007/AMD2:2014 calls for verification of operational capability, this shall be done according to 9.3.6.2.

The vibration tests shall be done on the equipment in the open and closed positions. The overload relay shall not trip during the test. To check the behavior of main and auxiliary contacts, tests can be done under any current / voltage value.

The shock test on the equipment shall be done in the open position.

For the dry heat test, the equipment shall be in the closed position during the conditioning period (see 5.3.3 of IEC 60068-2-2:2007). For categories A, B and C, the test may be done without current in the poles and for categories D, E and F, the test shall be done under the maximum rated AC-3 current, but may be limited to 100 A for practical reasons. During the last hour, the contactor shall be operated 5 times. During the whole test the overload relay may trip.

For the low temperature test, the test Ad is to be chosen instead of the test Ab and the equipment shall be in the open position during the cooling period. It shall then be energized for the last hour. For categories A, B and C, the test may be done without current in the poles and for categories D, E and F, the test is done under the maximum rated AC-3 current which may be limited to 100 A for practical reasons. During this last hour, the contactor shall be operated 5 times. During the whole test the overload relay shall not trip.

For the damp heat test, for categories A, B and C, the test may be done without current in the poles. For categories D, E and F the equipment shall be energized under the maximum rated AC-3 current for the first cycle and de-energized for the second cycle. The current may be limited to 100 A for practical reasons. After stabilization of the temperature, during the first 2 h of the first cycle and during the last 2 h of the second cycle, the contactor shall be operated 5 times. The overload relay may trip only if it is permitted according to its temperature characteristic.

With the agreement of the manufacturer, the duration of the recovery periods may be reduced.

After the salt mist test, the product may be washed where agreed by the manufacturer.

9.2 Compliance with constructional requirements

9.2.1 General

Subclause 8.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with the following additions:

9.2.2 Electrical performance of screwless-type clamping units

Subclause 8.2.4.7 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with the following changes:

The number of specimens shall be at least 4.

The insertion and disconnection of the conductors shall be made in accordance with the manufacturer's instructions.

A suitable test arrangement is shown in Figure 4. If the measurement points cannot be positioned within the 10 mm to the point of contact, the voltage difference between the ideal and the actual measuring points shall be deducted from the voltage drop measured. This voltage difference within the part of the conductor shall be determined with a suitable measurement method on one specimen at a stabilised temperature. The measurement methods and the results shall be documented in the test report. The test current is I_{th} .

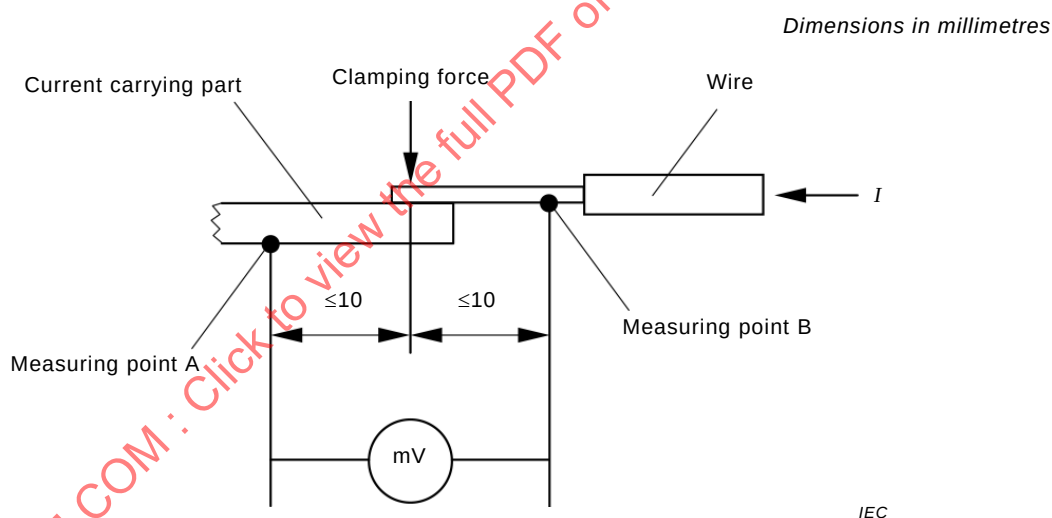


Figure 4 – Voltage drop measurement at contact point of the clamping terminal

NOTE 1 Usually it is possible to equip a IEC 60947-4-1 product with many different types of wires (stranded, solid, flexible etc.) which results in a sufficient number of tests for the same terminal.

NOTE 2 Particular testing method with conductor cross sections larger than 10 mm² is under consideration.

NOTE 3 The device sample can be provided with holes or equivalent arrangements which provide measurement access points for the voltage drop on the terminal.

9.2.3 Ageing test for screwless-type clamping units

Subclause 8.2.4.8 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with the following change:

The test shall be done on the device equipped with the clamping units.

The test current is I_{th} .

NOTE The device sample can be provided with holes or equivalent arrangements which provide measurement access points for the voltage drop on the terminal.

9.2.4 Limited energy source test

A limited energy source circuit shall be tested as follows, with the equipment operating under normal operating conditions.

In case the limited energy source requirement depends on over-current protective device(s), the device(s) shall be short-circuited.

With the equipment operating under normal operating conditions, a variable resistive load is connected to the parts under consideration and adjusted to obtain a level of required limited VA energy. Further adjustment is made, if necessary, to maintain the limited VA energy for a period specified in 8.1.14.

A variable resistive load is connected to the circuit under consideration and adjusted to obtain the limit of apparent power as indicated in Table 19, Table 20, or Table 21, as applicable. Further adjustment is made, if necessary, to maintain the limit of apparent energy for the time period indicated in Table 19, Table 20, or Table 21, as applicable.

The test is passed, if after the test period the available apparent energy does not exceed the limits indicated in Table 19, Table 20, or Table 21, as applicable.

In case the limited energy source requirement depends on over-current protective device(s), the current rating of at least one of the protective device(s) in the current path shall not exceed the limit in Table 20.

These tests shall be conducted under the most unfavourable combination within the manufacturer's operating specifications of the parameters as listed in 5.5.

9.2.5 Breakdown of components

9.2.5.1 General

The breakdown of a component, identified as a result of the circuit analysis of 8.1.16, shall be tested with the product operating with the load creating the more severe condition.

NOTE A possible loss of main function is permissible.

The test is not required:

- when circuit analysis indicates that no other component or portion of the circuit will be overloaded as a result of open- or short-circuit failure mode of another component;
- for components in circuits supplied by limited energy sources in compliance with 8.1.14;
- on power semiconductor devices when equivalent testing is accomplished during short-circuit tests;
- for components that have previously been positively evaluated considering their failure modes and the circuit conditions in which the component is used within the device.

9.2.5.2 Breakdown of components test

Each identified component shall be subjected to a breakdown of components test in open- and or short-circuit failure modes, whichever is most severe.

NOTE 1 The breakdown of components test can be done only with those circuits of the device that can affect the result of the test being fully energized and in operation.

During this test, there shall be no emission of flame or molten metal, nor ignition of cotton. The fusible element shall not open.

Components, such as capacitors or diodes, are short- or open-circuited. For device without a dedicated enclosure, an outer metal enclosure or a wire mesh cage (with surrounded cotton on the cage) that is 1,5 times the size of the device (or different, according to manufacturer declarations) shall be provided to simulate the potential grounded parts around the device. In case of dedicated enclosure, the cotton shall be placed over all openings. The outer dedicated enclosure or wire mesh cage (when provided) and any grounded or exposed dead-metal part shall be connected through a fusible element F, according to subclause 8.3.4.1.2 d) of IEC 60947-1:2007, to the supply circuit.

NOTE 2 The definition of enclosed equipment is given in Annex C of IEC 60947-1:2007, IEC 60947-1:2007/AMD1 2010.

9.3 Compliance with performance requirements

9.3.1 Test sequences

Each test sequence is made on a new sample.

NOTE 1 With the agreement of the manufacturer, more than one test sequence or all test sequences can be conducted on one sample. However, the tests are conducted in the sequence given for each sample.

NOTE 2 Some tests are included in the sequences solely to reduce the number of samples required, the results have no significance for the preceding or following tests in the sequence. Therefore, for convenience of testing and by agreement with the manufacturer, these tests can be conducted on separate new samples and omitted from the relevant sequence. This can only apply to the following tests when called for:

- 8.3.3.4.1, item 7) of IEC 60947-1:2007, Verification of creepage distances;
- 8.2.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, Mechanical and electrical properties of terminals;
- Annex C of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, Degrees of protection of enclosed equipment.

The test sequence shall be as follows:

a) Test sequence 1

- 1) verification of temperature-rise (see 9.3.3.3);
- 2) verification of operation and operating limits (see 9.3.3.1 and 9.3.3.2);
- 3) verification of dielectric properties (see 9.3.3.4).

b) Test sequence 2

- 1) verification of rated making and breaking capacities, change-over ability and reversibility, where applicable (see 9.3.3.5);
- 2) verification of conventional operational performance (see 9.3.3.6).

c) Test sequence 3

performance under short-circuit conditions (see 9.3.4);

d) Test sequence 4 (applicable to contactors only)

verification of ability to withstand overload currents (see 9.3.5);

e) Test sequence 5

- 1) verification of mechanical properties of terminals according to 8.2.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014, 9.2.2 and 9.2.3;
- 2) verification of degrees of protection of enclosed contactors and starters (see Annex C of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010).

There shall be no failure in any of the tests.

9.3.2 General test conditions

Subclause 8.3.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies with the following addition.

The selection of samples to be tested for a series of devices with same fundamental design and without significant difference in construction shall be based on engineering judgement.

Except for devices specifically rated for only one frequency, tests performed at 50 Hz are deemed to cover 60 Hz applications and vice-versa.

Unless otherwise specified in the relevant test subclause, the clamping torque for connections shall be that specified by the manufacturer or, if not specified, the torque given in Table 4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014.

Unless otherwise specified, tests of MPSD are to be performed with the maximum rated operational current(s) of a given physical size and similar construction, and are deemed to cover all rated currents of that physical size and construction.

NOTE "Similar construction" means the changes will have no negative impact on the performance of the product. For example, no change in the current carrying parts except current sensing means (e.g. bimetal), arc chamber, etc.

MPSD for unearthed or impedance earth systems (IT) shall be tested according to P.4.

9.3.3 Performance under no load, normal load and overload conditions

9.3.3.1 Operation

It shall be verified that contactors, overload relay and starters operate according to the requirements of 8.2.1.1.2.

To verify the insensitivity of the starter to contactor operation, the starter shall be loaded to attain a steady state temperature as stated in 8.2.2 and the contactor operated in the normal switching sequence three times without intentional delay between operations. The starter shall not trip due to the contactor operation.

When the overload relay has a combined stop and reset actuating mechanism, with the contactor closed, the resetting mechanism shall be operated and this shall cause the contactor to drop out. When the overload relay has either a reset only or separate stop and reset actuating mechanisms, with the contactor closed and the resetting mechanism in the reset position, the tripping mechanism shall be operated and the contactor shall have been caused to drop out. These tests are to verify that the overload tripping action cannot be defeated by holding the resetting mechanism in the reset position.

In the case of rheostatic rotor starters, tests shall be performed to verify that the time setting of time-delay relays and the calibration of any other devices used for controlling the rate of starting are within the limits stated by the manufacturer.

The value of the starting resistors shall be verified for each section to be within $\pm 10\%$ of the stated figures.

It shall also be verified that the rotor switching devices cut out the steps of resistors in the correct sequence.

It shall also be verified that the open-circuit voltages on the tapping terminals of the auto-transformer are in accordance with the designed figures and that the phase sequence at the motor terminals of the two-step auto-transformer starter is correct in both the starting and ON positions of the starter.

9.3.3.2 Operating limits

9.3.3.2.1 Power-operated equipment

9.3.3.2.1.1 General

Contactors and starters shall be tested to verify their performance according to the requirements given in 8.2.1.2.

The drop out test requirements of 8.3.3.2.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies.

9.3.3.2.1.2 Coil power consumption

9.3.3.2.1.2.1 General

The characteristics of the power, supplying a coil, necessary for the electromagnet of a contactor needs to be determined for both the holding power and the pick-up power.

In the case where different coils cover a range of voltages, 5 coils numbered i shall be tested as follows:

The coil with the lowest rated control circuit supply voltage U_{s1} , the coil with the highest rated control circuit supply voltage U_s , plus 3 other coils deemed to be representative of the coils with the highest calculated hold power at the discretion of the manufacturer.

The test shall be performed at ambient temperature $+23\text{ °C} \pm 3\text{ °C}$. The test shall be made without any load in the main and auxiliary circuits. The electromagnet shall be supplied with the rated control circuit supply voltage U_s and at the rated frequency. For a given coil, where a voltage range is declared, the test shall be made at the highest voltage at the respective frequency.

For alternating current controlled electromagnet, the measured values shall be obtained with a RMS measurement method covering at least a bandwidth from 0 Hz to 10 kHz. For direct current controlled electromagnet, the measured values shall be obtained as an average value. For alternating current as well as direct current controlled electromagnet, the resulting power values shall be given within a measurement uncertainty better than 5 %.

For electronically controlled electromagnet, the measurement method shall cover a bandwidth of at least 0 Hz to 100 kHz but not less than ten times the electronic control switching rate.

The declared value by the manufacturer shall be equal or higher than the average value of the 5 tested coils.

9.3.3.2.1.2.2 Holding power for conventional and electronically controlled electromagnet

The current measurement $I_{(i)}$ of the coil shall be performed after the electromagnet has been energized and has reached a stable temperature.

The holding power consumption is defined as follows:

$$S_{h(i)} = U_{s(i)} \times I_{(i)} \text{ [VA] for alternating current controlled electromagnet;}$$

$$P_{c(i)} = U_{s(i)} \times I_{(i)} \text{ [W] for direct current controlled electromagnet;}$$

$$S_h = \sum (U_{s(i)} \times I_{(i)}) / 5 \text{ [VA] respectively } P_c = \sum (U_{s(i)} \times I_{(i)}) / 5 \text{ [W].}$$

For electronically controlled electromagnet with alternating current and direct current ratings, the measurement should be performed for both ratings.

NOTE The power dissipation for an alternating current controlled electromagnet can also be expressed in [W], taking into account the power factor.

9.3.3.2.1.2.3 Pick-up power for direct current controlled electromagnet with separate pick-up and hold-on windings or alternating current controlled electromagnet

The pick-up measurement shall be performed directly after the measurement of the hold current (see 9.3.3.2.1.2.2).

The current measurement $I_{(i)}$ respectively $\hat{I}_{(i)}$ of the coil shall be performed immediately after the electromagnet has been de-energized, the contactor has been held in the OFF position and re-energized.

The pick-up power consumption is defined as follows:

$$S_{p(i)} = U_S \times \hat{I}_{(i)} \text{ [VA]}$$

$$S_p = \sum U_{S(i)} \times \hat{I}_{(i)} / 5 \text{ [VA]} \text{ for alternating current and direct current controlled electromagnet}$$

For direct current controlled electromagnet, the power consumption is expressed in VA in order to represent the total apparent power because of its nonlinear waveform but it may also be expressed in W.

NOTE 1 Unless otherwise stated in the manufacturer literature, for direct current conventional controlled electromagnet, the pick-up power is equal to the holding power.

NOTE 2 Depending on the design of the contactor with separate pick-up and hold-on windings, care is taken not to burn the coil by taking a short measurement (electromagnet energized for less than 1 s or 2 times the pick-up time published by the manufacturer if greater than 1 s).

9.3.3.2.1.2.4 Pick-up power for electronically controlled electromagnet

The pick-up measurement is under consideration.

9.3.3.2.1.3 Pole impedance

The pole impedance shall be determined during the test given in 9.3.3.3.4 and with the conditions given in 8.2.2.1.

The voltage drop U_d shall be measured between the line and load terminals (terminals included) of the contactor or starter preferably at the same time the temperature-rise is measured (see Figure 5).

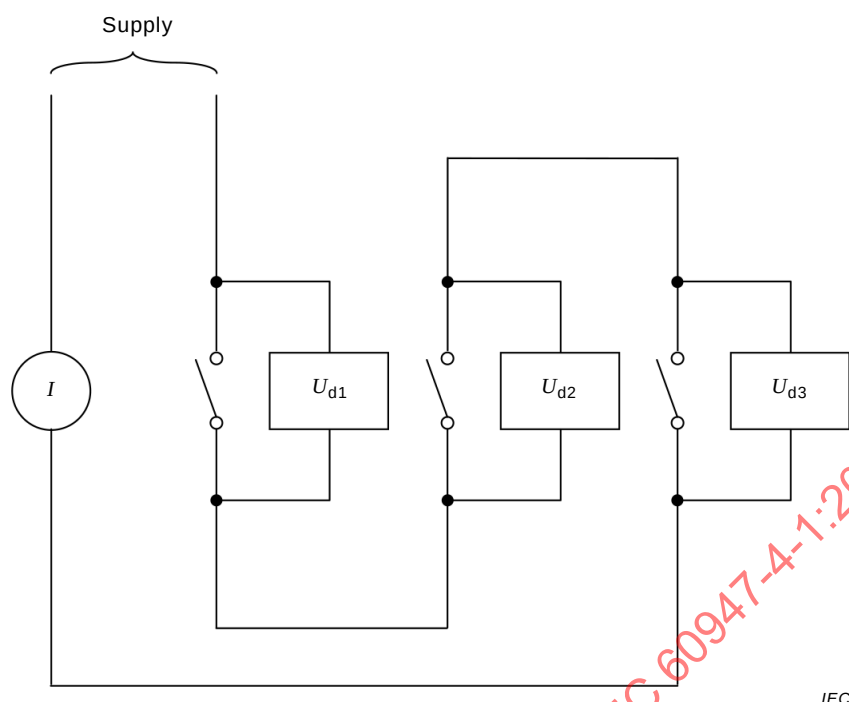


Figure 5 – Example of a pole impedance measurement for a 3 pole contactor

The impedance per pole is defined as follows:

$$Z = U_d / I_{th} [\Omega]$$

Care should be taken that voltage drop measurement does not significantly affect the temperature-rise nor affect significantly the impedance.

NOTE The method is the same irrespective of the number of poles of the contactor or starter.

9.3.3.2.2 Relays and releases

a) Operation of under-voltage relays and releases

Under-voltage relays or releases shall be tested for compliance with the requirements of 8.2.1.3. When associated with a switching device, the release shall be fitted to the switching device having the maximum current rating for which the release is suitable.

1) Drop-out voltage

The voltage shall be reduced from rated control circuit supply voltage at a rate to reach 0 V in approximately 30 s.

The test for the lower limit is made without previous heating of the release coil. In the case of a release with a range of rated control circuit supply voltage, this test applies to the maximum voltage of the range. When associated with a switching device, the test for the lower limit is made without current in the main circuit.

The test for the upper limit is made starting from a constant temperature corresponding to the application of rated control circuit supply voltage to the release and rated current in the main poles. This test may be combined with the temperature-rise test of 9.3.3.3. In the case of a release with a range of rated control circuit supply voltage, this test is made at the minimum rated control circuit supply voltage.

2) Test for limits of operation when associated with a switching device

Starting with the main circuit open, at the temperature of the test room, and with the supply voltage at 35 % rated maximum control supply voltage, it shall be verified that the switching device cannot be closed by the operation of its actuator. When the

supply voltage is raised to 85 % of the minimum control supply voltage, it shall be verified that the switching device can be closed by the operation of its actuator.

3) Performance under over-voltage conditions

When associated with a switching device, the test is made without current in the main circuit. The test at 110 % of the rated supply voltage shall be made for 30 min or until the temperature has reached thermal equilibrium and without impairing its functions. Verification shall be made according 2) above.

b) Shunt-coil operated releases

Shunt releases shall be tested for compliance with the requirements of 8.2.1.4 at the ambient temperature. When associated with a switching device, the release shall be fitted to the switching device having the maximum rated current for which the release is suitable.

In the case of a release having a range of rated control circuit supply voltages, the test voltages shall be 70 % of the minimum rated control circuit supply voltage and 110 % of the maximum rated control voltage.

c) Thermal, electronic and time-delay magnetic overload relays

Overload relays and starters shall be connected using conductors in accordance with Table 9, Table 10 and Table 11 of IEC 60947-1:2007 for test currents corresponding to:

- 100 % of the current setting of the overload relay for overload relays of trip classes 2, 3, 5 and 10A for all overload relay types (see Table 2) and 10, 20, 30 and 40 for electronic overload relay types;
- 125 % of the current setting of the overload relay for thermal overload relays of trip classes 10, 20, 30 and 40 (see Table 2) and for overload relays for which a maximum tripping time greater than 40 s is specified (see 5.7.3).

It shall be verified that relays and releases operate according to the requirements of 8.2.1.5.1 with all poles energized.

The characteristics defined in 8.2.1.5.1 shall be verified at –5 °C, +20 °C, +40 °C. In addition, any declared time-current characteristics outside the –5 °C, +40 °C range shall be verified at minimum and maximum temperatures. However, for relays or releases declared compensated for ambient temperature, in case of temperature range declared by the manufacturer is outside the range given in Table 3, the characteristics at –5 °C and/or +40 °C need not be verified if, when tested at the declared minimum and maximum temperatures, the corresponding tripping current values are in compliance with the limits specified for –5 °C and/or +40 °C in that Table 3.

For electronic overload relays, the thermal memory test verification of 8.2.1.5.1.2 shall be carried out at +20 °C.

Three-pole thermal or electronic overload relays energized on two poles only shall be tested as stated in 8.2.1.5.2 on all combinations of poles and at the maximum and minimum current settings for relays with adjustable settings.

d) Instantaneous magnetic overload relays

Each relay shall be tested separately. The current through the relay shall be increased at a rate suitable for an accurate reading to be made. The values shall be as stated in 8.2.1.5.3.

e) Short-circuit releases

Subclause 8.3.3.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with the following additions:

The ambient air temperature shall be measured as for the temperature-rise tests (see 8.2.2). Any separate release shall be mounted as under normal service conditions. The complete MPSD shall be mounted in accordance with 8.2.2.

For MPSD with adjustable short-circuit releases, tests shall be made at:

- 1) minimum current setting; and
- 2) maximum current setting,

in each case with conductors corresponding to the rated operational current I_e .

For tests for which the tripping characteristic is independent of the temperature of the terminals (e.g. electronic overload releases, magnetic releases), connection data (type, cross-section, length) may be different from those required in 8.3.3.3.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014.

The tests may be made at any convenient voltage.

The operation of short-circuit releases shall be verified at 80 % and 120 % of the short-circuit current setting of the release. The test currents shall have no asymmetry.

At a test current having a value equal to 80 % of the short-circuit current setting, the release shall not operate, the current being maintained for 0,2 s.

At a test current having a value equal to 120 % of the short-circuit current setting, the release shall operate within 0,2 s.

For MPSD with an electronic over-current release, the operation of the short-circuit releases may be verified by one test only on each pole individually.

For MPSD with electromagnetic over-current releases, the operation of multipole short-circuit releases shall be verified by one test only on each combination of two phase poles in series. In addition, the operation of the short-circuit releases shall be verified once on each pole individually, at 120 % of either the value declared by the manufacturer for individual poles, or the short-circuit current setting (if no value is declared for individual poles), at which value they shall operate within 0,2 s.

f) Under-current relays

The limits of operation shall be verified in accordance with 8.2.1.5.4.1.

g) Under-current relays in automatic change-over

The limits of operation shall be verified in accordance with 8.2.1.5.4.2.

h) Stall relays

The limits of operation shall be verified in accordance with 8.2.1.5.5.

For current sensing stall relays, the verification shall be made for the minimum and for the maximum set current values and for the minimum and maximum stall inhibit time (four settings).

For stall relays operating in conjunction with a rotation sensing mean, the verification shall be made for the minimum and maximum stall inhibit time. The sensor can be simulated by an appropriate signal on the sensor input of the stall relay.

i) Jam relays

The limits of operation shall be verified in accordance with 8.2.1.5.6.

The verification shall be made for the minimum and for the maximum set current values and for the minimum and maximum jam inhibit time (four settings).

For each of the four settings, the test shall be made under the following conditions:

- apply a test current of 95 % of the set current value. The jam relay shall not trip;
- increase the test current to 120 % of the set current value. The jam relay shall trip according to the requirements given in 8.2.1.5.6.

9.3.3.2.3 Verification of main contact position for manual starter and MPSD suitable for isolation

For manual starter and MPSD suitable for isolation, a test shall be made to verify the effectiveness of the indication of the main contact position in accordance with 8.2.5 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010.

9.3.3.3 Temperature-rise

9.3.3.3.1 Ambient air temperature

Subclause 8.3.3.3.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 applies.

9.3.3.3.2 Measurement of the temperature of parts

Subclause 8.3.3.3.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.

9.3.3.3.3 Temperature-rise of a part

Subclause 8.3.3.3.3 of IEC 60947-1:2007 applies.

9.3.3.3.4 Temperature-rise of the main circuit

Subclause 8.3.3.3.4 of IEC 60947-1:2007 applies with the following additions. The main circuit shall be loaded as stated in 8.2.2.4.

All auxiliary circuits which normally carry current shall be loaded at their maximum rated operational current (see 5.6) and the control circuits shall be energized at their rated voltages. The starter shall be fitted with an overload relay complying with 5.7.4 and selected as follows:

- Non-adjustable relay
The current setting shall be equal to the maximum operational current of the starter and the test shall be made at this current;
- Adjustable relay
The maximum current setting shall be that which is nearest to but not greater than the maximum operational current of the starter.
The test shall be made with that overload relay for which the current setting is nearest to the maximum of its scale.

NOTE 1 The selection method described above is designed to ensure that the temperature-rise of the field wiring terminals of the overload relay and the power dissipated by the starter are not less than those that will occur under any combination of relay and contactor. In cases where the effect of the overload relay on these values is insignificant (i.e. electronic overload relays), the test current can always be the maximum operational current of the starter.

For equipment intended for utilization category AC-6b, the test current for the temperature-rise test shall be equal to 1,35 times I_e (the rated capacitive current). I_e shall be calculated as follow:

- $I_e = Q \text{ (var)} / U_e$ for single-phase rating, where U_e is the minimum rated voltage;
- $I_e = Q \text{ (var)} / (U_e \times \sqrt{3})$ for three-phases rating, where U_e is the minimum rated voltage.

NOTE 2 This calculation is based on a thermal factor due to the capacitor tolerance (15 %) plus the harmonic effect.

The test shall be done with cross section of conductor based on 1,35 times I_e (the rated capacitive current).

9.3.3.3.5 Temperature-rise of control circuits

Subclause 8.3.3.3.5 of IEC 60947-1:2007 applies with the following addition.

The temperature-rise shall be measured during the test of 9.3.3.3.4.

9.3.3.3.6 Temperature-rise of coils and electromagnets

Subclause 8.3.3.3.6 of IEC 60947-1:2007 applies with the following additions.

The coil with the highest measured holding power consumption, for a given frequency AC or DC, according to 9.3.3.2.1.2.2 is deemed to be representative for all coils, for the same contactor, and shall be used for the temperature-rise test.

- a) Electromagnets of contactors or starters intended for uninterrupted or 8 h duty are subjected only to the conditions prescribed in 8.2.2.7.1, with the corresponding rated current flowing through the main circuit for the duration of the test. The temperature-rise shall be measured during the test of 9.3.3.3.4.
- b) Electromagnets of contactors or starters intended for intermittent duty shall be subjected to the test as stated above, and also to the test prescribed in 8.2.2.7.2 dealing with their duty class, with no current flowing through the main circuit.
- c) Specially rated (temporary and periodic duty) windings shall be tested as stated in 8.2.2.7.3, without the current in the main circuit.

9.3.3.3.7 Temperature-rise of auxiliary circuits

Subclause 8.3.3.3.7 of IEC 60947-1:2007 applies with the following addition.

The temperature-rise shall be measured during the test of 9.3.3.3.4.

9.3.3.3.8 Temperature-rise of starting resistors for rheostatic rotor starters

The temperature-rise of resistors shall not exceed the limits specified in Table 3 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014, when the starter is operated at its rated duty (see 5.3.4) and according to its starting characteristics (see 5.3.5.6.2).

The current through each section of the resistors shall be thermally equivalent to the current during the starting time when the controlled motor is operating with the maximum starting torque and the starting time for which the starter is rated (see 5.3.4 and 5.3.5.6.2); in practice, the current value I_m can be used.

Starting operations shall be evenly spaced in time according to the number of starts per hour.

The temperature-rise of the enclosures and of the issuing air shall not exceed the limits specified in Table 3 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014.

NOTE It is not practical to test the performance of starting resistors of every combination of motor output and rotor voltage and current; a sufficient number of tests can be made to prove, by interpolation or deduction, compliance with this document.

9.3.3.3.9 Temperature-rise of the auto-transformer for two-step auto-transformer starters

The temperature-rise of the auto-transformer shall not exceed the limits specified in Table 5 increased by 15 K (see 8.2.2) and those specified in Table 3 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014, when the starter is operated at its rated duty (see 5.3.4).

The current through each winding of the auto-transformer shall be thermally equivalent to the current carried when the controlled motor is operating with the maximum starting current and starting time for which the starter is rated (see 5.3.5.6.3); this condition is assumed to be reached when the current drawn from the auto-transformer during the starting time is equal to the maximum starting current specified in 5.3.5.6.3 multiplied by:

$$0,8 \times \frac{\text{starting voltage}}{U_e} \quad (\text{see 5.3.1.4})$$

The operating cycles shall be evenly spaced in time according to the number of starts per hour (see 5.3.4.3).

In the event of two successive operating cycles (see 5.3.4.3), the temperature-rise of the auto-transformer may exceed the maximum value given in 8.2.2 but no damage shall result to the auto-transformer.

In the case of an auto-transformer with several sets of taps, the test shall be made with the taps giving the highest power loss in the transformer; it shall be made over a period of time sufficient for the temperature-rise to reach a constant value.

In order to facilitate this test, star-connected impedances may be used in place of a motor.

9.3.3.4 Dielectric properties

9.3.3.4.1 Type tests

Subclause 8.3.3.4.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, and IEC 60947-1:2007/AMD2:2014 applies with the addition of:

- the following sentences, at the end of item 1):
The metal foil shall be applied to all surfaces where these are likely to be touched by people during normal operation or adjustment of the equipment and where such surfaces can also be touched by the standard test finger.
The metal foil shall not be applied for power frequency withstand verification after switching and short-circuit tests.
- the following sentence, after the second paragraph of item 2) b):
Circuits of a contactor or starter including devices which have been subjected to U_{imp} test voltages lower than those specified in 7.2.3.1 of IEC 60947-1:2007 and 8.3.3.4.2 of IEC 60947-1:2007 may be disconnected for the test, according to the manufacturer's instructions.
- the following sentence, after the paragraph of item 2) c) ii):
Where the control circuit normally connected to the main circuit is disconnected (according to 8.3.3.4.1, item 2) b) of IEC 60947-1:2007), the method used to maintain the main contacts closed shall be indicated in the test report.
- the following sentence at the end of 8.3.3.4.1, item 8) of IEC 60947-1:2007:
For equipment suitable for isolation, the leakage current shall be measured through each pole with the contacts in the open position, at a test voltage of $1,1 U_e$ and shall not exceed 0,5 mA.

Verification of impulse withstand voltage across open contacts is not required for equipment not suitable for isolation (see 8.3.3.4.1, item 2) c) iv) of IEC 60947-1:2007).

9.3.3.5 Making and breaking capacities

9.3.3.5.1 General test conditions

Subclause 8.3.3.5 of IEC 60947-1:2007 applies with the following additions.

The tests shall be made, under the operating conditions stated in Table 7, without failure, see 9.3.3.5.5 f).

The control supply voltage shall be 100 % of U_s , except that, for the make only test of utilization categories AC-3, AC-3e and AC-4, the control supply voltage shall be 110 % of U_s for half the number of operating cycles and 85 % of U_s for the other half.

Connections to the main circuit shall be similar to those intended to be used when the contactor or starter is in service with the cross-section given in Table 9, Table 10 and Table 11 of IEC 60947-1:2007 for a utilization category. If necessary, or for convenience, the control and auxiliary circuits, and in particular the coil of the contactor or starter, may be supplied by an independent source. Such a source shall deliver the same kind of current and the same voltage as specified for service conditions.

The overload relay and the SCPD of the starter may be short-circuited for the purpose of carrying out the rated making and breaking capacity tests.

9.3.3.5.2 Test circuit

Subclause 8.3.3.5.2 of IEC 60947-1:2007 applies.

9.3.3.5.3 Characteristics of transient recovery voltage

Subclause 8.3.3.5.3 of IEC 60947-1:2007 applies to utilization categories AC-2, AC-3, AC-3e, AC-4, AC-8a and AC-8b (see Table 7).

It is not necessary to adjust factor γ or the oscillatory frequency for testing making capacity only (in AC-3, AC-3e and AC-4).

9.3.3.5.4 Void

9.3.3.5.5 Rated making and breaking capacities

If the contactor in a starter has separately satisfied the requirements of item a) hereafter for the utilization category of the starter, the starter need not be tested.

a) Rated making and breaking capacities of contactors

The contactor shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 7. See also item d) hereafter for reversing contactors.

Contactors of utilization categories AC-3, AC-3e and AC-4 shall be subjected to 50 making only operations followed by 50 making and breaking operations.

b) Rated making and breaking capacity of direct-on-line and reversing starters (AC-3 and AC-3e) and stator switching devices of rheostatic rotor starters (AC-2)

The starter shall make and break the current corresponding to its utilization category for the number of operating cycles given in Table 7.

Starters of utilization category AC-3 and AC-3e shall be subjected to 50 making only operations followed by 50 making and breaking operations.

c) Rated making and breaking capacities and change-over ability of star-delta starters (AC-3 and AC-3e) and two-step auto-transformer starters (AC-3 and AC-3e)

The starter shall make and break the currents corresponding to its utilization category given in Table 7.

Both the starting and the ON or delta position of the starters shall first be subjected to 50 making only operations, the current being broken by a separate switching device.

The starter shall then be subjected to the 50 making and breaking operations. Each operating cycle shall consist of the following sequences:

- make the current in the starting or star position;
- break the current in the starting or star position;
- make the current in the ON or delta position;
- break the current in the ON or delta position;
- off period.

The load circuit shall be connected to the starter as would be the windings of a motor. The rated operational current of the starter (I_e) is the current in the ON or delta position.

NOTE In the case of star-delta starters, it is important that the test currents be measured in star and delta since the supply impedance has a significant effect on the transformation ratio.

When a transformer has more than one output voltage, it shall be connected to give the highest starting voltage.

The on-time in the starting and ON positions and the off-time shall be as stated in Table 7.

- d) Rated making and breaking capacities of direct-on-line starter with plugging or frequent inching (jogging) (AC-4)

The starters shall make and break the currents given in Table 7.

The 50 making only operations shall be done first, the current being broken by a separate switching device, followed by the 50 making and breaking operations.

The load circuit shall be connected to the starter as would be the windings of a motor.

For starters incorporating two contactors, two contactors A and B shall be used and wired as in normal application. Each sequence of the 50 operations shall be:

close A – open A – close B –
open B – off period

The change-over from "open A" to "close B" shall be made as fast as the normal control system will allow.

Mechanical or electrical interlocking means provided in the starter or available for associating contactors as reversing devices shall be used.

If the reversing circuit arrangement is such that both contactors can be energized simultaneously, ten additional sequences shall be conducted with both contactors energized simultaneously.

- e) Rated making and breaking capacities of the rotor switching devices of a rheostatic rotor starter

Verification of the making and breaking capacities of the rotor switching devices shall be performed as in 9.3.3.5.5 b) for AC-2 category where $I_e = I_{er}$, the maximum rated rotor current for which the starter is designed. $U_e = U_{er}$ (rated rotor operational voltage) and U/U_e shall be 0,8. The power factor shall be 0,95. The starting resistors may be disconnected for these tests and, for starters having more than two steps, the test shall be performed on each switching device in turn. Since the rotor switching devices in starters having more than two steps do not break and make at the full rotor voltage, the voltage for these tests may be reduced in the ratio:

$$\frac{\text{Starting resistance switched}}{\text{Total starting resistance}}$$

When a starter is so connected that the circuit is opened by the stator switch before the rotor switching devices open, no verification of the breaking capacity is necessary.

For rotor switching devices which have previously satisfied the requirements corresponding to those specified above, no further tests are needed.

- f) Behaviour and condition of the contactor or starter during and after the making and breaking capacity, change-over and plugging tests

During the tests within the limits of the specified making and breaking capacities of 9.3.3.5 and the verification of conventional operational performance of 9.3.3.6.1 to 9.3.3.6.6, there shall be no permanent arcing, no flash-over between poles, no blowing of the fusible element in the earth circuit (see 9.3.3.5.2) and no welding of the contacts.

The contacts shall operate when the contactor or starter is switched by the applicable method of control.

9.3.3.6 Operational performance capability

9.3.3.6.1 General

Subclause 8.3.3.6 of IEC 60947-1:2007 applies with the following additions.

Tests concerning the verification of conventional operational performance are intended to verify that a contactor or starter is capable of fulfilling the requirements given in Table 10.

Connections to the main circuit shall be similar to those intended to be used when the contactor or starter is in service with the cross-section given in Table 9, Table 10 and Table 11 of IEC 60947-1:2007 for a utilization category.

The overload relay and the SCPD of the starter may be short-circuited for the purpose of carrying out the tests.

The test circuit given in 9.3.3.5.2 is applicable and the load is to be tuned according to 9.3.3.5.3.

The control voltage shall be 100 % of the rated control circuit supply voltage.

If the contactor in a starter has separately satisfied the requirements of 9.3.3.6.1 for the utilization category of the starter, the starter need not be tested.

9.3.3.6.2 Conventional operational performance of contactors

The contactor shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 10. See also 9.3.3.6.5.

9.3.3.6.3 Conventional operational performance of direct-on-line and reversing starters (AC-3, AC-3e) and stator switching devices of rheostatic rotor starters (AC-2)

The starter shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 10.

9.3.3.6.4 Conventional operational performance of star-delta starters (AC-3, AC-3e) and two-step auto-transformer starters (AC-3, AC-3e)

The starter shall make and break the current corresponding to its utilization category for the number of operating cycles given in Table 10.

The test procedure shall be as stated in 9.3.3.5.5, item c), except that the 50 making only operations are not done.

9.3.3.6.5 Conventional operational performance of direct-on-line starter with plugging or frequent inching (jogging) (AC-4)

The starter shall make and break the current corresponding to its utilization category for the number of operating cycles given in Table 10.

The test procedure shall be as stated in 9.3.3.5.5, item d), except that the 50 making only operations and the 10 additional sequences of simultaneous energizing are not done.

9.3.3.6.6 Conventional operational performance of the rotor switching devices of a rheostatic rotor starter

Verification of conventional operational performance of the rotor switching devices shall be performed as in 9.3.3.6.1 for the AC-2 category given in Table 10.

The test procedure shall be as stated in 9.3.3.5.5, item e).

9.3.3.6.7 Behaviour of the contactor or starter during, and its condition after, the conventional operational performance tests

The requirements of 9.3.3.5.5, item f), shall be fulfilled and then the verification of power frequency withstand according to 8.3.3.4.1, item 4), of IEC 60947-1:2007 shall be made.

For equipment suitable for isolation, the leakage current shall be measured through each pole, with the contacts in the open position, at a test voltage of $1,1 U_e$ and shall not exceed 2 mA.

For equipment provided with mirror contacts, the additional test of F.7.3 shall be carried out.

9.3.4 Performance under short-circuit conditions

9.3.4.1 General conditions for short-circuit tests

9.3.4.1.1 General requirements for short-circuit tests

This subclause specifies test conditions for verification of compliance with the requirements of 8.2.5.1. Specific requirements regarding test procedure, test sequences, condition of equipment after the test and types of co-ordination are given in 9.3.4.1 and 9.3.4.2.

The short-circuit test requirements of a MPSD are given in 8.2.4.7.

Subclause 8.3.4.1.1 of IEC 60947-1:2007 applies with the following modification.

If devices tested in free air may also be used in an individual enclosure, they shall be additionally tested in the smallest of such enclosures stated by the manufacturer. For devices tested only in free air, information shall be provided to indicate that the device has not been evaluated for use in an individual enclosure.

NOTE An individual enclosure is an enclosure designed and dimensioned to contain one device (starter, etc.) only.

The individual enclosure shall be in accordance with the manufacturer specifications. In case of multiple enclosure options are provided, the individual enclosure with the smallest volume shall be taken.

Enclosed stationary and moveable assemblies shall be tested according to the relevant part of IEC 61439 series.

9.3.4.1.2 Test circuit for the verification of short-circuit ratings

Subclause 8.3.4.1.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies except that, for type "1" co-ordination, the fusible element F and the resistor R_L are replaced by a solid 6 mm² wire of 1,2 m to 1,8 m in length, connected to the neutral, or with the agreement of the manufacturer, to one of the phases.

NOTE This larger size of wire is not used as a detector but to establish an "earth" condition allowing the damage to be evaluated.

9.3.4.1.3 Power-factor of the test circuit

Subclause 8.3.4.1.3 of IEC 60947-1:2007 applies.

If Table 14 is used, the power factor is given in this table.

9.3.4.1.4 Time-constant of the test circuit

Subclause 8.3.4.1.4 of IEC 60947-1:2007 applies.

9.3.4.1.5 Calibration of the test circuit

Subclause 8.3.4.1.5 of IEC 60947-1:2007 applies.

9.3.4.1.6 Test procedure

Subclause 8.3.4.1.6 of IEC 60947-1:2007 applies with the following additions.

The contactor or the starter and its associated SCPD, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall be mounted and connected as in normal use with the cross-section given in Table 9, Table 10 and Table 11 of IEC 60947-1:2007 for a utilization category. They shall be connected in the test circuit using a maximum of 2,4 m of cable corresponding to the operational current of the starter for each main circuit.

Three-phase tests are considered to cover single-phase applications.

9.3.4.1.7 Void

9.3.4.1.8 Interpretation of records

Subclause 8.3.4.1.8 of IEC 60947-1:2007 applies.

9.3.4.2 Conditional short-circuit current of contactors, starters, combination starters, combination switching devices, protected starters and protected switching devices

9.3.4.2.1 General requirements for the conditional short-circuit current test

The contactor or starter and the associated SCPD, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall be subjected to the tests given in 9.3.4.2.2 and 9.3.4.2.3. The tests shall be so conducted that conditions of maximum motor current I_e and of maximum U_e are covered.

For a magnetically operated contactor or starter, the magnet shall be held closed by a separate electrical supply at the rated control circuit supply voltage U_s . The SCPD used shall be as stated in 8.2.5.1. If the SCPD is a circuit-breaker with an adjustable current setting, the test shall be done with the circuit-breaker adjusted to the maximum setting for the declared type of co-ordination and discrimination.

During the test, all openings of the enclosure shall be closed as in normal service and the door or cover secured by the means provided.

A starter covering a range of motor ratings and equipped with interchangeable overload relays shall be tested with the overload relay with the highest impedance and the overload relay with the lowest impedance together with the corresponding SCPDs.

For type "1" co-ordination, a new test sample may be used for each operation stated in 9.3.4.2.2 and 9.3.4.2.3.

For type "2" co-ordination, one sample shall be used for the tests at the prospective current " r " (see 9.3.4.2.2) and one sample for the tests at current I_q (see 9.3.4.2.3).

By agreement of the manufacturer, the tests at r and I_q may be carried out on the same sample.

9.3.4.2.2 Test at the prospective current " r "

The circuit shall be adjusted to the prospective test current corresponding to the rated operational current I_e according to Table 13 or preferably Table 14 at the discretion of the manufacturer. Both tables are considered equivalent for the product to comply with this document.

The contactor or starter and the associated SCPD, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall then be connected in the circuit. The following sequence of operations shall be performed:

- a) one breaking operation of the SCPD shall be performed with all the switching devices closed prior to the test ("O" operation);
- b) one breaking operation of the SCPD shall be performed by closing the contactor or starter on to the short-circuit ("CO" operation).

Table 13 – Value of the prospective test current according to the rated operational current

Rated operational current I_e^a	Prospective current "r"
A	kA
$I_e \leq 16$	1
$16 < I_e \leq 63$	3
$63 < I_e \leq 125$	5
$125 < I_e \leq 315$	10
$315 < I_e \leq 630$	18
$630 < I_e \leq 1\,000$	30
$1\,000 < I_e \leq 1\,600$	42
$1\,600 < I_e$	Subject to agreement between manufacturer and user

^a If the contactor or starter is not specified according to utilization category AC-2, AC-3, AC-3e and AC-4, the prospective current "r" shall be subject of agreement between manufacturer and user.

Table 14 – Value of the prospective test current according to the rated operational current (harmonized table)

Rated operational current $I_e^{a, e}$	Prospective current "r"	Power factor
A	kA ^f	
$I_e \leq 12$	1	0,7 to 0,8
$12 < I_e \leq 50^b$	3	0,7 to 0,8
$50 < I_e \leq 100^c$	5	0,7 to 0,8
$100 < I_e \leq 250^d$	10	0,5 to 0,7
$250 < I_e \leq 500$	18	0,2 to 0,3
$500 < I_e \leq 800$	30	0,2 to 0,3
$800 < I_e \leq 1\,300$	42	0,2 to 0,3
$1\,300 < I_e$	Subject to agreement between manufacturer and user.	0,2 to 0,3

NOTE Table 14 has been introduced for harmonization purpose with UL 60947-4-1 and is equivalent to UL 60947-4-1.

^a If the contactor or starter is not specified according to utilization category AC-2, AC-3, AC-3e and AC-4, the prospective current "r" shall be subject of agreement between manufacturer and user.

^b at 690 V and above: $12 < I_e \leq 63$.

^c at 690 V and above: $63 < I_e \leq 125$.

^d at 690 V and above: $125 < I_e \leq 250$.

^e Rated operational current may be marked "motor full load current" in North America.

^f Prospective current "r" may be called "standard fault current" in North America.

9.3.4.2.3 Test at the rated conditional short-circuit current I_q

NOTE This test is done if the current I_q is higher than the current "r".

The circuit shall be adjusted to the prospective short-circuit current I_q equal to the rated conditional short-circuit current.

If the SCPD is a fuse and the test current is within the current-limiting range of the fuse, then, if possible, the fuse shall be selected to permit the maximum peak let-through current (I_p) and the maximum let-through energy (I^2t).

The contactor or starter and the associated SCPD, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall then be connected to the circuit.

The following sequence of operations shall be performed:

- a) one breaking operation of the SCPD shall be performed with all the switching devices closed ("O" operation) prior to the test.
- b) one breaking operation of the SCPD shall be performed by closing ("CO" operation) the contactor or starter on to the short-circuit.
- c) in the case of a combination starter or a protected starter, with the switching device of the SCPD having a short-circuit breaking capacity or rated conditional short-circuit current less than the rated conditional short-circuit current of the combination starter or protected starter the following additional test shall be made. One breaking operation of the SCPD shall be performed by closing ("CO" operation) the switching device (switch or circuit-breaker) on to the short-circuit, the contactor or starter already being closed. This operation may be performed either on a new sample (starter and SCPD) or on the first sample with the agreement of the manufacturer. After this operation only conditions a) to g) of 9.3.4.2.4 shall be verified.

9.3.4.2.4 Results to be obtained

The contactor, starter, or the combination starter, the combination switching device, the protected starter or the protected switching device, shall be considered to have passed the tests at the prospective current " r " and, where applicable, the prospective current I_q , if the following conditions are met for the claimed type of co-ordination.

Both types of co-ordination (all devices):

- a) The fault current has been successfully interrupted by the SCPD, the combination starter or the combination switching device and the fuse or fusible element or solid connection between the enclosure and supply shall not have melted.
- b) The door or cover of the enclosure has not been blown open and it is possible to open the door or cover. Deformation of the enclosure is considered acceptable provided that the degree of protection by the enclosure is not less than IP2X.
- c) There is no damage to the conductors or terminals and the conductors have not been separated from the terminals.
- d) There is no cracking or breaking of an insulating base to the extent that the integrity of mounting of a live part is impaired.

Both types of co-ordination (combination starters, combination switching devices, protected starters and protected switching devices only):

- e) The circuit-breaker or the switch is capable of being opened manually by its operating means.
- f) Neither end of the SCPD is completely separated from its mounting means to an exposed conductive part.
- g) If a circuit-breaker with rated ultimate short-circuit breaking capacity less than the rated conditional short-circuit current assigned to the combination starter, the combination switching device, the protected starter or the protected switching device is employed, the circuit-breaker shall be tested to trip as follows:

- 1) circuit-breakers with instantaneous trip relays or releases: at 120 % of the trip current.
- 2) circuit-breakers with overload relays or releases: at 250 % of the rated current of the circuit-breaker.

Type "1" co-ordination (all devices):

- h) There has been no discharge of parts beyond the enclosure. Damage to the contactor and the overload relay is acceptable. The starter other than MPSD may be inoperative after each operation. The starter shall therefore be inspected and the contactor and/or the overload relay and the release of the circuit-breaker shall be reset if necessary and, in the case of fuse protection, all fuse-links shall be replaced.

Type "1" co-ordination (combination and protected starters only):

- i) The adequacy of insulation in accordance with 8.3.3.4.1, item 4), of IEC 60947-1:2007 is verified after each operation (at currents " r " and " I_q ") by a dielectric test on the complete unit under test (SCPD plus contactor/starter but before replacement of parts) using a power frequency withstand voltage of twice the rated operational voltage U_e but not less than 1 000 V. The test voltage shall be applied to the incoming supply terminals, with the switch or the circuit-breaker in the open position, as follows:
 - between each pole and all other poles connected to the frame of the starter;
 - between all live parts of all poles connected together and the frame of the starter;
 - between the terminals of the line side connected together and terminals of the other side connected together.

For equipment suitable for isolation, the leakage current shall be measured through each pole, with the contacts in the open position, at a test voltage of $1,1 U_e$ and shall not exceed 6 mA.

Type "2" co-ordination (all devices):

- j) No damage to the overload relay or other parts has occurred, except that welding of contactor or starter contacts other than MPSD contacts is permitted, if they are easily separated (e.g. by energizing several times the coil of the contactor or moving the operating means or using a tool such as a screwdriver for separating the welded contact according to the manufacturer instructions) without significant deformation (without impairing the insulation of the contactor according to d) and i)), but no replacement of parts is permitted during the test, except that, in the case of fuse protection, all fuse-links shall be replaced.

In the case of welded contacts as described above, the functionality of the device shall be verified by carrying out 10 operating cycles under the conditions of Table 10 for the applicable utilization category.

- k) The tripping of the overload relay shall be verified at a multiple of the current setting and shall conform to the published tripping characteristics, according to 5.7.5, both before and after the short-circuit test.
- l) The adequacy of the insulation in accordance with 8.3.3.4.1, item 4), of IEC 60947-1:2007 shall be verified by a dielectric test on the contactor, the starter, the combination starter, the combination switching device, the protected starter or the protected switching device, using a power frequency withstand voltage of twice the rated operational voltage U_e but not less than 1 000 V.

In the case of combination starters, combination switching devices, protected starters and protected switching devices, additional tests according to 8.3.3.4.1, item 4), of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 shall be made across the main poles of the device with the contacts of the switch or of the circuit-breaker open and the contacts of the starter closed.

For equipment suitable for isolation, the leakage current shall be measured through each pole, with the contacts in the open position, at a test voltage of $1,1 U_e$ and shall not exceed 2 mA.

Fuse-links, if any, are shorted.

9.3.5 Overload current withstand capability of contactors

For the test, the contactor shall be mounted, wired and operated as specified in 9.3.2.

All poles of the contactors are simultaneously subjected to one test with the overload current and duration values stated in 8.2.4.4. The test is performed at any convenient voltage and it starts with the contactor at room temperature.

After the test, the contactor shall be substantially in the same condition as before the test. This is verified by visual inspection.

NOTE The I^2t value (Joule integral) calculated from this test cannot be used to estimate the performance of the contactor under short-circuit conditions.

9.3.6 Routine tests and sampling tests

9.3.6.1 General

The tests shall be carried out under the same conditions as those specified for type tests in the relevant parts of 9.1.2 or under equivalent conditions. However, the limits of operation in 9.3.3.2 may be verified at the prevailing ambient air temperature and on the overload relay alone, but a correction may be necessary to allow for normal ambient conditions.

If devices are tested separately, their combination shall be tested with the dielectric test and other relevant operational tests. However, if the combination is built up with already tested connection systems or auxiliaries, an additional dielectric test is not necessary.

9.3.6.2 Operation and operating limits

For electromagnetic, pneumatic and electro-pneumatic contactors or starters, tests are carried out to verify operation within the limits specified in 8.2.1.2.

For manual starters, tests are carried out to verify the proper operation of the starter. Manual operation of MPSD shall be verified according to 9.3.6.4.

The calibration of the short-circuit release of a MPSD shall be verified according to 9.3.6.5.

NOTE 1 In these tests, it is not necessary to reach thermal equilibrium. The lack of thermal equilibrium can be compensated by using a series resistor or by appropriately decreasing the voltage limit.

Tests shall be made to verify the calibration of relays. In the case of a time delay overload relay, this may be a single test with all poles equally energized at a multiple of the current setting, to check that the tripping time conforms (within tolerances) to the curves supplied by the manufacturer; in the case of an instantaneous magnetic overload relay, the test shall be carried out at 1,1 times the current setting. For under-current relays, stall relays and jam relays, tests shall be carried out to verify the proper operation of these relays (see 8.2.1.5.4, 8.2.1.5.5 and 8.2.1.5.6).

NOTE 2 In the case of a time-delay magnetic overload relay comprising a time-delay device working with a fluid dashpot, calibration can be carried out with the dashpot empty, at a percentage of the current setting indicated by the manufacturer and capable of being justified by a special test.

9.3.6.3 Dielectric tests

9.3.6.3.1 General

Subclause 8.3.3.4.2 of IEC 60947-1:2007 applies with the following addition.

In the case of a rheostatic rotor starter, all the poles of the rotor switching devices will normally be connected through the starting resistors; the dielectric test is therefore confined to the application of the test voltage between the rotor circuit and the frame of the starter.

The use of the metal foil is not necessary.

NOTE The combined test of 8.3.3.4.2 of IEC 60947-1:2007 is possible.

9.3.6.3.2 Routine power frequency test for devices incorporating voltage limiting components

At the discretion of the manufacturer, the device incorporating voltage limiting components are to be tested with the following sequence a) to b):

a) Application of the test voltage

The test shall be performed in accordance with 8.3.3.4.2 2) of IEC 60947-1:2007. The value of the test voltage shall be the U_V RMS value (max. operational voltage of the voltage limiting components) or the maximum U_V DC value of the voltage limiting components with a tolerance of -10 %.

Acceptance criteria: The over-current relay of the test apparatus shall not trip (lower tripping limit).

b) Verification of the proper function of the voltage limiting components

The test shall be performed in accordance with 8.3.3.4.2 2) of IEC 60947-1:2007. The value of the test voltage shall be chosen by the manufacturer so that a current is generated between the upper tripping limit and the lower tripping limit of the test apparatus.

Acceptance criteria: The current shall be between a) and b) and the voltage limiting component shall not be damaged.

NOTE The main purpose of this test is to check the proper operation of the voltage limiting component.

9.3.6.4 Mechanical operation tests of a MPSD

The following tests shall be carried out without current in the main circuit, except when required for the operation of releases. During the tests, no adjustments shall be made and the operation shall be satisfactory.

The following tests shall be made:

- two close-open operations;
- two trip-free operations.

NOTE For the definition of a trip-free mechanical switching device, see 2.4.23 of IEC 60947-1:2007.

9.3.6.5 Verification of the calibration of the short-circuit release of a MPSD

The verification of the calibration of the instantaneous short-circuit releases shall check the non-operation and operation of the releases at the values of current given in 9.3.3.2.2 e) without measurement of break time being required.

The tests may be made by loading two poles in series with the test current, using all possible combinations of poles having releases, or by loading each pole having a release individually with the test current.

One method of determining the tripping level consists in applying a slowly rising test current, starting from a value below the lower limit until tripping of the MPSD occurs. Tripping shall occur between the lower and upper limits of test current.

9.4 EMC tests

9.4.1 General

Subclause 8.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 completed with 9.4.2 and 9.4.3 of this document applies with the following additions.

Where a range of contactors or starters comprise similar control electronics, within similar frame sizes, it is only necessary to test a single representative sample of the contactor or starter as specified by the manufacturer.

The test report and the instruction manual shall include any special measures that have been taken to achieve compliance, for example the use of shielded or special cables. If auxiliary equipment is used with the contactor or starter in order to comply with immunity or emission requirements, it shall be included in the report and the instruction manual.

The test sample shall be in the open or closed position, whichever is the worse, and shall be operated with the rated control circuit supply.

9.4.2 Immunity

The tests of Table 16 are required. Special requirements are specified from 9.4.2.1 to 9.4.2.7.

If, during the EMC tests, conductors are to be connected to the test sample, the cross-section and the type of the conductors are optional but shall be in accordance with the manufacturer's literature.

Table 16 – EMC immunity tests

Type of test	Test level required
Electrostatic discharge	Corresponding test level of Table 23 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.
Radiated radio-frequency electromagnetic field	Corresponding test level of Table 23 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.
Electrical fast transient/bursts ^a	Corresponding test level of Table 23 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.
Surges (1,2/50 μ s – 8/20 μ s)	Corresponding test level of Table 23 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.
Conducted disturbances induced by radio-frequency fields ^{b c}	Corresponding test level ^d of Table 23 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.
Voltage dips and short-time interruptions	Corresponding test level of Table 23 Class 3 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.
Harmonics in the supply	9.4.2.9
^a The contactor shall be operated at least one time during the test and the overload relay is loaded at 0,9 times the current setting with a maximum of 100 A. ^b Applicable to ports only interfacing with cables whose total length according to the manufacturer's functional specification may exceed 3 m. ^c The test level can also be defined as the equivalent current into a 150 Ω load. ^d Except for the ITU broadcast frequency band 47 MHz to 68 MHz, where the level shall be 3 V.	

9.4.2.1 Performance of the test sample during and after the test

The product shall perform according to the performance criteria given in Table 12. After the tests the operating limits of 9.3.6.2 shall be verified at ambient temperature.

9.4.2.2 Electrostatic discharge

Subclause 8.4.1.2.2 of IEC 60947-1:2007 applies with the following additions.

Discharges shall be applied only to points which are accessible during normal usage. Tests are not required on power terminals and IP00 device (open frame or chassis unit). In this last case, the manufacturer shall provide instructions on how to mitigate the possibility of damage due to static discharge.

The contactor or starter shall comply with performance criterion B of Table 12.

9.4.2.3 Radiated radio-frequency electromagnetic field

Subclause 8.4.1.2.3 of IEC 60947-1:2007 applies with the following additions.

The contactor or starter shall comply with performance criterion A of Table 12.

9.4.2.4 Conducted disturbances induced by radio-frequency fields

Subclause 8.4.1.2.6 of IEC 60947-1:2007 applies with the following addition.

This test is only applicable to ports with interfacing cables whose total length according to the manufacturer's functional specification may exceed 3 m.

The device shall comply with performance criterion A of Table 12.

9.4.2.5 Electrical fast transient/bursts

Subclause 8.4.1.2.4 of IEC 60947-1:2007 applies with the following additions.

Terminals for control and auxiliary circuits intended for the connection of conductors which extend more than 3 m shall be tested.

The contactor shall be operated at least one time during the test and the overload relay is loaded at 0,9 times the current setting with a maximum of 100 A.

The contactor or starter shall comply with performance criterion B of Table 12.

9.4.2.6 Surges (1,2/50 μ s – 8/20 μ s)

Subclause 8.4.1.2.5 of IEC 60947-1:2007 applies with the following additions.

The contactor or starter shall comply with performance criterion B of Table 12.

9.4.2.7 Power frequency magnetic fields

Subclause 8.4.1.2.7 of IEC 60947-1:2007 applies with the following additions.

The contactor or starter shall comply with performance criterion A of Table 12.

9.4.2.8 Voltage dips and short-time interruptions

Subclause 8.4.1.2.8 of IEC 60947-1:2007 applies for class 3 with the performance criterion C of Table 12 except for 0,5 cycle and 1 cycle for which the performance criterion B of Table 12 applies.

For contactors only the general criteria of Table 12 apply. During the test, the contactor or starter may open temporally but it shall remain fully operational without reset.

9.4.2.9 Harmonics in the supply

For MPSD with electronic over-current release, the true RMS response, in order to avoid unwanted tripping at 0,9 times the current setting for 10 times the tripping time, shall be verified up to the fifth harmonic component at 50 % of the fundamental component:

- by test according to F.4.1 of IEC 60947-2:2016; or
- by simulation, using models for which the validity has to be demonstrated; or
- by design assessment, i.e. confirmation of the correct application of calculations and design rules, including use of appropriate safety margins.

For other device, harmonic test requirement from F.4.1 of IEC 60947-2:2016 is under consideration.

NOTE Current waveform asymmetry, typically in case of failure of a power semiconductor connected on the network, is creating a significant unbalance and can affect the current detection of an electronic overload protection and therefore a true RMS measurement is relevant.

9.4.3 Emission

9.4.3.1 Conducted radio-frequency emission tests

A description of the test, the test method and the test set-up are given in CISPR 11.

It shall be sufficient to test two samples from a range of contactors or starters of different power ratings which represent the highest and lowest power ratings of the range.

The emission shall not exceed the levels given in Table 17.

Table 17 – Terminal disturbance voltage limits for conducted radio-frequency emission (for mains ports)

Frequency band MHz	Environment A dB(μV)	Environment B dB(μV)
0,15 to 0,5	79 quasi-peak 66 average	66 to 56 quasi-peak 56 to 46 average (decrease with log of frequency)
0,5 to 5,0	73 quasi-peak 60 average	56 quasi-peak 46 average
5 to 30	73 quasi-peak 60 average	60 quasi-peak 50 average
NOTE Limits are in accordance with CISPR 11:2015, CISPR 11:2015/AMD1:2016, Group 1 for mains input ports and total rated power less than 20 kVA.		

9.4.3.2 Radiated radio-frequency emission tests

A description of the test, the test method and the test set-up are given in Clause 7 of CISPR 11:2015, CISPR 11:2015/AMD1:2016.

Tests are required where the control and auxiliary circuits contain components with fundamental switching frequencies greater than 9 kHz, for example switch-mode power supplies, etc.

The emission shall not exceed the levels given in Table 18.

Table 18 – Radiated emission test limits

Frequency range MHz	Environment A ^a Quasi-peak dB (μV)			Environment B ^a Quasi-peak dB (μV)	
	at 30 m	at 10 m	at 3 m	at 10 m	at 3 m
30 to 230	30	40	50	30	40
230 to 1 000	37	47	57	37	47

^a Tests may be carried out at 3 m distance only to small equipment (equipment, either positioned on a table top or standing on the floor which, including its cables fits in a cylindrical test volume of 1,2 m in diameter and 1,5 m above the ground plane).

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 PLV

Annex A (normative)

Marking and identification of terminals of contactors, starters and associated overload relays

A.1 General

Annex L of IEC 60947-1:2007 applies with the following addition.

A.2 Marking and identification of terminals of main circuits

The terminals of the main circuits shall be marked by single figure numbers and an alphanumeric system according to Figure A.1.

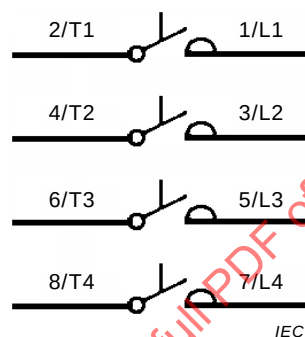


Figure A.1 – Main circuit

NOTE The present alternative methods of marking, i.e. 1-2 and L1-T1, will be progressively superseded by the new method above.

Alternatively, terminals may be identified on the wiring diagram supplied with the device.

A.3 Marking and identification of terminals of overload relays

The terminals of the main circuits of overload relays shall be marked in the same manner as the terminals of the main circuits of contactors (see A.1). Examples are given in Figure A.2.

The terminals of the auxiliary circuits of overload relays shall be marked in the same manner as the terminals of the auxiliary circuits of contactors with specified functions (see L.3.2 of IEC 60947-1:2007).

The sequence number shall be 9; if a second sequence number is required, it shall be 0.

EXAMPLES

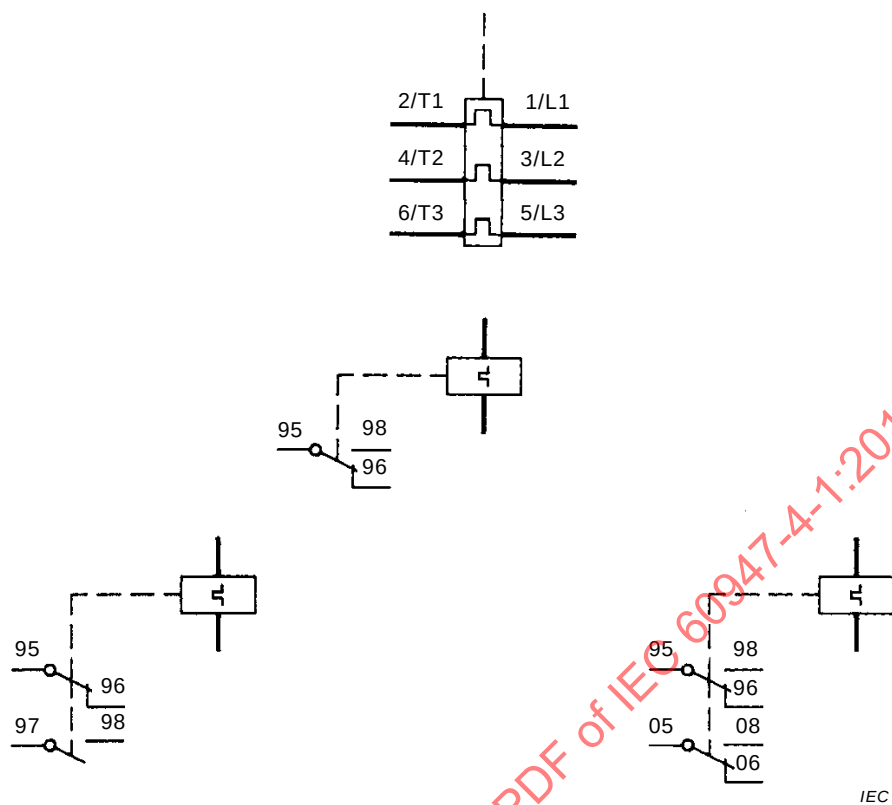


Figure A.2 – Overload relays

Alternatively, terminals may be identified on the wiring diagram supplied with the device.

Annex B (normative)

Special tests

B.1 General

Special tests are done at the discretion of the manufacturer.

B.2 Mechanical durability

B.2.1 General

By convention, the mechanical durability of a design of contactor or starter is defined as the number of no-load operating cycles which would be attained or exceeded by 90 % of all the apparatus of this design before it becomes necessary to service or replace any parts (including electronic parts of electronically controlled electromagnet and any mechanical part); however, normal maintenance according to the information given by the manufacturer (including replacement of contacts), as specified in B.2.2.1 and B.2.2.3, is permitted.

NOTE This method is different than the method of Annex K, for which the value obtained can be different.

The preferred numbers of no-load operating cycles, expressed in millions, are:

0,001 – 0,003 – 0,01 – 0,03 – 0,1 – 0,3 – 1 – 3 and 10.

B.2.2 Verification of mechanical durability

B.2.2.1 Condition of the contactor or starter for tests

The contactor or starter shall be installed as for normal service; in particular, the conductors shall be connected in the same manner as for normal use.

During the test, there shall be no voltage or current in the main circuit. The contactor or starter may be lubricated before the test if lubrication is prescribed in normal service.

B.2.2.2 Operating conditions

The coils of the control electromagnets shall be supplied at their rated voltage and, if applicable, at their rated frequency.

If a resistance or an impedance is provided in series with the coils, whether short-circuited during the operation or not, the tests shall be carried out with these elements connected as in normal operation.

Pneumatic and electro-pneumatic contactors or starters shall be supplied with compressed air at the rated pressure.

Manual starters shall be operated as in normal service.

B.2.2.3 Test procedure

- a) The tests are carried out at the frequency of operations corresponding to the class of intermittent duty. However, if the manufacturer considers that the contactor or starter can satisfy the required conditions when using a higher frequency of operations, he may do so.

- b) In the case of electromagnetic and electro-pneumatic contactors or starters, the duration of energization of the control electromagnet shall be greater than the time of operation of the contactor or starter and the time for which the electromagnet is not energized shall be of such a duration that the contactor or starter can come to rest at both extreme positions.

The number of operating cycles to be carried out shall be not less than the number of no-load operating cycles stated by the manufacturer.

The verification of mechanical durability may be made separately on the various components of the starter which are not mechanically linked together, unless a mechanical interlock not previously tested with its contactor is involved.

- c) For contactors or starters fitted with releases with shunt coils or under voltage releases, at least 10 % of the total number of opening operations shall be performed by these releases.
- d) After each tenth of the total number of operating cycles given in B.2.1 has been carried out, it is permissible before carrying on with the test:
- to clean the whole contactor or starter without dismantling;
 - to lubricate parts for which lubrication is prescribed by the manufacturer for normal service;
 - to adjust the travel and the pressure of the contacts if the design of the contactor or starter enables this to be done.
- e) This maintenance work shall not include any replacement of parts.
- f) In the case of star-delta starters, the built-in device causing time-delay between closing on star connection and closing on delta connection, if adjustable, may be set at its lowest value.
- g) In the case of rheostatic starters, the built-in device causing time-delay between closing of the rotor switching devices, if adjustable, may be set at its lowest value.
- h) In the case of auto-transformer starters, the built-in device causing time-delay between closing on the starting position and closing on the ON position, if adjustable, may be set at its lowest value.

B.2.2.4 Results to be obtained

Following the tests of mechanical durability, the contactor or starter shall still be capable of complying with the operating conditions specified in 9.3.6.2 and 9.3.6.3 at room temperature.

Any timing relays or other devices for the automatic control shall still be operating.

B.2.2.5 Statistical analysis of test results for contactors or starters

The mechanical durability of a design of a contactor or starter is assigned by the manufacturer and verified by a statistical analysis of the results of the tests.

For contactors or starters which are produced in small quantities, the tests described in B.2.2.6 and B.2.2.7 do not apply.

However, for contactors or starters which are produced in small quantities and which also differ from a basic design only by minor variations without notable influence on characteristics, the manufacturer may assign mechanical durability on the basis of experience with similar designs, analysis, properties of materials, etc., and on the basis of the analysis of test results on large quantity production of the same basic design.

After this assignment, one of the two tests described below shall be performed. It should be selected by the manufacturer as being the most suitable in each case, for example according to the quantities of planned production or according to the conventional thermal current.

NOTE This test is not intended to be a lot-by-lot or production acceptance test for application by the user.

B.2.2.6 Single 8 test

Eight contactors or starters shall be tested to the assigned mechanical durability.

If the number of failures does not exceed two, the test is considered passed.

B.2.2.7 Double 3 test

Three contactors or starters shall be tested to the assigned mechanical durability.

The test is considered passed if there is no failure, and failed if there is more than one failure. Should there be one failure, then three additional contactors or starters are tested up to assigned mechanical durability and, providing there is no additional failure, the test is considered passed. The test is failed if at any time there is a total of two or more failures.

B.2.2.8 Other methods

Other methods given in ISO 2859-1 may also be used. The maximum acceptance quality level shall be 10 %. The chosen method shall be indicated in the test report. Methods given in IEC 61649 can also be used.

NOTE The single 8 test and the double 3 test are both given in ISO 2859-1:1999 (see Table 10-C-2 and Table 10-D-2). These two tests have been chosen with the objective of basing them on testing a limited number of contactors or starters on essentially the same statistical characteristics (acceptance quality level: 10 %).

B.3 Electrical durability

B.3.1 General

With respect to its resistance to electrical wear, a contactor or starter is by convention characterized by the number of on-load operating cycles corresponding to the different utilization categories given in Table B.1 which can be made without repair or replacement.

Since, for star-delta, two-step auto-transformer and rheostatic rotor starters, the operation is subjected to large variations in the service conditions, it is deemed convenient not to give standard values for the test conditions. However, it is recommended that the manufacturer indicate the electrical durability of the starter for stated service conditions; this electrical durability may be estimated from the results of tests on the component parts of the starter.

For categories AC-3, AC-3e and AC-4, the test circuit shall comprise inductors and resistors so arranged as to give the appropriate values of current, voltage and power factor given in Table B.1; moreover, for AC-4, the test circuit testing the making and breaking capacity shall be used, see 9.3.3.5.2.

In all cases, the speed of operation shall be chosen by the manufacturer.

The tests shall be taken as valid if the values recorded in the test report differ from the values specified only within the following tolerances:

- current: $\pm 5 \%$;
- voltage: $\pm 5 \%$.

Tests shall be carried out with the contactor or the starter under the appropriate conditions of B.2.2.1 and B.2.2.2 using the test procedure, where applicable, of B.2.2.3, except that replacement of contacts is not permitted.

In the case of starters, if the associated contactor has already satisfied an equivalent test, the test need not be repeated on the starter.

**Table B.1 – Verification of the number of on-load operating cycles –
Conditions for making and breaking corresponding to the several utilization categories**

Utilization category	Value of the rated operational current	Make			Break		
		I / I_e	U / U_e	$\cos \phi^a$	I_c / I_e	U_r / U_e	$\cos \phi^a$
AC-1	All values	1	1	0,95	1	1	0,95
AC-2	All values	2,5	1	0,65	2,5	1	0,65
AC-3, AC-3e	$I_e \leq 17 \text{ A}$	6	1	0,65	1	0,17	0,65
	$I_e > 17 \text{ A}$	6	1	0,35	1	0,17	0,35
AC-4	$I_e \leq 17 \text{ A}$	6	1	0,65	6	1	0,65
	$I_e > 17 \text{ A}$	6	1	0,35	6	1	0,35
		I / I_e	U / U_e	L/R^b ms	I_c / I_e	U_r / U_e	L/R^b ms
DC-1	All values	1	1	1	1	1	1
DC-3	All values	2,5	1	2	2,5	1	2
DC-5	All values	2,5	1	7,5	2,5	1	7,5
I_e rated operational current U_e rated operational voltage I current made In alternating current the conditions for making are expressed in RMS values but it is understood that the peak value of symmetrical current corresponding to the power factor of the circuit may assume a higher value. U applied voltage U_r power-frequency or direct current recovery voltage I_c current broken							
^a Tolerance for $\cos \phi$: $\pm 0,05$.							
^b Tolerance for L/R : $\pm 15 \%$.							

B.3.2 Results to be obtained

After the test, the contactor or the starter shall fulfil the operating conditions as specified in 9.3.6.2 of this document at ambient temperature and withstand a dielectric test voltage as given in 8.3.3.4.1, item 4) b), of IEC 60947-1:2007, and applied as in 8.3.3.4.1, item 4), of IEC 60947-1:2007, the test voltage being applied only:

- between all poles connected together and the frame of the contactor or starter, and
- between each pole and all the other poles connected to the frame of the contactor or starter.

B.3.3 Statistical analysis of test results for contactors or starters

B.3.3.1 General

The electrical durability of a design of a contactor or starter is assigned by the manufacturer and verified by a statistical analysis of the results of the tests. One of the three test methods shall be selected by the manufacturer between B.3.3.2, B.3.3.3 and B.3.3.4 as being the most suitable for example according to the quantities of planned production or according to the conventional thermal current.

For contactors or starters which are produced in small quantities, the tests described in B.3.3.2 and B.3.3.3 do not apply. However, for contactors or starters which are produced in small quantities and which also differ from a basic design only by minor variations without notable influence on characteristics, the manufacturer may assign electrical durability on the

basis of experience with similar designs, analysis, properties of materials, etc., and on the basis of the analysis of test results on large quantity production of the same basic design.

NOTE This test is not intended to be a lot-by-lot or production acceptance test for application by the user.

B.3.3.2 Single 8 test

Eight contactors or starters shall be tested to the assigned electrical durability. If the number of failures does not exceed two, the test is considered passed.

B.3.3.3 Double 3 test

Three contactors or starters shall be tested to the assigned electrical durability. The test is considered passed if there is no failure, and failed if there is more than one failure. Should there be one failure, then three additional contactors or starters are tested up to assigned electrical durability and, providing there is no additional failure, the test is considered passed. The test is failed if at any time there is a total of two or more failures.

B.3.3.4 Other methods

Other methods given in ISO 2859-1 may also be used. The maximum acceptance quality level shall be 10 %. The chosen method shall be indicated in the test report.

NOTE The single 8 test and the double 3 test are both given in ISO 2859-1:1999 (see Table 10-C-2 and Table 10-D-2). These two tests have been chosen with the objective of basing them on testing a limited number of contactors or starters on essentially the same statistical characteristics (acceptance quality level: 10 %).

B.4 Coordination at the crossover current between the starter and associated SCPD

B.4.1 General and definitions

B.4.1.1 General

This annex states different methods of verifying the performance of starters and the associated SCPD(s) at currents below and above the intersection I_{co} of their respective time-current characteristics, provided by the starter and SCPD manufacturer(s), and the corresponding types of co-ordination described in 8.2.5.1.

Co-ordination at the crossover current between the starter and the SCPD can be verified either by the direct method with the special test of B.4.2 or, for type "2" co-ordination only, by the indirect method as in B.4.5.

B.4.1.2 Terms and definitions

B.4.1.2.1 crossover current

I_{co}
current corresponding to the crossover point of the mean or published curves representing the time-current characteristics of the overload relay and the SCPD respectively

Note 1 to entry: The mean curves are the curves corresponding to the average values calculated from the tolerances on the time-current characteristics given by the manufacturer.

B.4.1.2.2 time-current withstand characteristic capability of contactors/starters locus of the currents a contactor/starter can withstand as a function of time

B.4.2 Condition for the test for the verification of co-ordination at the crossover current by a direct method

The starter and its associated SCPD shall be mounted and connected as in normal use. All the tests shall be performed starting from the cold state.

B.4.3 Test currents and test circuits

The test circuit shall be according to 8.3.3.5.2 of IEC 60947-1:2007 except that the oscillatory transient voltage need not be adjusted. The currents for the tests shall be:

(i) $0,75 I_{CO} \begin{smallmatrix} 0 \\ -5 \end{smallmatrix} \%$; and

(ii) $1,25 I_{CO} \begin{smallmatrix} +5 \\ 0 \end{smallmatrix} \%$.

The power factor of the test circuit shall be in accordance with Table 7. In the case of small relays having a high resistance, inductors should be mainly used in order to have a value of power factor as low as possible. The recovery voltage shall be 1,05 times the rated operational voltage.

The SCPD shall be as stated in 8.2.5.1 and of the same rating and characteristics as used in the tests of 9.3.4.2.

If the switching device is a contactor, its coil shall be energized from a separate source at the rated control circuit supply voltage of the contactor coil and connected so that the contactor opens when the overload relay operates.

B.4.4 Test procedure and results to be obtained

B.4.4.1 Test procedure

With the starter and the SCPD closed, the test currents stated in B.4.3 shall be applied by a separate closing device. In each case, the device tested shall be at room temperature.

After each test, it is necessary to inspect the SCPD, reset the overload relay and the release of the circuit-breaker, if necessary, or to replace all fuses if at least one of them has melted.

B.4.4.2 Results to be obtained

After the test at the lower current (i) in B.4.3, the SCPD shall not have operated and the overload relay or release shall have operated to open the starter. There shall be no damage to the starter.

After the test at the higher current (ii) in B.4.3, the SCPD shall have operated before the starter. The starter shall meet the conditions of 9.3.4.2.3 for the type of co-ordination stated by the manufacturer.

B.4.5 Verification of co-ordination at the crossover current by an indirect method

The indirect method consists in verifying on a diagram (see Figure B.1a) and Figure B.1b)) that the following conditions for the verification of co-ordination at the crossover current are met:

- the time-current characteristic of the overload relay/release, starting from cold state, supplied by the manufacturer, shall indicate how the tripping time varies with the current up to a value of at least I_{CO} ; this curve has to lie below the time-current characteristic of the SCPD up to I_{CO} ;
- I_{cd} of the starter, tested as in B.4.5.1, shall be higher than I_{CO} ;

- the time-current withstand characteristic of the contactor, tested as in B.4.5.2, shall be above the time-current characteristic (starting from cold state) of the overload relay up to I_{CO} .

B.4.5.1 Test for I_{cd}

Subclause 9.3.4.1 applies with the following addition.

- Test procedure: the contactor or starter shall make and break the test current (I_{cd}) for the number of operating cycles given in Table B.2. This is made without the SCPD in the circuit.

Table B.2 – Test conditions

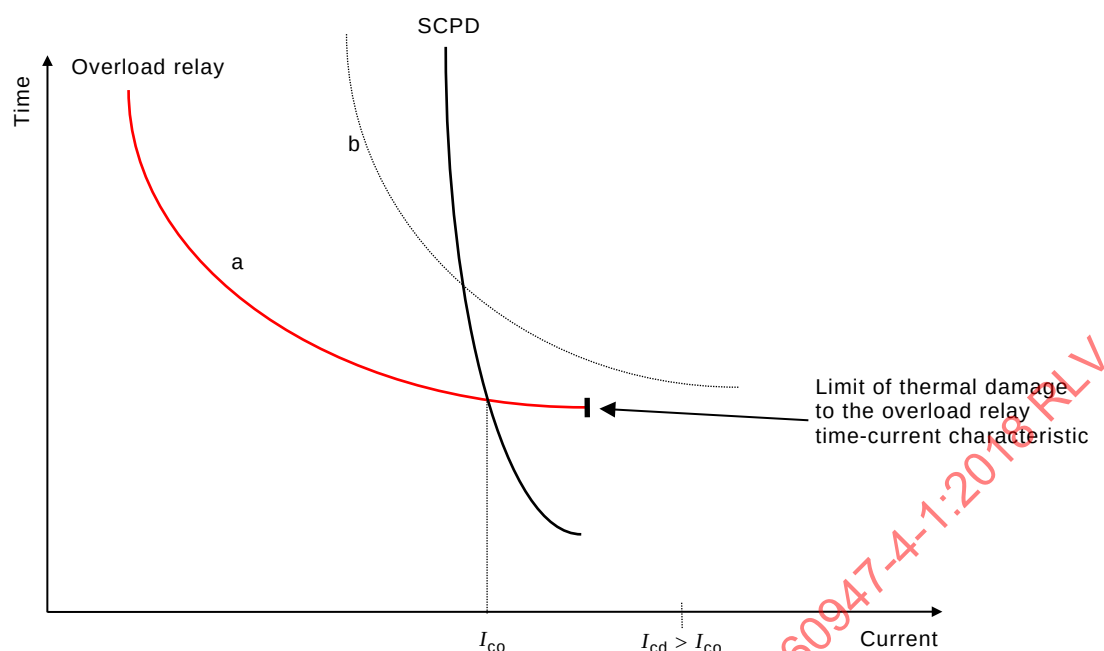
	U_r/U_e	$\cos \phi$	On-time (see Note 2) s	Off-time s	Number of operations
I_{cd}	1,05	See Note 1	0,05	See Note 3	3
NOTE 1 Power factor to be selected according to Table 16 of IEC 60947-1:2007.					
NOTE 2 Time may be less than 0,05 s provided that contacts are allowed to become properly seated before re-opening.					
NOTE 3 See Table 8.					

- Behaviour of contactors or starters during and after the I_{cd} test:
 - a) during the test, there shall be no permanent arcing, no flash-over between poles, no blowing of the fusible element in the earth circuit (see 9.3.4.1.2) and no welding of contacts;
 - b) after the test,
 - 1) the contacts shall operate correctly when the contactor or starter is switched by the applicable method of control;
 - 2) the dielectric properties of the contactors and starters shall be verified by a dielectric test on the contactor or starter using an essentially sinusoidal test voltage of twice the rated operational voltage U_e used for the I_{cd} test, with a minimum of 1 000 V. The test voltage shall be applied, as specified in 8.3.3.4.1, items 2) c) i) and 2) c) ii) of IEC 60947-1:2007.

B.4.5.2 Time-current characteristic withstand capability of contactors/starters

This characteristic is issued by the manufacturer and the values are obtained according to the test procedure specified in 9.3.5 but with combinations of overload currents and durations to establish the characteristic at least up to I_{CO} , in addition to those stated in 8.2.4.4.

This characteristic is valid for overload currents, starting with the contactor at room temperature. The minimum cooling duration required by the contactor between two such overload tests should be stated by the manufacturer.

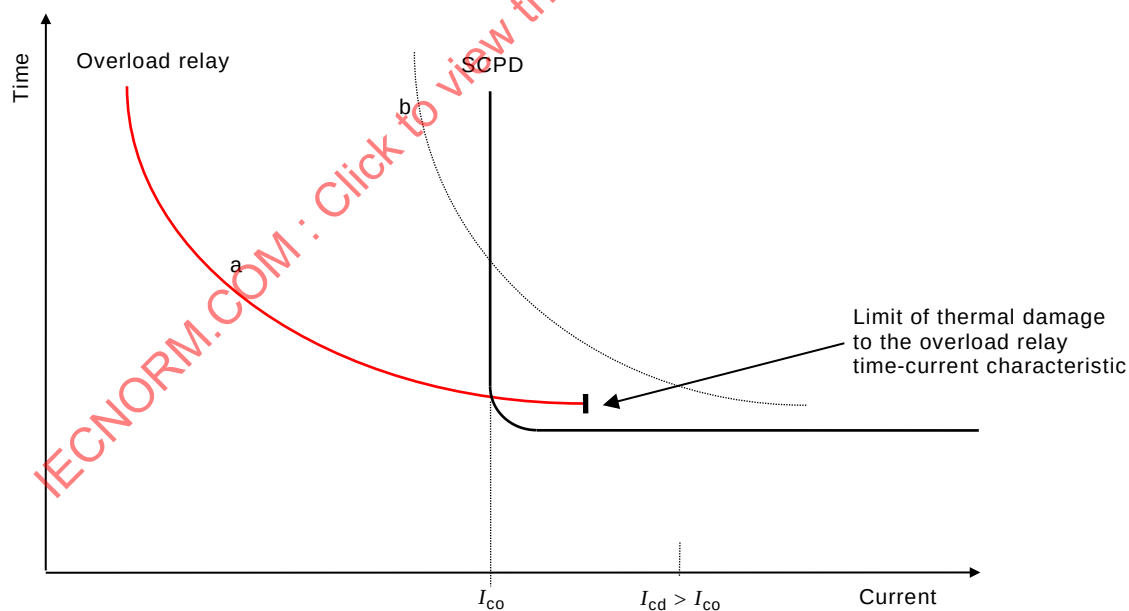


IEC

Key

- a mean overload relay time-current characteristic from cold state
- b time-current characteristic withstand capability of contactor

a) Co-ordination with fuse



IEC

Key

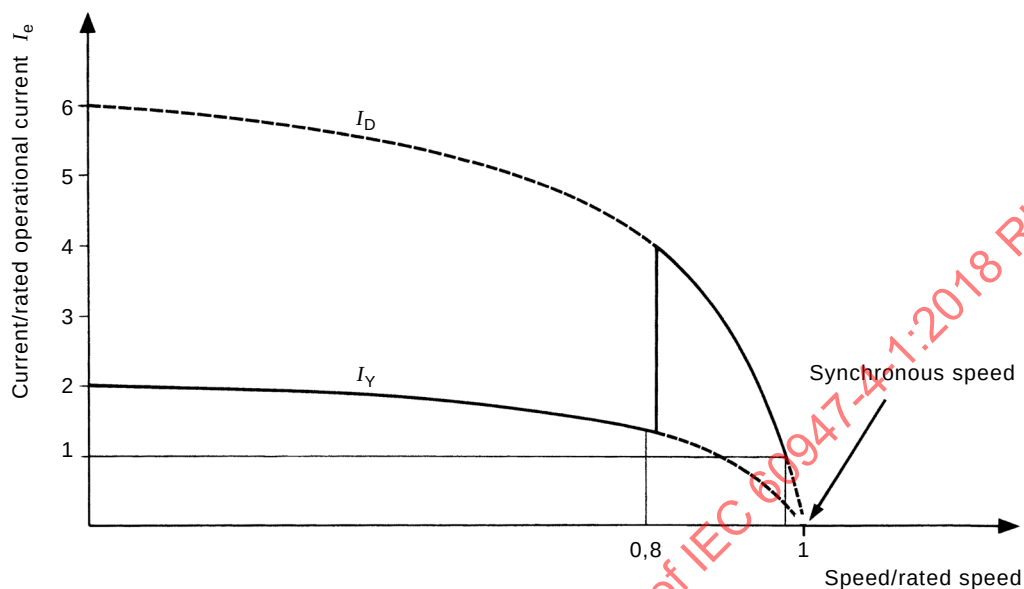
- a mean overload relay time-current characteristic from cold state
- b time-current characteristic withstand capability of contactor

b) Co-ordination with circuit-breaker

Figure B.1 – Examples of time-current withstand characteristic

Annex C (informative)

Typical characteristics of starters

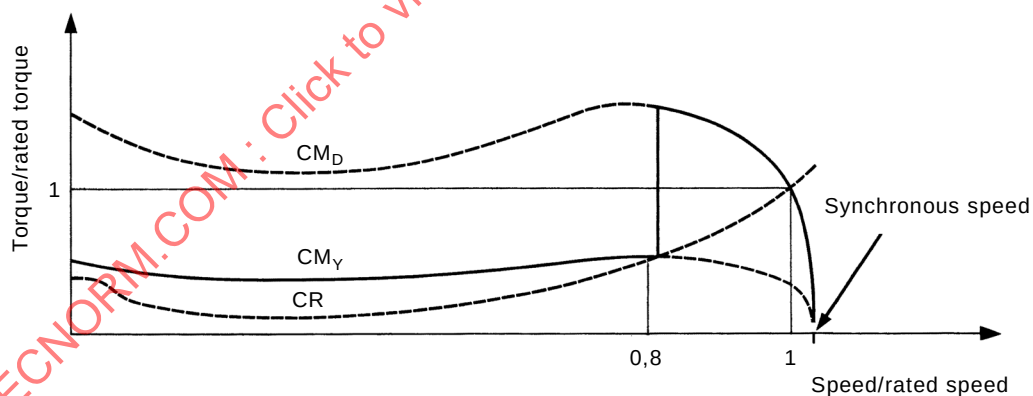


IEC

Key

- I_Y Current in star connection
 I_D Current in delta connection

a) Typical currents during a star-delta start



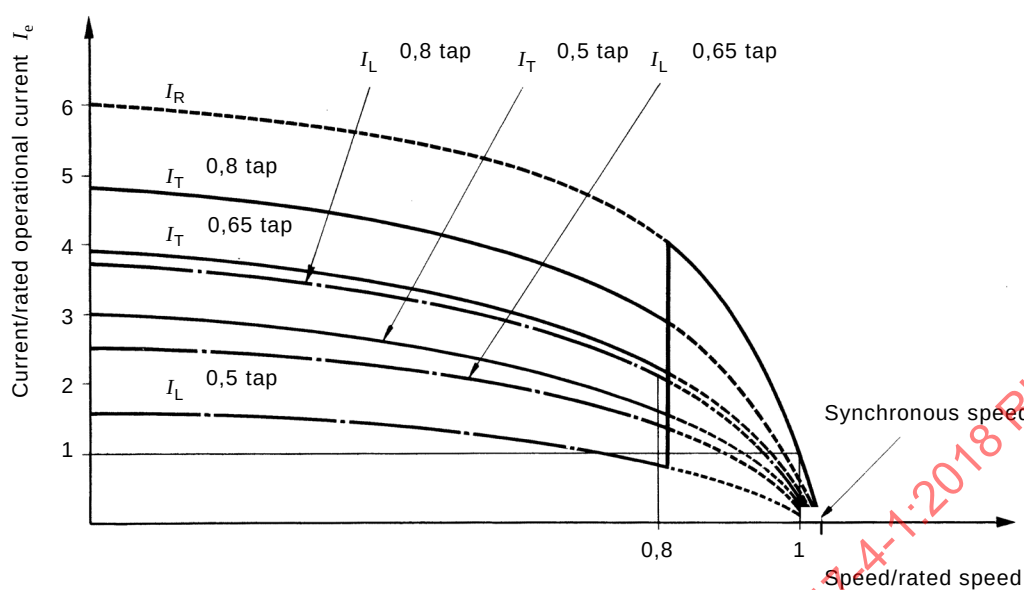
IEC

Key

- CM motor torque
 CR load torque

b) Typical torques during a star-delta start

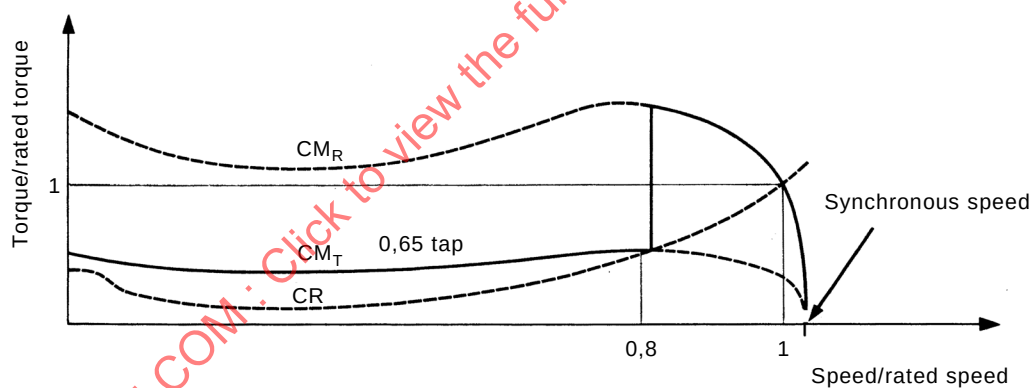
Figure C.1 – Typical curves of currents and torques during a star-delta start (see 3.4.4.1)



Key

- I_R motor current at rated voltage
- I_T motor current at reduced voltage
- I_L line current at reduced voltage

a) Typical currents during an auto-transformer start

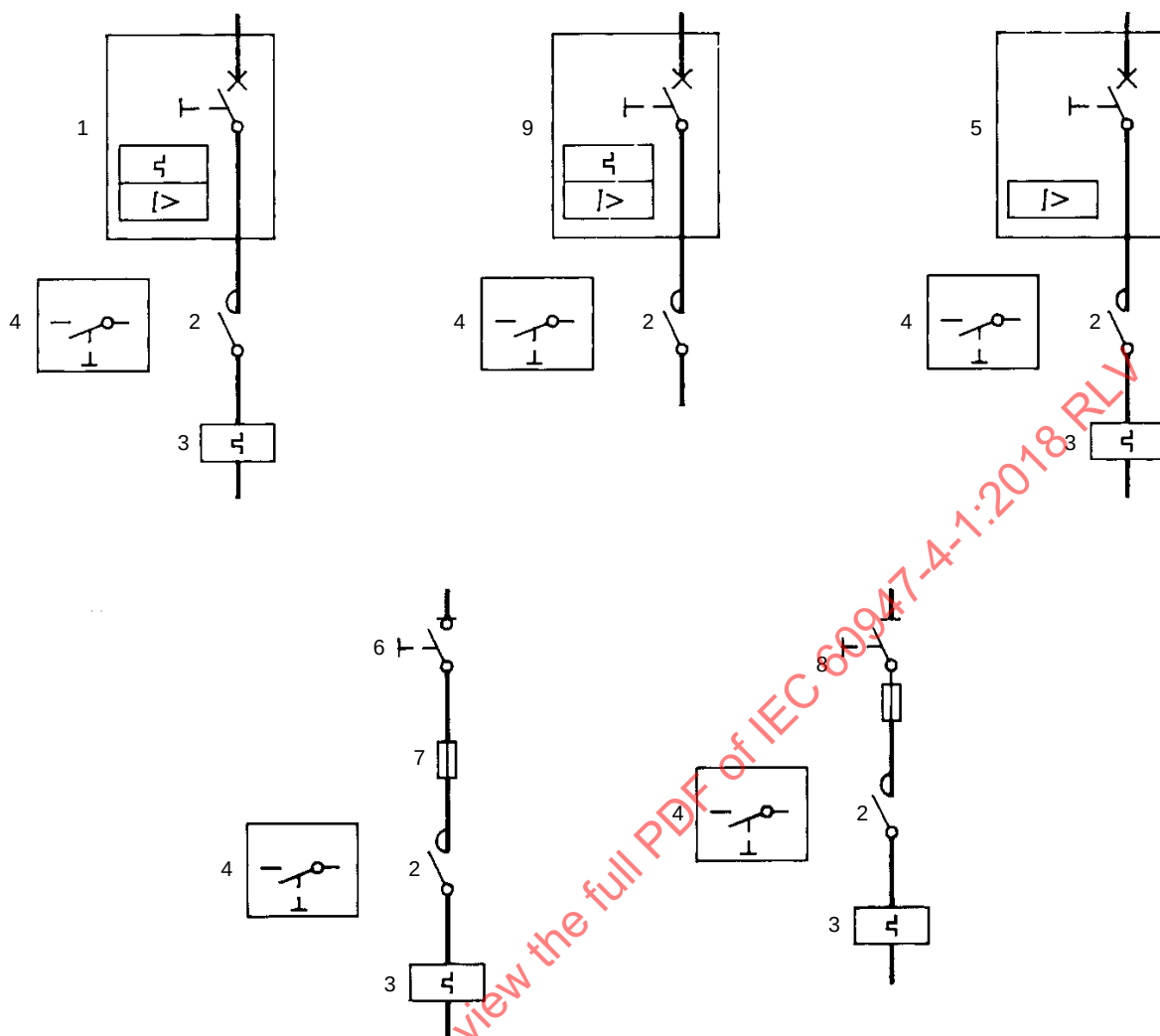


Key

- CR load torque
- CM_R motor torque at rated voltage
- CM_T motor torque at reduced voltage

b) Typical torques during an auto-transformer start

Figure C.2 – Typical curves of currents and torques during an auto-transformer start (see 3.4.4.2)

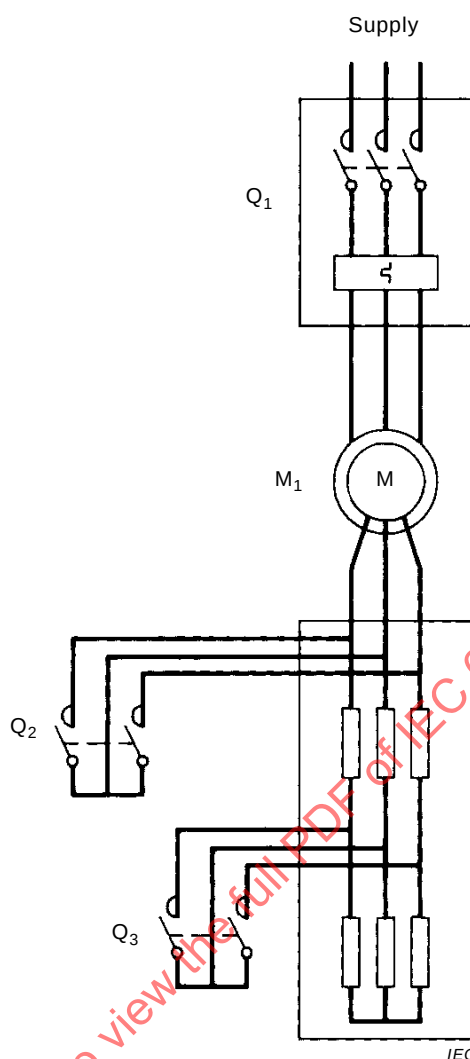


IEC

Key

- 1 circuit-breaker according to IEC 60947-2
- 2 contactor
- 3 overload relay
- 4 control switch
- 5 circuit-breaker magnetic trip only
- 6 switch-disconnector
- 7 fuse
- 8 disconnecting fuse
- 9 motor protective switching device (MPSD)

Figure C.3 – Typical variants of protected starters, combination starters, protected switching devices and combination switching devices



Position of the mechanical switching devices

Mechanical switching device	Position of the starter	Starting		
		Stop	1st step	2nd step
Q_1	O	C	C	C
Q_2	O	O	O	C
Q_3	O	O	C	C
O mechanical switching device open		Q contactor		
C mechanical switching device closed		M motor		

Figure C.4 – Example of three-phase diagram of a rheostatic rotor starter with three starting steps and one direction of rotation (in the case when all the mechanical switching devices are contactors)

SERIES CLOSED
TRANSITION

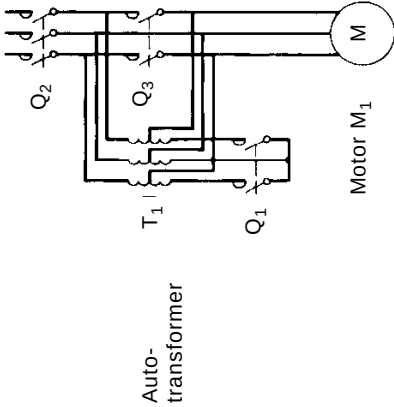


Diagram A₁

PARALLEL OPEN OR
CLOSED TRANSITION

Three-coil transformer

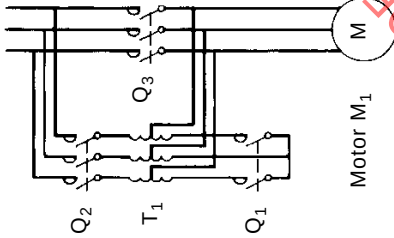


Diagram B₁

Two-coil transformer

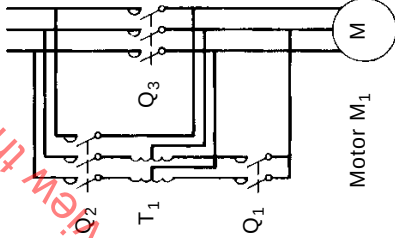


Diagram B₂

PARALLEL OPEN
TRANSITION

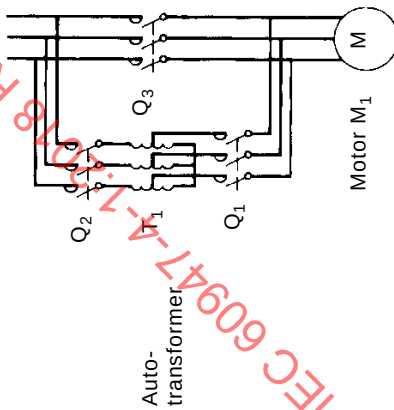


Diagram C₁

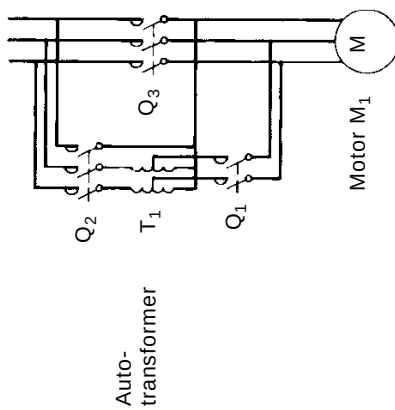


Diagram C₂

IEC

Contact sequence			
Contacts	Start	Transition	On
Q ₁	C	O	O
Q ₂	C	C	C
Q ₃	O	O	C

C = contact closed
O = contact open

Contact sequence				
Contacts	Start	Transition		On
		Open	Close	
			1 2	
Q ₁	C	O	O	O
Q ₂	C	O	C	O
Q ₃	O	O	O	C

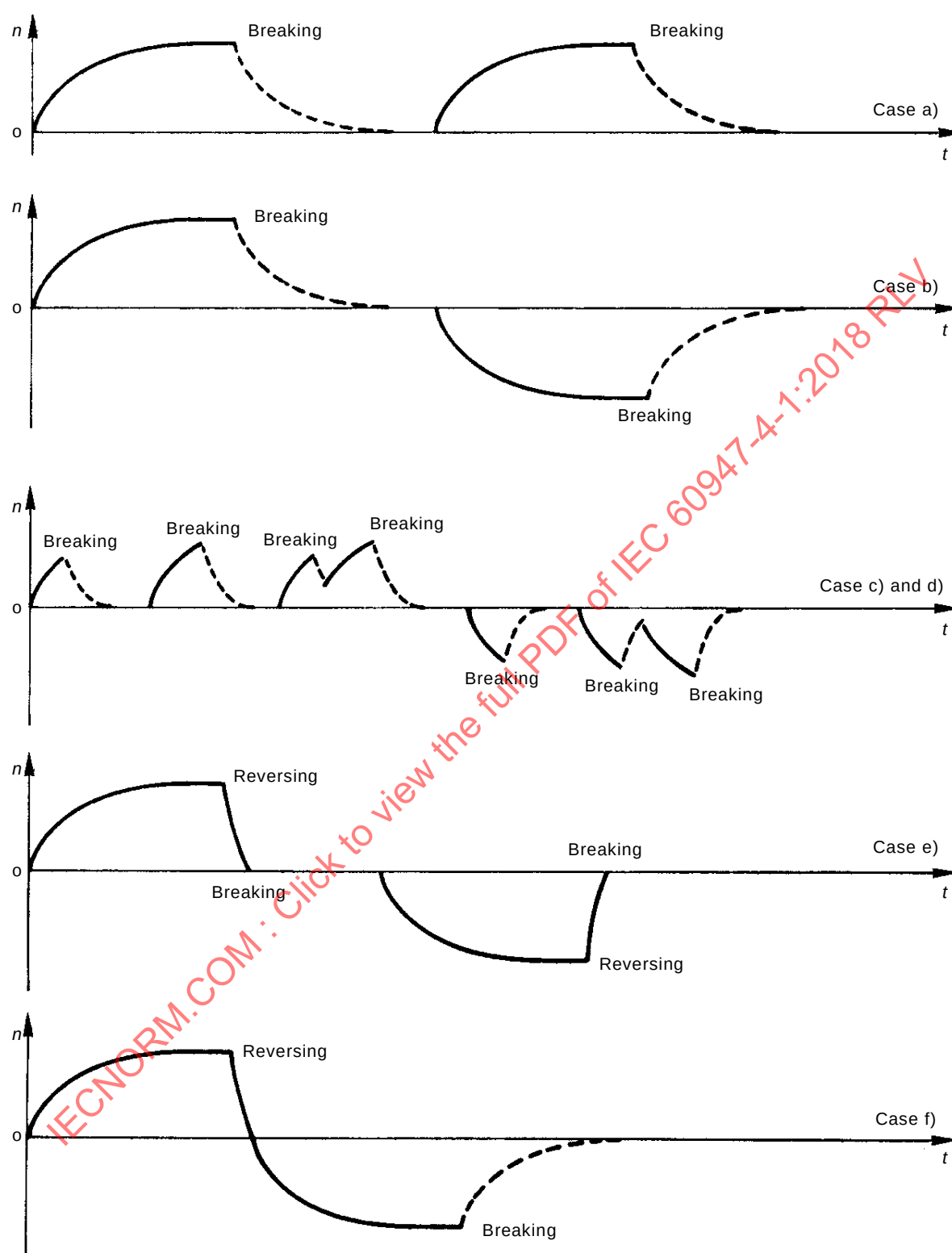
For open transition, Q₁ and Q₂ may be contacts of the same mechanical switching device

Q₁ and Q₂ may be contacts of the same mechanical switching device.

NOTE The graphical symbols utilized above correspond to the case where all the mechanical switching devices are contactors.

Figure C.5 – Typical methods and diagrams of starting alternating-current induction motors by means of auto-transformers

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018



IEC

NOTE The dotted parts of the curves correspond to the periods when no current flows through the motor.

Figure C.6 – Examples of speed/time curves corresponding to cases a), b), c), d), e) and f) of 5.3.5.6.1

Annex D (informative)

Items subject to agreement between manufacturer and user

NOTE For the purpose of this annex:

- *agreement* is used in a very wide sense;
- *user* includes testing stations.

Annex J of IEC 60947-1:2007 applies, as far as covered by clauses and subclauses of this document, with the following additions.

Clause or subclause number of this document	Item
5.3.4.3 – Note	Overload protection of starters for intermittent duty
5.3.5.6.4	Time interval between two successive starts of auto-transformer starters having a starting time exceeding 15 s
5.4	Types of utilization other than the utilization categories defined in Table 1
5.7.2	Specific applications of instantaneous overload relays or releases and of relays or releases listed in 5.7.2 e)
5.7.3	Protection of the rotor circuit for a rheostatic rotor starter
5.7.3	Protection of the auto-transformer for an auto-transformer starter
5.7.5	Tolerances on time-current characteristics of overload relays (to be indicated by the manufacturer)
5.10.2	Characteristics of devices for automatic acceleration control
5.11; 5.12	Nature and dimensions of the connecting links: a) between an auto-transformer starter and the auto-transformer, if this is provided separately b) between a rheostatic rotor starter and the resistors, if these are provided separately Agreement for items a) and b) is to be concluded between the starter manufacturer and the manufacturer of the transformer, or of the resistors, as the case may be
8.2.2.7.3	Ratings of specially rated windings (to be stated by the manufacturer)
Table 7	Verification of the make conditions when this verification is carried out during the make and break test (manufacturer's agreement)
Table 11	Footnote ^a
Table 13	Value of the prospective current "r" for the conditional short-circuit current test of devices of $I_e > 1\,600\text{ A}$

Annex E

(Void)

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

Annex F (normative)

Requirements for auxiliary contact linked with power contact (mirror contact)

F.1 Application and object

F.1.1 Application

This annex applies to auxiliary contacts mechanically linked with power contacts of a contactor and designated as mirror contacts in order to avoid any confusion with mechanically linked contact elements covered by Annex L of IEC 60947-5-1:2016. However, that does not prevent a given auxiliary contact to comply with both requirements for mirror contact of this annex and for mechanically linked contact of Annex L of IEC 60947-5-1:2016.

NOTE 1 A typical application of mirror contacts is to have, in the machine control circuit, a highly reliable monitoring of the status of the contactor. However, mirror contact cannot be relied upon exclusively as a means to ensure the integrity of a safety function.

NOTE 2 Mirror contacts have previously been referred to as positively safety contacts, forced contacts, linked contacts or positively driven contacts.

NOTE 3 The meaning of “mechanically linked” is also applicable to additional contact blocks which can be mounted by the user.

F.1.2 Object

This annex provides additional specifications (definition, requirements and tests) which shall be used for stating the required design characteristics, marking and performance of mirror contact.

F.2 Terms and definitions

For the purposes of this annex, the following term and definition applies.

F.2.1

mirror contact

normally closed auxiliary contact which cannot be in closed position simultaneously with the normally open main contact under conditions defined in Clause F.7

Note 1 to entry: One contactor may have more than one mirror contact.

F.3 Characteristics

All mirror contacts shall also comply with the relevant requirements given in IEC 60947-5-1:2016.

F.4 Product information

Clause 5 of IEC 60947-5-1:2016 applies with the following addition.

Mirror contacts shall be clearly identified:

- on the contactor itself, or
- in the manufacturer documentation, or

– both.

Where a symbol is used to identify a mirror contact, it shall be as shown in Figure F.1 (IEC 60617- S01462:2003).



Figure F.1 – Mirror contact

F.5 Normal service, mounting and transport conditions

There are no supplementary requirements.

F.6 Constructional and performance requirements

Clause 7 of IEC 60947-5-1:2016 applies with the following addition.

When any of the main contacts is closed, no mirror contact shall be closed.

F.7 Tests

F.7.1 General

Clause 8 of IEC 60947-5-1:2016 applies with the following addition.

Tests according to both F.7.2 and F.7.3 shall be carried out.

F.7.2 Tests on products in a new condition

For each mirror contact, the test shall be carried out on m products, where m is the number of main contacts.

NOTE Depending of the product construction, the needed quantity m of products can be minimized based on engineering judgment for covering the worst cases.

A new product is used for testing each mirror contact with each of the main contacts.

The tests shall be carried out on products in a new and clean condition. The test procedure shall be as follows:

- a) To simulate the occurrence of welding on one main pole, one main contact shall be maintained in the closed position, e.g. by welding or gluing each point of contact (e.g. for double breaking contact, welding is carried out at the two contact points). The thickness of welding or gluing shall be such that the distance between contacts is not modified significantly and the method used shall be described in the test report.
- b1) With the operating coil de-energized, an impulse test voltage of 2,5 kV at sea level (correction should be made according to Table F.1 given below, calculated from Table 12 of IEC 60947-1:2007) shall be applied across the mirror contact. There shall be no disruptive discharge.

Table F.1 – Test voltage according to altitude

Sea level	200 m	500 m	1 000 m	2 000 m
2,5 kV	2,37 kV	2,37 kV	2,29 kV	2,12 kV
NOTE This test ensures a minimum gap of 0,5 mm in accordance with Figure A.1, Figure A.2 and Figure A.3 of IEC 60664-1:2007 from which Table 13 of IEC 60947-1:2007 is issued.				

b2) As an alternative to item b1) above, with the operating coil de-energized, the gap of the contact shall be measured with direct means; it shall be more than 0,5 mm. In case of two or more contact gaps in series, the sum of contact gaps shall be more than 0,5 mm.

The sequences a) and b1) or b2) are repeated on new samples for each main contact welded successively.

F.7.3 Test after conventional operational performance (defined under Table 10)

At the end of the conventional operational performance tests according to 9.3.3.6, it shall be verified that, when the electromagnet is energized, the mirror contact shall withstand its rated insulation voltage U_i .

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

Annex G (informative)

Rated operational currents and rated operational powers of switching devices for electrical motors

G.1 General

The given values in Table G.1 are guide values for the relationship between rated operational currents and rated operational powers. They should be considered for use when information concerning products has to be given to the customers.

The statements of this annex are applicable to all kind of switching devices for electrical motors.

The figures are harmonized within the IEC and therefore state the basis for all the product information given by the manufacturer.

The values given in Table G.1 are typical rated operational currents ($\pm 5\%$) of motors for the corresponding rated operational powers. Design NE and HE motors are within the given variation of $\pm 5\%$.

If the devices are in compliance with these values, they are able to switch on and off most of the existing electrical motors.

These values state a harmonized guideline for design of switching devices.

G.2 Rated operational powers and rated operational currents

Rated operational power is linked with individual rated operational currents at different voltages according to Table G.1.

The guide values for rated operational currents are determined on the basis of a four-pole squirrel-cage motor at 400 V, 1 500 min⁻¹ and 50 Hz. The rated operational currents for the other voltages are calculated on the basis of values at 400 V.

Table G.1 – Rated operational powers and rated operational currents of motors

Rated operational power		Guide values of rated operational currents at											
		110 V to 120 V	200 V	208 V	230 V	220 V to 240 V	380 V to 415 V	400 V	440 V to 480 V	500 V	550 V to 600 V	690 V	
kW ^a	hp ^b	A	A	A	A	A	A	A	A	A	A	A	
0,06	–	–	–	–	0,35	–	–	0,20	–	0,16	–	0,12	
0,09	–	–	–	–	0,52	–	–	0,30	–	0,24	–	0,17	
0,12	–	–	–	–	0,70	–	–	0,44	–	0,32	–	0,23	
0,18	–	–	–	–	1,0	–	–	0,60	–	0,48	–	0,35	
0,25	–	–	–	–	1,5	–	–	0,85	–	0,68	–	0,49	
0,37	–	–	–	–	1,9	–	–	1,10	–	0,88	–	0,64	
–	1/2	4,4	2,5	2,4	–	2,2	1,3	–	1,1	–	0,9	–	
0,55	–	–	–	–	2,6	–	–	1,5	–	1,2	–	0,87	
–	3/4	6,4	3,7	3,5	–	3,2	1,8	–	1,6	–	1,3	–	
–	1	8,4	4,8	4,6	–	4,2	2,3	–	2,1	–	1,7	–	
0,75	–	–	–	–	3,3	–	–	1,9	–	1,5	–	1,1	
1,1	–	–	–	–	4,7	–	–	2,7	–	2,2	–	1,6	
–	1-1/2	12,0	6,9	6,6	–	6,0	3,3	–	3,0	–	2,4	–	
–	2	13,6	7,8	7,5	–	6,8	4,3	–	3,4	–	2,7	–	
1,5	–	–	–	–	6,3	–	–	3,6	–	2,9	–	2,1	
2,2	–	–	–	–	8,5	–	–	4,9	–	3,9	–	2,8	
–	3	19,2	11,0	10,6	–	9,6	6,1	–	4,8	–	3,9	–	
3,0	–	–	–	–	11,3	–	–	6,5	–	5,2	–	3,8	
4	–	–	–	–	15	–	–	8,5	–	6,8	–	4,9	
–	5	30,4	17,5	16,7	–	15,2	9,7	–	7,6	–	6,1	–	
5,5	–	–	–	–	20	–	–	11,5	–	9,2	–	6,7	
–	7-1/2	44,0	25,3	24,2	–	22,0	14,0	–	11,0	–	9,0	–	
–	10	56,0	32,2	30,8	–	28,0	18,0	–	14,0	–	11,0	–	
7,5	–	–	–	–	27	–	–	15,5	–	12,4	–	8,9	
11	–	–	–	–	38,0	–	–	22,0	–	17,6	–	12,8	
15	–	84	48,3	46,2	–	42,0	27,0	–	21,0	–	17,0	–	
–	20	108	62,1	59,4	–	54,0	34,0	–	27,0	–	22,0	–	
15	–	–	–	–	51	–	–	29	–	23	–	17	
18,5	–	–	–	–	61	–	–	35	–	28	–	21	
–	25	136	78,2	74,8	–	68	44	–	34	–	27	–	

Rated operational power		Guide values of rated operational currents at										
		110 V to 120 V	200 V	208 V	230 V	220 V to 240 V	380 V to 415 V	400 V	440 V to 480 V	500 V	550 V to 600 V	690 V
kW ^a	hp ^b	A	A	A	A	A	A	A	A	A	A	A
315	–	–	–	–	940	–	–	540	–	432	–	313
–	450	–	–	–	–	1 030	–	–	515	–	412	–
335	–	–	–	–	–	–	–	–	–	–	–	–
355	–	–	–	–	1 061	–	–	610	–	488	–	354
–	500	–	–	–	–	1 180	786	–	590	–	472	–
375	–	–	–	–	–	–	–	–	–	–	–	–
400	–	–	–	–	1 200	–	–	690	–	552	–	400
425	–	–	–	–	–	–	–	–	–	–	–	–
450	–	–	–	–	–	–	–	–	–	–	–	–
475	–	–	–	–	–	–	–	–	–	–	–	–
500	–	–	–	–	1 478	–	–	850	–	680	–	493
530	–	–	–	–	–	–	–	–	–	–	–	–
560	–	–	–	–	1 652	–	–	950	–	760	–	551
600	–	–	–	–	–	–	–	–	–	–	–	–
630	–	–	–	–	1 844	–	–	1 060	–	848	–	615
670	–	–	–	–	–	–	–	–	–	–	–	–
710	–	–	–	–	2 070	–	–	1 190	–	952	–	690
750	–	–	–	–	–	–	–	–	–	–	–	–
800	–	–	–	–	2 340	–	–	1 346	–	1 076	–	780
850	–	–	–	–	–	–	–	–	–	–	–	–
900	–	–	–	–	2 640	–	–	1 518	–	1 214	–	880
950	–	–	–	–	–	–	–	–	–	–	–	–
1 000	–	–	–	–	2 910	–	–	1 673	–	1 339	–	970

^a Preferred rated values according to IEC 60072-1:1991 (primary series).

^b Horsepower and currents values according to Table 45.2 of UL 508:2013 (60 Hz).

Annex H (normative)

Extended functions to electronic overload relays

H.1 General

Annex T of IEC 60947-1:2007:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 applies with the following additions.

Load monitoring indicators for energy efficiency management embedded in electronic overload relays are defined in Annex O.

H.2 Terms and definitions

H.2.1

electronic overload relay with control functions

multipole electronic relay with motor control operations through its inputs and outputs

Note 1 to entry: Example of control functions: reversing control, two speed control, star-delta control, etc.

H.2.2

electronic overload relay with under-voltage restarting function

electronic relay which operates when the voltage applied to the main circuit or control circuit is reduced below a predetermined value and automatically resets (with or without time delay) when the voltage is recovered

H.2.3

electronic overload relay with main circuit under-voltage restarting function

electronic overload relay with under-voltage restarting function monitoring only the main circuit

H.2.4

electronic overload relay with control circuit under-voltage restarting function

electronic overload relay with under-voltage restarting function monitoring only the control circuit

Note 1 to entry: The automatic restarting function can be de-activated.

H.3 Limits of operation of control functions

H.3.1 General

The operation time sequences, the interactions with the inputs and outputs and the limits of operation shall be described in the manufacturer literature.

For motor restart functions, the ranges and tolerances of time and voltage dip detection and of the delay of restarting after voltage restoration shall be given in the manufacturer literature.

H.3.2 Limits of electronic overload relay with main circuit under-voltage restarting function

When under-voltage or loss of voltage occurs in the main circuit, the relay will operate. The following applies:

- a) if the voltage resumes within T1 (off-time for immediate reset), the overload relay shall control the starter circuit to immediately restore the running condition;
- b) if the voltage resumes between T1 and T2 (off-time for reset), the relay shall reset to the starting sequence;
- c) if the voltage resumes after T2, the relay shall not reset automatically.

T1 and T2 are adjustable, and the value of T2 is greater than T1.

The tolerance of the threshold voltage and of the time settings shall be specified by the manufacturer but no more than $\pm 10\%$. If the time setting value is lower than 1 s, the manufacturer shall state the tolerances.

H.4 Test of the control functions

The test of the control functions shall be verified according to H.3, and each control function should be verified at least 3 times.

For restart functions, the detection time for a voltage dip and the delay of restarting shall be verified according to H.3.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

Annex I (informative)

AC-1 contactors for use with semiconductor controlled motor load

Contactors are often used with semiconductor controllers, starters or drives. Contactors for such applications are not intended to make or break motor load currents at the stated system voltage.

The intended use is to carry motor currents either on the line or on the load side of such controller, and to provide a galvanic opening between the controller and the line and/or the load in the OFF-state of the semiconductor controller. A further use is to by-pass controllers, usually for the purpose of reducing thermal losses, in the up-to speed condition. In such applications the contactors should be so controlled and interlocked so as to prevent them being opened or closed when the load current is present.

When the above conditions are met, the contactors may be chosen according to category AC-1.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018

Annex J

(Void)

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

Annex K

(normative)

Procedure to determine data for electromechanical contactors used in functional safety applications

K.1 General

Annex K of IEC 60947-1:2007/AMD2:2014 applies with the following additions.

K.2 Test requirements

Mechanical durability shall be determined in accordance with B.2.2.1 to B.2.2.4. For the no-make-break-current utilisation, the mechanical durability is applicable.

Electrical durability shall be determined in accordance with B.3.1 to B.3.2 using utilization category AC-3, AC-3e unless otherwise stated by the manufacturer.

The test environment shall be in accordance with Clause 7.

K.3 Characterization of a failure mode

Table K.1 gives the typical failure modes of a contactor.

Table K.1 – Failure mode of contactors

Failure modes	Characteristics for a normally open contactor
Failure to open	– current remaining after the electromagnet is de-energised
Failure to close	– no current in one or more poles after the electromagnet is energised
Short-circuit between poles	– insulation failure between poles
Short-circuit between pole and any adjacent part	– insulation failure with any adjacent part

K.4 Failure ratios of a contactor

In addition to the data listed in K.5 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014, the typical failure ratios of a contactor are given by Table K.2.

The hardware fault tolerance for one contactor is generally zero.

NOTE In IEC 62061, a hardware fault tolerance of N means that N+1 faults can cause a loss of the function.

Table K.2 – Typical failure ratios for normally open contactors

Failure modes	Typical failure ratios F associated with AC-3 electrical durability test results for normally open contactors ^a	Typical failure ratios F associated with mechanical durability test results for normally open contactors ^a
Failure to open ^b	73 %	50 %
Failure to close	25 %	50 %
Short-circuit between poles	1 %	0 %
Short-circuit between poles and any adjacent part (e.g. auxiliary, earth plate, coil)	1 %	0 %
If a contactor is used in such a way that a hazardous situation can be caused by a failure mode for which the failure ratio is above 40 %, the system may need a diagnostic function and appropriate fault reaction function(s).		
^a The typical values result from tests performed on different contactors. ^b The diagnostic coverage of the subsystem incorporating a contactor with mirror contacts can be 99 % if an appropriate fault reaction function(s) is provided.		

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 PLV

Annex L

(normative)

Assessment procedure for electromechanical overload protection used in safety applications and especially in explosive atmospheres

L.1 Application and object

L.1.1 Application

Provision of this assessment is optional, at the discretion of the manufacturer.

This electromechanical overload protection function is only a supplementary risk reduction measure within a motor driven system. In addition, thermal protection based on a thermal sensing element (see IEC 60947-8) may be applied.

L.1.2 Object

This annex specifies the procedure to achieve the minimum SIL 1-capability or equivalent performance level required for the use of the functional unit “electromechanical overload protection” in safety applications. The electromechanical overload protection is considered as a part of a complete safety function. For low demand application the main focus is to minimize the systematic failures which can be achieved by using a quality management system during the whole lifecycle.

The evaluation of the overall safety function at a system level is not addressed in this annex.

NOTE 1 In Europe, EN 50495 is applicable.

NOTE 2 A typical example is the overload protection of a motor which is located in an explosive atmosphere (Type of protection “e” according to IEC 60079-7).

NOTE 3 The quality system ISO/IEC 80079-34, applies.

L.2 Terms, definitions and symbols

For the purposes of this annex, the following terms, definitions and symbols apply.

L.2.1 Terms and definitions

L.2.1.1

safe state

state of the safety device which leads to a safe condition of the EUC

Note 1 to entry: In this annex, the safe state is the condition of the interruption of the motor load circuit.

L.2.1.2

hardware fault tolerance

HFT

ability of a safety device to continue to perform a required function in the presence of faults

L.2.1.3

SIL-capability

characteristic of functional units that comply with the requirements of IEC 61508-2 and IEC 61508-3 suitable for use in functions which are allocated a SIL 1, 2 or 3 respectively

[SOURCE: IEC 60079-29-3:2014, 3.15]

L.2.1.4

systematic failure

failure, related in a deterministic way to a certain cause, which can only be eliminated by a modification of the design or of the manufacturing process, operational procedures, documentation or other relevant factors

Note 1 to entry: Corrective maintenance without modification will usually not eliminate the failure cause.

Note 2 to entry: A systematic failure can be induced by simulating the failure cause.

Note 3 to entry: Examples of causes of systematic failures include human error in:

- the safety requirements specification;
- the design, manufacture, installation, operation of the hardware.

[SOURCE: IEC 61508-4:2010, 3.6.6, modified – Third example of Note 3 and Note 4 deleted]

L.2.1.5

electromechanical overload protection

protection of a rotating electrical machine in case of excessive temperatures resulting from certain conditions of overload by means of thermo mechanical detection that initiate the interruption of the motor load circuit

Note 1 to entry: Electromechanical overload protection is typically provided by thermal overload relays or motor protective switching devices (MPSD).

L.2.1.6

safety integrity level

SIL

discrete level (one out of a possible four), corresponding to a range of safety integrity values, where safety integrity level 4 has the highest level of safety integrity and safety integrity level 1 has the lowest

[SOURCE: IEC 61508-4:2010, 3.5.8, modified – Notes to entry deleted]

L.2.1.7

risk priority number

RPN

one of the methods of quantitative determination of criticality is the Risk Priority Number

[SOURCE: derived from IEC 60812:2006, 5.3.2]

L.2.2 Symbols and abbreviations

HFT	Hardware Fault Tolerance
EUC	Equipment under control
FMEA	Failure mode effect analysis
RPN	Risk priority number
MPSD	Motor protective switching device
SIL	Safety integrity level
FRU	Field replaceable unit
FTA	Fault tree analysis

L.3 Procedure

L.3.1 General

This procedure consists of assessing and mitigating the risk of each sub function failure of the electromechanical overload protection listed under L.3.2 The risk assessment shall identify the failure modes and the behaviour of each sub function as well as to define measures to minimize the risk.

For this procedure, any experience of use, accident, incident or malfunction history of the actual or similar design shall be considered.

The safety function of the electromechanical overload protection is composed of the following sub functions:

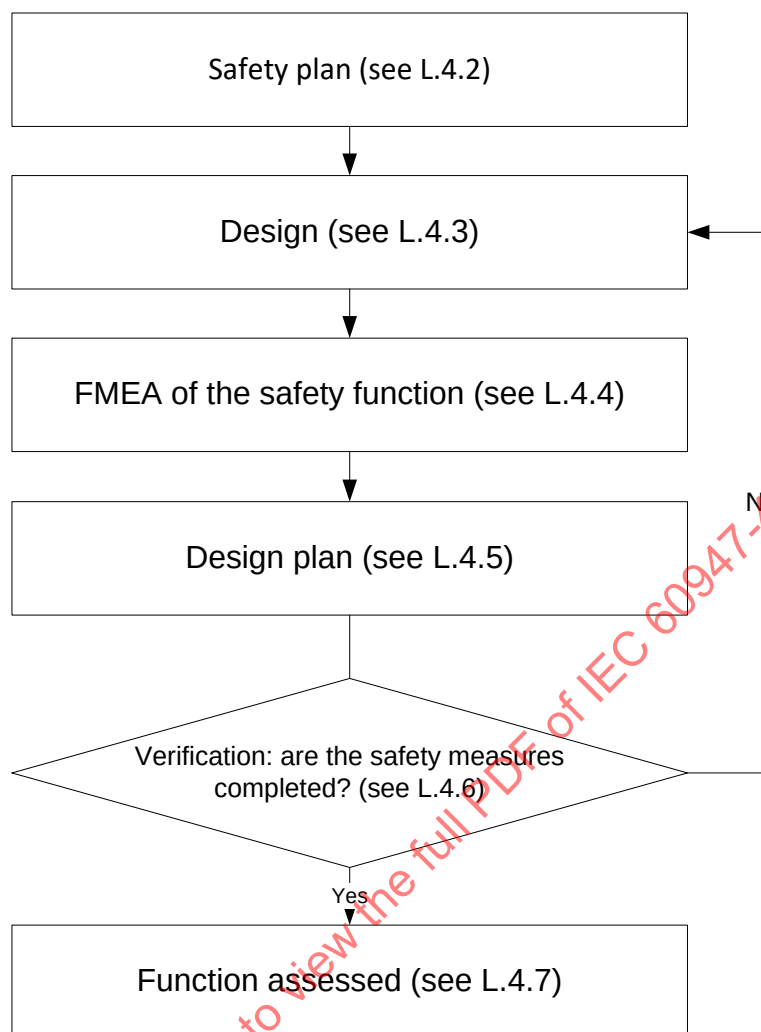
- continuously sensing of the motor current;
- comparing the sensing current to the setting based on the current of the motor and detecting thermal overload current;
- operating the release system in case of detection of thermal overload current in order to initiate the interruption of the motor load circuit.

The safety function shall be performed reliably under the specified environmental and operational conditions of the electromechanical overload protection.

NOTE The magnetic trip function of a MPSD is not part of this safety function.

L.3.2 Safety design process

The safety design process can be implemented as shown in Figure L.1. Each item shall be fulfilled. Iterations are usually necessary to reduce the risk of hazard as far as practicable.



IEC

Figure L.1 – Safety design process

L.4 Requirements

L.4.1 General

Existing designs that have been evaluated for use in safety applications are assumed to fulfil the basic safety principles of this annex and do not need a re-evaluation.

L.4.2 Safety plan

L.4.2.1 General

The safety plan related to technical performance includes the following items:

- the relevant activities specified in development and realisation lifecycle and modifications;
- the procedures and resources to record and maintain information relevant to the functional safety of thermal overload protection:
 - results of the hazard identification and risk assessment;
 - procedures necessary to achieve and maintain functional safety of thermal overload protection.
- the verification plan (L.4.2.2).

L.4.2.2 Verification plan

A verification plan includes the following items:

- selection of verification strategies and techniques;
- selection of verification activities;
- acceptance criteria;
- evaluation of verification results;
- functional assessment;
- actions to be taken in the event of failure to meet the acceptance criteria.

The verification plan should indicate whether devices with thermal overload protection are to be subjected to routine test, type test and/or sample test and which special tests are necessary.

L.4.3 Design

L.4.3.1 Characteristics

The characteristic of the electromechanical protection shall be described with the following:

- 5.7.3 b);
- minimum SIL-capability 1;
- useful lifetime;
- environmental conditions.

L.4.3.2 Functional design

The overload protection function should be decomposed in functional blocks. High level diagrams should be created, highlighting all the functions essential to the system. The detail of the decomposition will depend on the failure mode analysis itself (see Figure L.2 and Figure L.3).

As a minimum, the block diagram should contain the following:

- breakdown in blocks where a failure will result into the loss of the overload protection;
- all appropriately labelled inputs and outputs and identifications by which each block is consistently referenced.

L.4.4 Failure mode and effects analysis of the safety function

L.4.4.1 General

By principle electromechanical overload protection is realized by electromechanical reliable parts without wear effect. Therefore, the probabilistic determination methods are not suitable.

Systematic failures are avoided by use of proven in use principles and by the quality management system within the full life cycle. Thermal overload protection is a proven technology, if the device is developed in accordance with this document. However additional measures may be necessary depending on the results of the failure mode and effects analysis (FMEA).

Experience has shown that random failures are negligible. Therefore, no calculation is required, as the failure rate is low enough for fault exclusion.

The main potential risk of failures is due to electromechanical stress. The risk of failures for these simple constructions shall be reduced by using well known elements which are

designed based on engineering knowledge, field experience and incident reports. Therefore, the following analysis will be focussed on systematic failure.

L.4.4.2 Failure mode and effects analysis

The purpose of the FMEA is to analyse the design, by examining systematically all possible sources of failure of components and determining the effects of these failures on the behaviour and safety of the overload protection.

The analysis usually takes place through a meeting of engineers. Each component is analysed in turn to give a set of failure modes for the component, their causes and effects (locally and at overall system level), detection procedures and recommendations. If the recommendations are acted upon, they are documented as remedial action taken.

Any proven methods can be used (e.g. FMEA, or FTA, Markov graphs or Petri nets), however examples of Table L.1, Table L.2 and Table L.3 are appropriate for analysing an electromechanical overload protection function.

L.4.5 Design plan

The design plan shall provide measures to address incorrect specifications, implementations or modification issues.

L.4.6 Verification

During the safety design process (see L.3.2) and according to the verification plan (L.4.2.2), it shall be checked and recorded after each design phase that the requirements of the design phase have been fulfilled. Verification can be performed using assessment, analysis, examination, review and/or testing.

NOTE The verification can include for example:

- 1) review of the documentation of the respective phase,
- 2) design reviews,
- 3) functional tests.

L.4.7 Function assessed

When the verification (see L.4.6) leads to the conclusion that all specified requirements are met, the minimum SIL-capability level 1 is considered as achieved.

L.5 Documentation

L.5.1 Technical safety documentation

The documentation shall contain information as follows:

- test reports or analysis of fault behaviour leading to the loss of the safety function or reference to qualified example;
- risk assessment;
- documentation related to the decisions taken from the risk assessment.

L.5.2 Safety instructions

The manufacturer of an electromechanical overload protection shall provide safety instructions in a separate part of the instruction manual. The safety instructions shall contain information according to IEC 60079-14 and the necessary information for the design and the operation of the safety-related system, e.g.:

- description of the device and its safety function;
- safety relevant instructions for installation, calibration, putting into service and use including any required inspection procedure;
- nominal values for the interfaces (voltage, current, power, etc.);
- the associated type of protection, if relevant;
- safety level (e.g. SIL-capability) depending on the system architecture;
- hardware fault tolerance (HFT);
- safe state and power off condition;
- interface for the safety function;
- ambient and operational conditions;
- operation limits;
- useful lifetime.

L.6 Example

L.6.1 architecture description

Figure L.2 and Figure L.3 shows the examples of functional decomposition of a thermal overload relay and MPSD (respectively). See also Annex B to IEC 61508-6:2010.

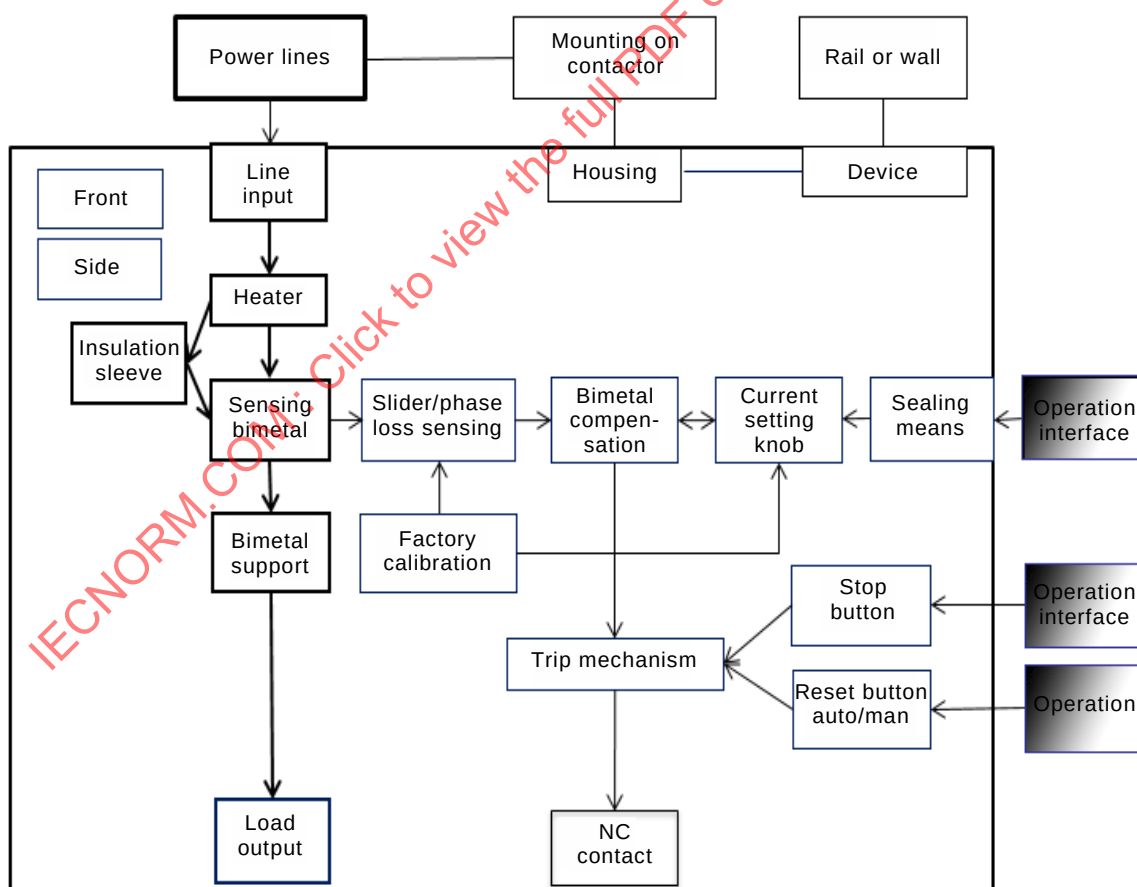
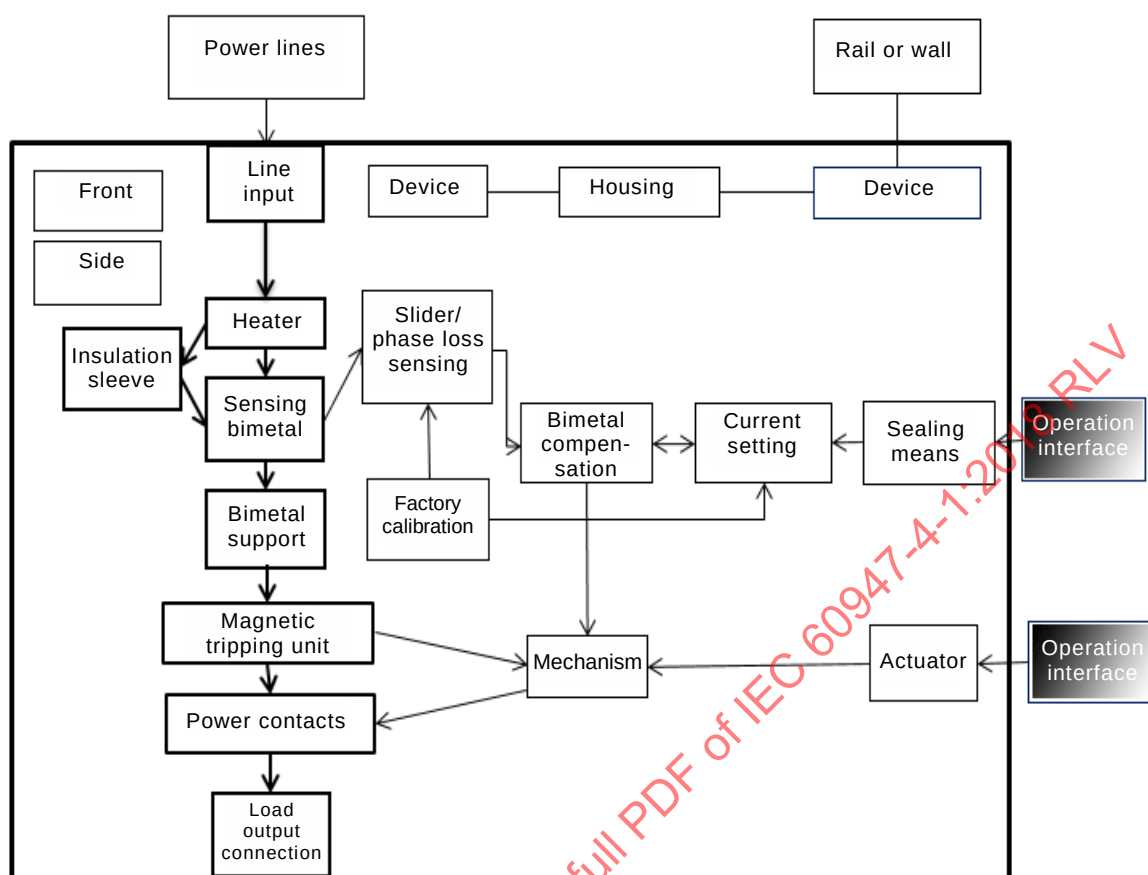


Figure L.2 – Typical structure of a thermal overload relay



IEC

Figure L.3 – typical structure of MPD

L.6.2 FMEA

Table L.1 – Severity

Level	Criticality	Failure mode
1 to 4	Insignificant	Failure mode of a minor nature without any noticeable degradation in product performance
5 to 7	Moderately significant	Failure mode which could causes harm to one person or the system failure, normally reversible or repairable in short term
8 and 9	Significant	Failure mode which could causes harm to several persons or damage in wider environment, normally reversible or repairable in long term
10	Critical	Failure mode which could causes the death of people or injuries normally irreversible

Table L.2 – Occurrence

Ranking	Qualitative approach Likelihood of failure
1	Remote possibility of happening. Similar parts are used for similar functions in previous designs and failures have been non-existent.
2 and 3	Low failure rate with similar parts having similar functions in previous designs.
4 to 6	Moderate failure rate with similar parts having similar functions in previous designs.
7 and 8	Frequent failure rate with similar parts or devices having similar functions in previous designs.
9	High likelihood of failure where there is almost certainty of failure in major proportions.
10	Failure is virtually guaranteed to occur in major proportions.

Table L.3 – Detection levels

Ranking	Detection	Component fault detection	System fault detection
1	Almost certain	Design control will almost certainly detect a potential cause/mechanism and subsequent failure mode.	Proactive detection, Isolation to FRU (Field Replaceable Unit), Visual Indication or Report.
2	Very high	Very high chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Isolation to FRU, Visual Indication or Report.
3	High	High chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Isolation for FRU, Standard Test Equipment.
4	Moderately high	Moderately high chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Isolation to FRU, Specialized Test Equipment.
5	Moderate	Moderate chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Isolation, but to Non-FRU, Visual Indication or Report.
6	Low	Low chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Isolation, but to Non-FRU, Standard Test Equipment.
7	Very low	Very low chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Isolation, but to Non-FRU, Specialized Test Equipment.
8	Remote	Remote chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Undetectable, No Isolation or Incorrect Isolation.
9	Very remote	Very remote chance that design control will detect a potential cause/mechanism and subsequent failure mode.	Undetectable, not applicable.
10	Absolute uncertainty	Design control will not or cannot detect a potential cause/mechanism and subsequent failure mode.	Hazardous action, not applicable.

Table L.4 shows an example on how to take the decision of further action depending on the RPN.

Table L.4 – Conclusion

RPN	Initial	R1	R2	Final	Action
1 to 40	52	51	0	0	No action
41 to 60	2	0	0	0	Action recommended to reduce number
61 to 1000	1	0	0	0	Not accepted, action mandatory to reduce number

Table L.5 shows the example of an FMEA for thermal overload relay.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 Rev

S	E	C	P	R	RESPONSE	PART
POTENTIAL	Q	C	D	R	STATUS/ACTION TAKEN	
CAUSES OF FAILURES	C	E	P	E		
FAILURES	C	T	N	V		
CAUSES OF FAILURES	b					

I T E M	PART DESCRIPTION	POTENTIAL FAILURE MODE	POTENTIAL EFFECTS of FAILURE related to the safety function	S	POTENTIAL CAUSES OF FAILURES	O	Compensating provision against failure	D	R	RECOMMENDED ACTIONS	STATUS/ ACTION TAKEN	RESULTING 1	RESPONSIBLE PARTY	RESULTING 2	RESPONSIBLE PARTY	FINAL	RESPONSIBLE PARTY
Existing system (to convert current into bending of the bimetal)																	
1	Line input connection or power connection	bad connection on one or more terminals	unwanted tripping due to temperature-rise on the terminals and the housing	1	wrong torque	1	safety application environment controlled	2	2			0					
2				1	bad connection (welding, soldering, crimping...), damaged wire, etc.	5	type testing, Q-System	5	25			0					
3				1	corrosion	1	type testing, Q-System	4	4			0					
4		interruption in one phase	unwanted tripping	1	bad connection (welding, soldering, crimping...), damaged wire, etc.	5	routine test, Q-system	5	25			0					
5	Heater, Insulation sleeve, Sensing Bimetal	no bending	no tripping	5	wrong bi metal, wrong material, wrong heather, wrong welding ...	1	routine test, Q-system	1	5			0					
6		not enough bending	no tripping or late tripping	5	wrong bi metal, wrong material, wrong heather...	2	routine test of tripping, Q-System	5	50	Extended sampling test for tripping behavior	integrated into the process	5	1	2	10		
7		too much bending	unwanted tripping	1	wrong bi metal, wrong material, wrong heather...	2	routine test of tripping, Q-System	5	10			0					
8		wrong bending direction	no tripping	5	wrong bi metal mounting	1	routine test, Q-system	1	5			0					

[illegible]

[illegible]

[illegible]

Annex M (normative)

DC contactors for use in photovoltaic (PV) applications

M.1 Application

PV applications have particular characteristics and require equipment with specific performance. This annex gives the relevant performance requirements for these applications.

NOTE The abbreviation “PV” (photovoltaic) is used in this annex.

M.2 Object

This annex applies to direct current contactors, rated up to 1 500 V DC, intended for use with photovoltaic (PV) systems as defined by IEC 60364-7-712 and hereafter referred to as “PV contactor”.

A contactor for PV utilization is intended for providing galvanic opening of the circuit to be used between the PV module(s) and a semiconductor switching device. The purpose is to provide galvanic separation. Consequently, in normal operational condition, the contactor is carrying full current but making and breaking with low current (e.g. leakage current). However, in abnormal operational condition, the contactor shall be able to make and break full load current.

Contactors used in PV systems are subjected to electrical, environmental and operational conditions which differ from the general conditions taken into account in the body of present standard. The requirements have thus been adapted to reflect these conditions of use.

The object of this annex is to state:

- the requirements for contactors to be used with semiconductor controller on the direct current side of PV applications;
- the tests to verify that the product performance is consistent with the PV application and the expected life in PV environmental condition.

M.3 Terms and definitions

For the purposes of this annex, the following definition applies.

M.3.1 critical load current

I_{crit}
value of breaking current, within the range of service conditions, at which the arcing time is significantly extended

Note 1 to entry: This phenomenon, crucial for PV applications, is due to the low magnetic field coming from the arc current, creating a slow moving arc.

[SOURCE: IEC 60947-1:2007, 2.5.16, modified – Addition of Note 1 to entry]

M.3.2 rated conventional switching current

I_{scl}

rated current assigned to a contactor for switching the current controlled to a low level by a semiconductor, taking into the account the rated operational voltage, the rated frequency and the rated duty

Note 1 to entry: This current is typically lower than I_e .

M.4 Classification

Clause 4 applies.

M.5 Characteristics

M.5.1 General

Clause 5 applies with the following additions.

M.5.2 Rated impulse withstand voltage

The rated impulse voltage (U_{imp}) of PV contactor shall comply with Table M.1.

Table M.1 – Rated impulse voltage levels for PV contactors

Maximum value of rated operational voltage (V)	Value of rated impulse voltage (V)
100	800
150	1 500
300	2 500
600	4 000
1 000	6 000
1 500	8 000
NOTE These values are based on requirements in IEC 60364-7-712 for overvoltage category II.	

M.5.3 Utilization category

The utilization categories define the intended application and are given in Table M.2.

Each utilization category is characterized by the values of the currents and voltages, expressed as multiples of the rated operational current and rated operational voltage, as well as the time constant of the circuit. The conditions for making and breaking given in Table M.4 correspond to the application listed in Table M.2.

Table M.2 – Utilization categories

Utilization category	Typical applications
DC-PV3	Carrying full current and switching ON and OFF PV circuit(s) at low current.
DC-PV4	Switching ON and OFF circuits where significant over-current can occur, where several circuit branches are connected in parallel and to the same semiconductor switching device.

M.6 Product information

Subclause 6.2 applies with the following additions:

A contactor rated for use not only on PV installations shall have the PV ratings clearly separated from the other ratings.

A PV contactor shall be marked “IEC 60947-4-1 Annex M”. The rated conventional switching current I_{sc1} shall be marked on the contactor.

A PV contactor shall have the following information marked under the conditions of 6.2):

- method and diagram of series connection of poles as necessary for each rating;
- operational characteristics according to M.7.2;
- direction of current, if the device is unidirectional.

The following data shall be made available in the manufacturer's published information:

- appropriate connection to the PV generator and load, if applicable;
- suitability for indoor or outdoor use.

M.7 Normal service, mounting and transport conditions

M.7.1 General

Clause 7 applies, with exception of 6.1.1 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 which is replaced by the following.

M.7.2 Ambient air temperature

The equipment shall be able to operate in an ambient air temperature given in Table M.3 according to the rating table of thermal current provided by the manufacturer.

Table M.3 – Ambient air temperature conditions

Environmental class	Maximum ambient temperature without de-rating	Minimum ambient temperature	Comment
Unenclosed	+40 °C	–5 °C	Guidance on de-rating for higher ambient air temperature up to +70 °C may be provided. In addition, guidance on operation at temperature lower than –5 °C may also be given.
Enclosed – Outdoor	+40 °C (without solar effects)	–25 °C	Rating apply when the enclosed equipment is subject to solar radiation of 1,2 kW/m ² and the maximum ambient temperature. Guidance may be provided on de-rating of enclosed equipment to be installed in locations with a higher maximum ambient temperature and/or lower minimum ambient temperature.

Ambient air temperature is that existing in the vicinity of the equipment if supplied without an enclosure, or in the vicinity of the enclosure if supplied with an enclosure.

M.7.3 Altitude

Item q) of 6.1.2 applies.

Altitude up to 4 000 m is under consideration.

M.8 Constructional and performance requirements

M.8.1 Constructional requirements

Subclause 8.1 applies with the following modifications:

The minimum rated impulse voltage shall be in accordance with Table M.1.

M.8.2 Performance requirements

M.8.2.1 General

Subclause 8.2 applies with the following modifications.

The minimum rated impulse voltage shall be in accordance with Table M.1.

M.8.2.2 Making and breaking capacities

Contactors or starters shall be capable of making and breaking currents without failure under the conditions stated in Table M.4 for the required utilization categories.

**Table M.4 – Verification of rated making and breaking capacities –
Conditions for making and breaking corresponding to the DC-PV category**

Utilization categories	I_c/I_e	U/U_e	L/R ms	On-time ^b s	Off-time s	Number of operating cycles ^a
DC-PV3	1,5	1,05	1	0,05	^c	50
DC-PV4	4	1,05	1	0,05	^c	50
^a If polarity not marked on the device, 25 operating cycles with one polarity and 25 operating cycles with reverse polarity						
^b The time may be less than 0,05 s, provided that contacts are allowed to become properly seated before reopening.						
^c Maximum off-time given in Table 8 which can be reduced in agreement with the manufacturer.						

M.8.2.3 Conventional operational performance

Subclause 7.2.4.2 of IEC 60947-1:2007 applies with the following addition.

Contactors or starters shall be capable of making and breaking currents without failure under the conventional conditions stated in Table M.5 for the required utilization categories.

Table M.5 – Conventional operational performance – Making and breaking condition corresponding to the DC-PV category

Utilization categories	I_c/I_{sc1} ^a	U/U_e	L/R ms	On-time ^c s	Off-time s	Number of operating cycles ^b
DC-PV3	1	1,05	1	0,05	^d	6 000
DC-PV4	1	1,05	1	0,05	^d	6 000
^a I_{sc1} shall be defined by the manufacturer. ^b If the polarity not marked on the device, 3 000 operating cycles with one polarity and 3 000 operating cycles with reverse polarity ^c The time may be less than 0,05 s, provided that contacts are allowed to become properly seated before reopening. ^d Maximum off-time given in Table 8 which can be reduced in agreement with the manufacturer.						

M.8.2.4 Critical load current performance

The main circuits of an equipment shall be capable of making and breaking its critical load current according to M.9.7.

M.8.3 Electromagnetic compatibility (EMC)

Subclause 8.3 applies.

M.9 Tests

M.9.1 General

Clause 9 applies with the following modification of the type tests and their sequences.

Each test sequence is made on a new sample.

NOTE With the agreement of the manufacturer, more than one test sequence or all test sequences can be conducted on one sample. However, the tests are conducted in the sequence given for each sample.

For all tests, the connection of poles of the PV contactor shall be as in accordance with the manufacturer installation instructions.

M.9.2 Type tests

Type tests shall be performed according to the sequences of Table M.6.

Table M.6 – Overall scheme of test sequences

Sequences	Test
Making and breaking capacities and conventional operational performance (see M.9.3)	Verification of rated making and breaking capacities. Verification of conventional operational performance Behaviour of the contactor and its condition
Thermal cycling test (see M.9.4)	Thermal cycling test Mechanical operation Temperature-rise verification Verification of operation and operating limits Dielectric test according to M.9.6
Climatic test (see M.9.5)	Climatic test
Critical load current test (see M.9.7)	Critical load current test Behaviour of the contactor and its condition
Mechanical properties (see M.9.8) and Degree of protection of enclosed contactors (see M.9.9)	Mechanical properties Verification of degrees of protection of enclosed contactors
EMC (see M.9.10)	EMC test
Clearance and creepage distance (see M.9.11)	Measurement of creepage and clearance distances

M.9.3 Making and breaking capacities and conventional operational performance

The test sequence 2 of 9.3.1, the requirements of Subclauses M.8.2.2 and M.8.2.3 apply. The behaviour of the contactor during, and its condition after the conventional operational performance tests shall be verified according to 9.3.3.6.6.

M.9.4 Thermal cycling test

PV contactors shall be subjected to temperature cycling according to IEC 60068-2-14:2009, test Nb, consisting of 50 cycles, each cycle consisting of 1 h at – 40 °C followed by 1 h at + 85 °C. Temperature change rate shall be 1 K/min. At the conclusion of the 50 cycles, the devices shall be returned to room temperature of 25 ± 5 °C for a minimum of 3 h.

The device shall then be subjected to:

- a visual inspection to confirm that there is no distortion or damage to parts that will affect normal operation and protection;
- one open and close operation to confirm normal mechanical operation;
- test sequence 1 as in 9.3.1.

M.9.5 Climatic test

PV contactors shall be subjected to the climatic tests of Annex Q, category B of IEC 60947-1:2007, IEC 60947-1/AMD1:2010, IEC 60947-1/AMD2:2014, environment subject to temperature and humidity, except that the dry heat test and the low temperature test are not required, as they are deemed to be covered by the thermal cycling test of M.9.3.

Where Table Q.1 of IEC 60947-1/AMD2:2014 requires the verification of operational performance capability, this shall be made by performing the test of 9.3.6.2.

M.9.6 Dielectric test

Subclause 9.3.3.4 applies with the following modifications:

Test voltage for verification of impulse withstand voltage shall use Table M.1 with altitude correction according to Table 12 of IEC 60947-1:2007.

M.9.7 Critical load current test

M.9.7.1 Test circuit

Subclause 8.3.3.5.2 of IEC 60947-1:2007 applies with the following addition.

The time constant of the test circuit shall be 1 ms.

M.9.7.2 Determination of critical load current

The test shall be made at the maximum operational direct current voltage (U_e max) assigned by the manufacturer to the contactor.

At the discretion of the manufacturer, a higher value of time constant may be used. The same value of time constant should be used for all tests carried out to determine the critical load current. In this case, it should be stated in the test report.

The PV contactor shall be opened 5 times on to each of the test currents. Start at 4 A, and go up to I_e in steps of two times the previous current until a maximum arcing time is determined. If the extinction time does not show a peak with shorter times each side, within the range of test currents, there is no critical load current. If a maximum in arcing time is shown, this is at the critical load current (see Figure M.1). Test currents shall be within the nominal value ± 10 %. At the manufacturer's discretion, the test at each value of current may be carried out on a new sample.

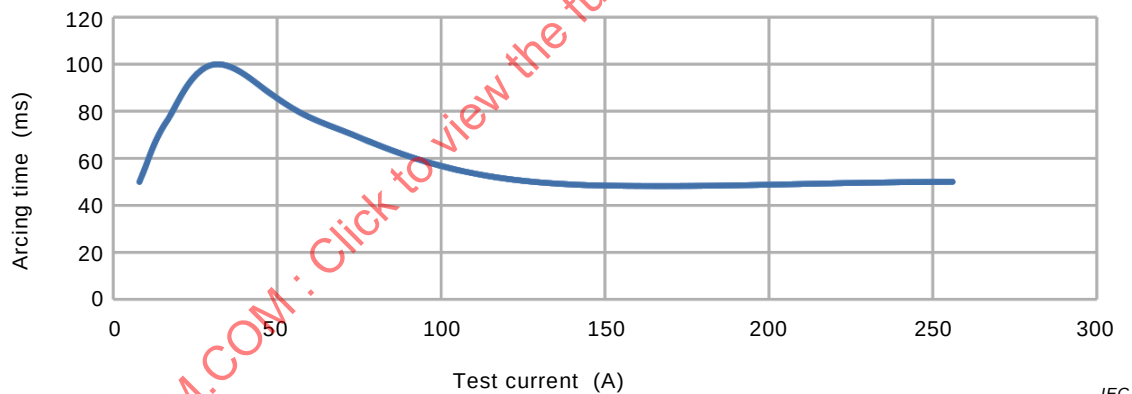


Figure M.1 – Critical current

During each cycle, the PV contactor shall remain closed for a time sufficient to ensure that the full current is established, but not exceeding 2 s. The number of operation cycles per hour shall be in accordance with Table M.7.

Table M.7 – Number of operating cycles corresponding to the critical load current

Category	Rating of the product A	Number of operating cycles per hours
DC-PV3 and DC-PV4	$I_e \leq 315$	120
	$315 < I_e \leq 630$	60
	$630 < I_e \leq 2\,500$	20
	$I_e < 2\,500$	10

If the direction of current flow is specified by the manufacturer, the test shall be made with the current flowing in the specified direction, as indicated by the polarity and line/load marking; if not, 5 operations shall be made in the forward direction, and 5 in the reverse direction.

M.9.7.3 Critical load current

The arcing time during the test shall be recorded and shall not exceed 1 000 ms.

When all operations are carried out with the current flow in the same direction, for each value of test current the average arcing time is calculated for each direction.

I_{crit} is the current corresponding to the maximum average arcing time. If no critical load current is identified below the rated operational current, the critical load current performance test need not be carried out.

M.9.7.4 Critical load current performance

The test requirements of 9.3.3.6 applies with the following modifications.

The test may be carried out with the same sample as in M.9.7.2. The test supply shall be connected in accordance with the generator – load and polarity markings where applicable. For contactors capable of current flow in both directions, the supply shall be connected so as to provide the longest arc duration at the critical load current, as determined in M.9.7.2 and Table M.8.

Table M.8 – Critical load current performance

Utilization categories	I	U/U_e	L/R ms	On-time s	Off-time s	Number of operating cycles
DC-PV3	I_{crit}	1,05	1	0,05	^a	100
DC-PV4	I_{crit}	1,05	1	0,05	^a	100
^a See Table M.7.						

The behaviour of the contactor during, and its condition after, the critical load current performance tests shall be verified according to 9.3.3.6.6.

M.9.8 Mechanical properties

The verification of mechanical properties of terminals shall be performed according to 8.2.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, and IEC 60947-1:2007/AMD2:2014, and 9.2.2).

M.9.9 Degree of protection of enclosed contactors

The verification of the degrees of protection of enclosed contactors and starters shall be performed according to Annex C of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010.

M.9.10 EMC

Electromagnetic compatibility shall be verified in accordance with 9.4.

M.9.11 Clearance and creepage distances

Clearance and creepage distances shall be measured to confirm compliance with 8.1.4 (see Annex G of IEC 60947-1:2007 for guidance on measurement of clearance and creepage distances).

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 REV

Annex N (normative)

Additional requirements and tests for equipment with protective separation

N.1 General

The purpose of this annex is to provide additional requirements to Annex N of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014.

N.2 Definitions

For the purposes of this document, the terms and definitions of Clause N.2 of IEC 60947-1:2007, as well as the following terms and definitions applies.

N.2.1

touch current

electric current passing through a human body or through an animal body when it touches one or more accessible parts of an electrical installation or electrical equipment

[SOURCE: IEC 60050-826:2004, 826-11-12]

N.3 Requirements

N.3.1 Test method for implementing protective impedance

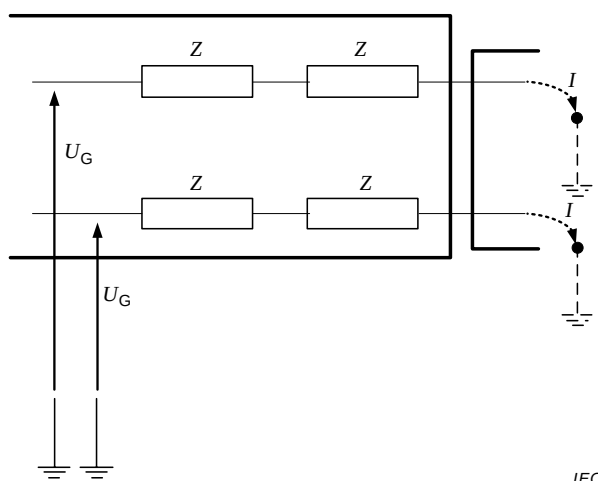
Protective impedance shall be arranged so that under both normal and single fault conditions, according respectively to 4.2 and 4.3 of IEC 61140:2016, the touch current and the discharge energy available shall be limited.

The protective impedances shall be designed and tested to withstand the impulse voltages and temporary overvoltages for the circuits to which they are connected.

Compliance with the requirement for the limitation of touch current is checked by test of N.3.2.

Compliance with a limited value of 0,5 mJ for the discharge energy shall be checked by performing calculations and/or measurements to determine the voltage and capacitance.

Figure N.1 shows examples of the method used to implement protective impedance.



Key

- Z impedance
 U_G hazardous voltage, earthed or unearthed
 I touch current

NOTE 1 To provide protection in single-fault conditions, use the following equation $I = \frac{U_G}{Z}$

NOTE 2 This figure is reproduced from Figure A.2 of IEC 62477-1:2012.

Figure N.1 – Protection by means of protective impedance

N.3.2 Touch current measurement

The equipment under test shall be set up in an insulated state without any connection to the earth and shall be operated at rated voltage. Under these conditions, the touch current shall be measured between the touchable parts and the earth according to the test circuit of Figure N.2.

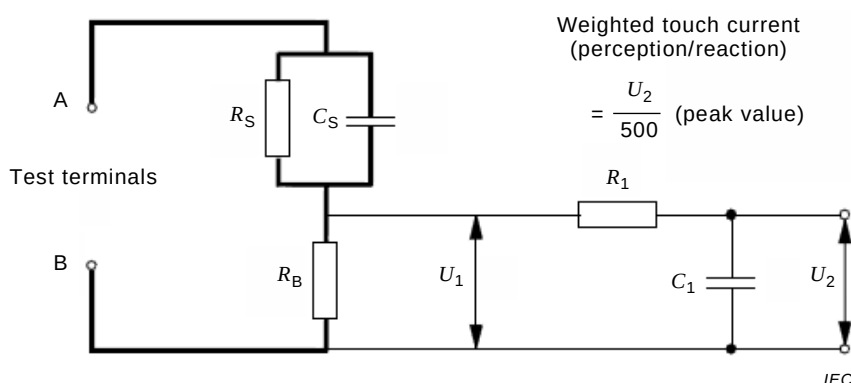
For an equipment to be connected to an earthed neutral system, the neutral of the mains of the test site shall be directly connected to earth.

For an equipment to be connected to an earthed neutral system or impedance system, the neutral of the mains of the test circuit shall be directly connected to earth.

The following maximum values of touch current (alternating current values for frequencies up to 100 Hz) are permitted:

- a steady-state current flowing between simultaneously accessible conductive parts not exceeding 0,5 mA AC or DC under normal operating conditions;
- values not exceeding 3,5 mA AC or 10 mA DC under single fault conditions.

As shown in Figure N.2, the voltage U_2 is measured and the current is calculated by dividing the measured voltage U_2 by 500.



Voltmeter or oscilloscope (RMS or peak reading)

input resistance: $> 1 \text{ M}\Omega$

input capacitance: $< 200 \text{ pF}$

frequency range: 15 Hz up to 1 MHz (appropriate for the highest frequency of interest)

Key

R_S 1 500 Ω

R_B 500 Ω

R_1 10 k Ω

C_S 0,22 μF

C_1 0,022 μF

NOTE The measuring test circuit of this figure is reproduced from Figure 4 of IEC 60990:2016.

Figure N.2 – Measuring instrument

Electrical measuring instruments shall have adequate bandwidth to provide accurate readings, taking into account all components (alternating current, direct current mains supply frequency, high frequency and harmonic content) of the parameter being measured. If the RMS value is measured, care shall be taken that measuring instruments give true RMS readings of non-sinusoidal waveforms as well as sinusoidal waveforms.

Annex O (informative)

Load monitoring indicators

O.1 General

The implementation of an energy efficiency (EE) approach for AC motor-driven systems (e.g. pumps, compressors) or asset management activities requires load monitoring indicators based on electrical supply quantities.

An example implementation of such load monitoring indicators is to detect sudden changes or drifts in active power or phase current.

O.2 Indicators list

Table O.1 shows the minimum requirements for a proposed set of indicators recommended for EE analysis or asset management.

Trueness and repeatability as stated in Table O.1 apply to the complete monitoring chain, including external sensors if any.

The selection of the indicators within Table O.1 is at the discretion of the manufacturer.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 PLV

Table O.1 – AC monitoring indicators list

Indicator name	Definition	Units ^a	Symbol	Minimum range	Trueness ^c	Repeatability ^d
phase <i>x</i> current	the value of the current flowing in phase <i>x</i> of an electrical distribution system	A	I_x	$0,4 \times I_e - 0,7 \times I_e$	± 25 %	2 %
				$0,7 \times I_e - 1,1 \times I_e$	± 10 %	2 %
phase to phase voltage	the voltage between phases	V	U_{pg}	$0,9 \times U_e - 1,1 \times U_e$	± 5 %	2 %
phase to neutral voltage	the voltage between a phase in a polyphase system and the neutral point	V	V_{pN}	$0,9 \times U_e / \sqrt{3} - 1,1 \times U_e / \sqrt{3}$	± 5 %	2 %
total active power	the sum of the active powers in all phases of an electrical distribution system	W	P	PF ≥ 0,9	± 20 %	3 %
total apparent power	the sum of the apparent powers in all phases of an electrical distribution system	VA	S	-	± 25 %	3 %
current imbalance ^b	the ratio between the maximum current deviation of any phase from average current and the average current	%	I_{imb}	70 % to 130 %	± 10 points ^e	± 2 points ^e
power factor	under periodic conditions, ratio of the absolute value of the active power P to the apparent power S : $\lambda = \frac{ P }{S}$	No unit	PF (λ in IEC 60050 series)	0,5 – 1	± 0,3 ^f	± 0,04 ^f

NOTE 1 Unless otherwise stated by manufacturer, ambient air temperature effects are assumed to be compensated. When not, the reference ambient air temperature is specified by the manufacturer.

NOTE 2 Performances could be referred according to PROFIEnergy classes X to Y, Accuracy domain 2, which combines trueness and repeatability into "accuracy".

^a Absolute or per unit (ratio to a reference value, e.g. FLA for current).

^b See Annex T of IEC 60947-1:2007/AMD2:2014.

^c Trueness is characterized by the systematic error of the measured value (see 3.3.3 of ISO 3534-2:2006).

^d Repeatability represents the random part of the measurement error. It is a variation parameter characterizing the dispersion of the measurements, taken under the same conditions. This value should be declared together with a time-window or number of measurements (see O.3).

^e "point" is an absolute deviation from a measurement expressed in percent. For example, if the measured imbalance value is 8 %, then the associated repeatability criterion is to measure values between 6 % and 10 %.

^f PF has no unit. Therefore, limit is expressed as an absolute deviation from the measured value.

The refresh interval is a global requirement, and should not be more than 1 min. It can be defined individually for each indicator. The minimum bandwidth of the measurement should be up to the 7th harmonic of the fundamental frequency.

The values given for trueness and repeatability in Table O.1 are given for the minimum range, and cannot be used to characterize the accuracy of the motor overload protection.

O.3 Uncertainty

Uncertainty of measurement is the combination of systematic error and random error, both referring to the conventional true value which is obtained with a measuring instrument typically 10 times more accurate than the device under test.

The systematic error quantifies the trueness of the measurement, i.e. how close the average measurement results are to the true value. In given conditions, the systematic error results from factors having a fixed impact on the measurement results, such as the imperfect calibration or correction of the measurement chain resulting from temperature effects.

The random error is resulting from factors having an unpredictable impact on the measurement results such as noise in the different parts of the measurement chain, imperfections in the measurement algorithms, crosstalk and other electromagnetic compatibility issues. The random error quantifies the precision or repeatability of the measurement, i.e. how close repeated measurement results are to each other. The most common statistical indicator used is the standard deviation σ . It can be estimated from a series of N measurement results in the same conditions as:

$$\sigma = \sqrt{\frac{\sum_{i=1}^N (x_i - \bar{x})^2}{N-1}} \quad \text{with} \quad \bar{x} = \frac{1}{N} \times \sum_{i=1}^N x_i$$

For load monitoring applications and especially the evaluation of energy efficiency, the systematic error of individual measurements is not relevant because the goal is to detect trends or check the impact of process changes. For example, one might want to check the impact of Energy Efficiency actions or process changes on the average power consumption as shown in Figure O.1.

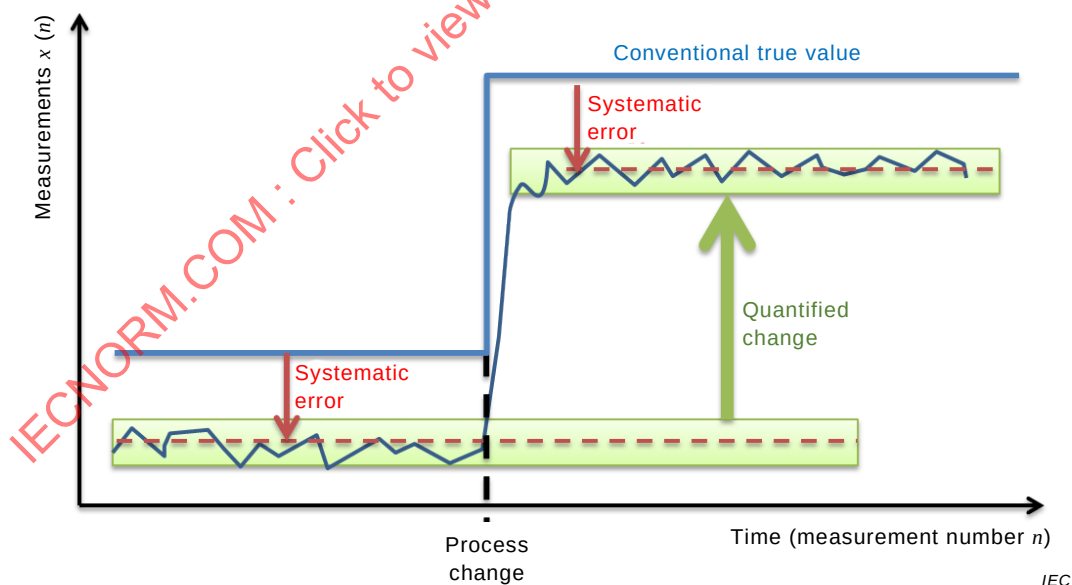


Figure O.1 – Example of quantification of a process change

The systematic error does not matter so much for change detection: as soon as the impact is significantly greater than the random error, it easily shows up on the measurement results and the change will be well quantified. In borderline cases, some averaging may be needed.

Any integrated or subsequent integration or averaging process tends to reduce the random error so that only the systematic error remains significant. Therefore, changes and trends are

easily detected on such integrated/averaged quantities, whatever the uncertainty (trueness and precision) of the measurement device.

O.4 Tests

O.4.1 Routine tests

No routine tests are required.

O.4.2 Type tests

O.4.2.1 General

Various methods for verification (see Table O.2) of indicators performances include:

- verification by measurement;
- verification by simulation, using models for which the validity has to be demonstrated;
- verification by design assessment, i.e. confirmation of the correct application of calculations and design rules, including use of appropriate safety margins.

Table O.2 – Different possibilities authorized for verification of indicators

Indicator	Fundamental	Harmonics	Non-tested phase
phase x current	Measurement	Measurement Simulation Design assessment	Measurement Simulation Design assessment
phase to phase voltage	Measurement	Measurement Simulation Design assessment	Measurement Simulation Design assessment
phase to neutral voltage	Measurement	Measurement Simulation Design assessment	Measurement Simulation Design assessment
total active power	Measurement	Measurement Simulation Design assessment	Not applicable
total apparent power	Measurement	Measurement Simulation Design assessment	Not applicable
current imbalance	Measurement	N/A	Not applicable
Total power factor	Measurement	Measurement Simulation Design assessment	Not applicable

O.4.2.2 Test conditions

When the product has only-one rating, one product sample should be tested. For a product range, the minimum and maximum ratings should be tested.

Test has to be performed under conditions stated in Table O.3.

Table O.3 – Reference for verification conditions

	Value
Current	Minimum value (see Table O.1) ^a
Voltage	Minimum value (see Table O.1) ^a
Power factor	0,7 IND
Frequency	50 Hz or 60 Hz
Ambient temperature ^b	23 °C
^a When manufacturer range specification is different from Table O.1, it has to be tested according to minimum rated voltage/current values.	
^b When not compensated, ambient temperature has to be specified by manufacturer.	

Harmonic levels for verification are given in following Table O.4.

Table O.4 – Harmonic levels

Harmonic	Voltage %	Current %
5 th	12	12
7 th	10	10
NOTE Harmonics are expressed in per-cent of the fundamental value.		

O.4.2.3 Test criteria

Performance evaluation is to be considered as statistical approach. For details, refer to O.3. The coverage factor for assessing repeatability of measured indicator values is equal to two.

Annex P (normative)

Short-circuit breaking tests of MPSD

P.1 General test conditions

For short-circuit breaking capacity tests other than those in an individual enclosure, a wire mesh shall be placed at all points of the MPSD likely to be a source of external phenomena capable of producing a breakdown, in accordance with the arrangements and distances specified by the manufacturer. Details, including distance from the MPSD under test to wire-mesh, shall be stated in the test report. MPSD's intended for use in an individual enclosure shall, in addition, be tested in the smallest of such enclosure stated by the manufacturer.

If a MPSD is fitted with adjustable short-circuit releases, the setting of the releases shall be as specified for each test sequence.

For MPSD having a rated current up to and including 630 A, a cable of maximum length 75 cm, having a cross-section corresponding to the conventional thermal current (see 8.3.3.3.4, Tables 9 and 10 of IEC 60947-1:2007) shall be included as follows:

- approximately 50 cm on the supply side;
- approximately 25 cm on the load side.

The sequence of operations shall be that which is applicable to the test sequence as specified in P.2, P.3 and P.4.

The following symbols are used for defining the sequence of operations:

- O represents a breaking operation;
- CO represents a making operation followed, after the appropriate opening time, by a breaking operation;
- t represents the time interval between two successive short-circuit operations which shall be as short as possible, allowing for the resetting time of the MPSD, but not less than 3 min. The actual value of t shall be stated in the test report.

The maximum resetting time shall be 15 min or such longer time as may be stated by the manufacturer, during which time the MPSD shall not be displaced. Attempts to reclose the MPSD during the resetting time shall be spaced by at least 1 min.

The maximum value of I^2t (see 2.5.18 of IEC 60947-1:2007) during these tests shall be recorded in the test report.

The behaviour of the MPSD during short-circuit tests shall be according to 8.3.4.1.7 of IEC 60947-1:2007 and the interpretation of the test result shall be according to 8.3.4.1.8 of IEC 60947-1:2007.

After the short-circuit tests, the result shall be verified according to 9.3.4.2.4.

P.2 Rated service short-circuit breaking capacity

P.2.1 General

The following tests shall be realised in the following sequence:

- rated service short-circuit breaking capacity (P.2.2);

- verification of operational performance capability (P.2.3);
- verification of dielectric withstand (P.2.4);
- verification of temperature-rise (P.2.5);
- verification of overload releases (P.2.6).

P.2.2 Test of rated service short-circuit breaking capacity

A short-circuit test is made under the general conditions of 9.3.4.1 and P.1 with a value of prospective current equal to the rated service short-circuit breaking capacity I_{cs} , as declared by the manufacturer in accordance with 5.3.6.2.

The power factor for this test shall be according to Table 16 of IEC 60947-1:2007, for the appropriate test current.

The sequence of operations shall be:

O – t – CO – t – CO

t represents the time interval between two successive short-circuit operations which shall be 3 min or the resetting time of the MPSD. The actual value of t shall be stated in the test report.

P.2.3 Verification of operational performance capability

Following the test according to P.2.2, the operational performance capability shall be verified in accordance with 9.3.3.6 except that this verification shall be made at the same rated operational voltage as used for the test of P.2.2, and that the number of operations shall be 5 % of the on-load operations given in Table 10.

Following the test, the dielectric withstand shall be verified according to P.2.4.

P.2.4 Verification of dielectric withstand

P.2.4.1 General

The test shall be performed on the MPSD whilst it remains mounted for the preceding test. If this is not practicable it may be disconnected and removed from the test circuit, although measures shall be taken to ensure that this does not influence the result of the test.

P.2.4.2 Test voltage

Subclause 8.3.3.4.1, item 3) b), of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 applies.

The value of the test voltage shall be $2 U_e$ with a minimum of 1 000 V RMS, or 1 415 V DC if an AC voltage cannot be applied. The value of U_e referred to is that at which the preceding switching and/or short-circuit tests have been performed.

P.2.4.3 Application of the test voltage

The test voltage shall be applied for 60 s in accordance with 8.3.3.4.1, items 2) c) i), ii) and iii), of IEC 60947-1:2007 and, in addition, between the incoming and outgoing terminals of each pole with the MPSD open. The use of the metal foil as specified in 8.3.3.4.1, item 1), of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 is not required. For the purposes of this document, circuits incorporating solid-state devices connected to the main circuit may be disconnected for the tests. The normal positions of operation include the tripped position, if any.

For MPSD suitable for isolation the leakage current shall be measured in accordance with 9.3.3.4.1, fourth item, except that the leakage current shall not exceed 2 mA.

P.2.4.4 Acceptance criteria

Subclause 8.3.3.4.1, item 3) d), of IEC 60947-1:2007 applies.

P.2.5 Verification of temperature-rise

Following the test according to P.2.4, the temperature-rise at the main terminals shall be verified in accordance with 9.3.3.3. The temperature-rise shall not exceed the values given in Table 2 of IEC 60947-1:2007 plus 15 K but not exceeding 80 K.

P.2.6 Verification of overload releases

The operation of overload releases shall be verified in accordance with 9.3.4.2.4 k).

P.3 Rated ultimate short-circuit breaking capacity

P.3.1 General

Where $I_{CS} = I_{CU}$, this test sequence need not to be made, but the following verifications shall additionally be made in the test sequence P.2:

- the verification of P.3.2 at the beginning of the test sequence;
- the verification of P.3.5 at the end of the test sequence.

The following tests shall be realised in the following sequence:

- verification of overload releases (P.3.2);
- test of rated ultimate short-circuit breaking capacity (P.3.3);
- verification of dielectric withstand (P.3.4);
- verification of overload releases (P.3.5).

An additional test with reverse connection is required on a new sample at the highest rated operational voltage applicable U_e in the following cases:

- no information is given with the product on how to connect the line and load phases to the terminals e.g with marking L and T, or;
- the manufacturer claims the suitability for reverse connection.

P.3.2 Verification of overload releases

The operation of overload releases shall be verified at twice the value of their current setting. This test may be made at any convenient voltage.

If the ambient temperature differs from the reference temperature, the test current shall be corrected in accordance with the manufacturer's temperature/current data, for releases dependent on ambient temperature.

For tests for which the tripping characteristic is independent of the temperature of the terminals (e.g. electronic overload releases, magnetic releases), connection data (type, cross-section, length) may be different from those required in 8.3.3.3.4 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014. The connections should be compatible with the test current and induced thermal stresses.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the current setting at the reference temperature.

NOTE This test is performed on all 3 poles together to avoid a trip under phase loss condition.

P.3.3 Test of rated ultimate short-circuit breaking capacity

Following the test according to P.3.2, a short-circuit breaking capacity test is made with a value of prospective current equal to the ultimate rated short-circuit breaking capacity as declared by the manufacturer, under the general conditions according to 9.4.3.1 and P.1.

The sequence of operations shall be:

O – t – CO

P.3.4 Verification of dielectric withstand

Following the test according to P.3.3, the dielectric withstand shall be verified according to P.2.4. For MPSD suitable for isolation, the leakage current shall not exceed 6 mA.

P.3.5 Verification of overload releases

Following the test according to P.3.4, the operation of overload releases shall be verified in accordance with P.3.2, except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature.

NOTE This test is performed on all 3 poles together to avoid a trip under phase loss condition.

P.4 Test of MPSD for IT system

NOTE This test is intended to cover the case of a second fault to earth in presence of a first fault on the opposite side of a MPSD when connected to an electrical installation having all live parts isolated from earth or one point connected to earth through an impedance.

P.4.1 General

This test shall apply to multipole MPSDs for application on IT system, in accordance with IEC 60364-1:2005; it comprises the following test sequence:

- individual pole short-circuit in P.4.2;
- verification of dielectric withstand in P.4.3;
- verification of overload releases in P.4.4.

Additional marking of the MPSD are given in P.4.5.

P.4.2 Individual pole short-circuit

A short-circuit test is made on the individual poles of a multipole MPSD under the general conditions of 9.3.4.1 and P.1, at a value of current I_{IT} equal to 1,2 times the maximum tripping current setting of the short-circuit release but not less than 500 A nor exceeding 50 kA.

NOTE 1 The prospective current of the test circuit can have to be increased to ensure that the test current exceeds the actual short-time or instantaneous tripping current, due to impedance of the MPSD and its connections.

NOTE 2 Values higher than I_{IT} can be required, tested instead and declared by the manufacturer.

The test voltage shall be the phase-to-phase voltage corresponding to the maximum rated operational voltage of the MPSD at which it is suitable for application on IT systems, taking into account the requirements for recovery voltage of 8.3.2.2.3, item a) of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014. The power factor shall be according to Table 16 of

IEC 60947-1:2007. When $I_{IT} = 50$ kA, the short-time or instantaneous tripping current setting shall be adjusted to the nearest setting lower than (50/1,2) kA.

The test circuit shall be according to 8.3.4.1.2 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 and Figure 9 of IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, the supply S being derived from two phases of a three-phase supply, the fusible element F being connected to the remaining phase. The remaining pole or poles shall also be connected to this phase via the fusible element F.

The sequence of operations shall be:

O – t – CO

and shall be made on each pole separately, in turn.

P.4.3 Verification of dielectric withstand

The dielectric withstand shall be verified according to P.2.4 except for MPSD suitable for isolation, the leakage current shall not exceed 6 mA.

P.4.4 Verification of overload releases

The operation of overload releases shall be verified in accordance with 9.3.4.2.4 k), except that the test current shall be 2,5 times the value of their current setting.

The operating time shall not exceed the maximum value stated by the manufacturer for twice the value of the current setting, at the reference temperature, on a pole singly.

P.4.5 Marking

MPSDs for which all values of rated voltage have been tested according to this annex or are covered by such testing require no additional marking.

MPSDs for which all values of rated voltage have not been tested according to this annex or are not covered by such testing shall be identified by the symbol  (IEC 60417-6363 “not suitable for use on IT systems”) which shall be marked on the MPSD immediately following these values of rated voltage (see EXAMPLE 1).

Where a MPSD has not been tested according to this annex, a single marking by the symbol  may be used provided it is so placed that it unmistakably covers all voltage ratings (see EXAMPLE 2).

EXAMPLE 1:

690 V 

EXAMPLE 2:

415 V
500 V
690 V } 

Annex Q (normative)

Co-ordination under short-circuit conditions between a MPSD and another short-circuit protective device associated in the same circuit

Q.1 Application

To ensure co-ordination under short-circuit conditions between a MPSD (C_1) and another short-circuit protective device (SCPD) associated with it in the same circuit, it is necessary to consider the characteristics of each of the two devices as well as their behaviour as an association.

NOTE An SCPD can incorporate additional protective means, for example, overload releases.

The SCPD may consist of a fuse (or a set of fuses) – see Figure Q.1 – or of a circuit-breaker (C_2) (see Figure Q.2 to Figure Q.5).

The comparison of the individual operating characteristics of each of the two associated devices may not be sufficient, when reference has to be made to the behaviour of these two devices operating in series, since the impedance of the devices is not always negligible. This should be taken into account. For short-circuit currents it is recommended that reference be made to I^2t instead of time.

C_1 is frequently connected in series with another SCPD for reasons such as the method of power distribution adopted for the installation or because the short-circuit breaking capacity of C_1 alone may be insufficient for the proposed application. In such instances, the SCPD may be mounted in locations remote from C_1 . The SCPD may be protecting a main feeder supplying a number of MPSDs C_1 or just an individual MPSD.

For such applications the user or specifying authority may have to decide, on the basis of a desk study alone, how the optimum level of co-ordination may best be achieved. This annex is intended to give guidance for this decision, and also on the type of information which the MPSD manufacturer should make available to the prospective user.

Guidance is also given on test requirements, where such tests are deemed necessary for the proposed application.

The term "co-ordination" includes consideration of selectivity (see 2.5.23 of IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 and also 2.17.2 and 2.17.3 of IEC 60947-2:2016).

Consideration of selectivity can in general be carried out by desk study (see Q.5).

When considering short-circuit breaking capacity of SCPD, reference can be made to the rated ultimate short-circuit breaking capacity (I_{cu}), or to the rated service short-circuit breaking capacity (I_{cs}), according to the desired criterion.

Q.2 Object

This annex gives guidance on and requirements for the co-ordination of a MPSD with other SCPDs associated in the same circuit, as regards selectivity.

The object of this annex is to state:

- the general requirements for the co-ordination of a MPSD with another SCPD;

- the methods and the tests (if deemed necessary) intended to verify that the conditions for co-ordination have been met.

Q.3 General requirements for the co-ordination of a MPSD with another SCPD

Q.3.1 General considerations

Ideally, the co-ordination should be such that a MPSD (C_1) alone will operate at all values of over-current up to the limit of its rated short-circuit breaking capacity I_{cu} .

NOTE If the value of the prospective fault current at the point of installation is less than the rated service short-circuit breaking capacity of C_1 , it can be assumed that the SCPD is only in the circuit for considerations other than those of back-up protection.

In practice, the following considerations apply:

- a) if the value of the selectivity limit current I_s (see 2.17.4 of IEC 60947-2:2016) is too low, there is a risk of unnecessary loss of selectivity;
- b) if the value of the prospective fault current at the point of installation exceeds the rated service short-circuit breaking capacity of C_1 , the SCPD shall be so selected that the behaviour of C_1 is in accordance with Q.3.2.

Whenever possible, the SCPD shall be located on the supply side of C_1 . If the SCPD is located on the load side, it is essential that the connection between C_1 and the SCPD be so arranged as to minimize any risk of short-circuit.

Q.3.2 Behaviour of C_1 in association with another SCPD

For all values of over-current up to and including the short-circuit breaking capacity of the association, C_1 shall comply with the requirements of 7.2.5 of IEC 60947-1:2007, and the association shall comply with the requirements of 8.2.1.5.7.

Where tests on combinations of short-circuit protective devices for over-current co-ordination are not performed (2.5.22 of IEC 60947-1:2007), the manufacturer shall provide information (usually curves) showing:

- maximum cut-off (let-through) peak current (2.5.19 of IEC 60947-1:2007) as a function of prospective current (RMS symmetrical);
- I^2t characteristics.

Conformity with this information may be checked during the relevant test of Annex P.

Q.4 Type and characteristics of the associated SCPD

On request, the manufacturer of the MPSD shall provide information on the type and the characteristics of the SCPD to be used with C_1 , and on the maximum prospective short-circuit current for which the association is suitable at the stated operational voltage.

Details of the SCPD used for any tests made in accordance with this annex, i.e. manufacturer's name, type designation, rated voltage, rated current and short-circuit breaking capacity, shall be given in the test report.

The maximum conditional short-circuit current (2.5.29 of IEC 60947-1:2007) shall not exceed the rated ultimate short-circuit breaking capacity of the SCPD or the rated service short-circuit breaking capacity of the SCPD in case of no rated ultimate short-circuit breaking capacity.

If the associated SCPD is a circuit-breaker, it shall meet the requirements of IEC 60947-2, or any other relevant standard. If the associated SCPD is a fuse, it shall be in accordance with the appropriate fuse standard.

Q.5 Verification of selectivity

Q.5.1 General

Selectivity can normally be considered by desk study alone, i.e. by a comparison of the operating characteristics of C_1 and the associated SCPD, for example, when the associated SCPD is a circuit-breaker (C_2) provided with an intentional time-delay.

The manufacturers of both the C_1 and the SCPD shall provide adequate data concerning the relevant operating characteristics so as to permit I_s to be determined for each individual association.

In certain cases, tests at I_s are necessary on the association, for example:

- when C_1 is of the current-limiting type and C_2 is not provided with an intentional time-delay;
- when the opening time of the SCPD is less than that corresponding to one half-cycle.

Selectivity may be partial (see Figure Q.4) or total up to the rated short-circuit breaking capacity I_{cu} of C_1 . For total selectivity, the non-tripping characteristic of C_2 or the pre-arcing characteristic of the fuse shall lie above the tripping (break-time) characteristic of C_1 .

Two illustrations of total selectivity are given in Figure Q.2 and Figure Q.3.

Q.5.2 Consideration of selectivity by desk study

Q.5.2.1 Selectivity in the overload zone

Two cases are considered hereafter, depending on whether the SCPD is a circuit-breaker or a fuse:

- a) MPD (C_1) and circuit-breakers (C_2) in series – selectivity determination by comparison of characteristics;

Selectivity in the time-delayed over-current zone is verified by comparison of the time-current characteristics. Separation of the characteristics in both the time and current axes ensures selective operation of C_1 with respect to C_2 , in this zone. There will be a tolerance applicable to the characteristics, which should be taken into account. The manufacturer's data should show a tolerance band or otherwise indicate the tolerance applicable, as required by this document.

- b) MPD (C_1) with fuse as SCPD – selectivity determination by comparison of characteristics.

Selectivity in the overload zone is determined by the comparison of time-current characteristics. Separation of the characteristics in both the time and current axes ensures selective operation of C_1 with respect to the fuse, in this zone. There will be a tolerance applicable to the characteristics, which should be taken into account. The manufacturer's data should show a tolerance band or otherwise indicate the tolerance applicable, as required by the product standards.

Q.5.2.2 Determination of selectivity in the fault current (short-circuit) zone

Determination from time-current characteristics, of selectivity between a MPD and a circuit-breaker in the fault current (short-circuit) zone (see Figure Q.2), is limited to the case where C_2 has a short-circuit release time-delay function provided by an electronic release.

- a) MPD (C_1) and circuit-breaker (C_2) in series – selectivity determination by consideration of peak let-through current;

In the case where the instantaneous tripping of C_2 depends on an electromagnetic effect (i.e. thermal/magnetic or magnetic-only circuit-breaker) or in the case of an electronic trip unit with an instantaneous release, the minimum level of selectivity between two circuit-breakers in the fault current zone may be determined as follows:

Selectivity is assured up to the fault current level at which the peak current let-through of C_1 is less than the peak value corresponding to the instantaneous short-circuit current setting (I_i) of C_2 , taking into account the tolerance.

NOTE 1 Example of selectivity calculation

$C_2 = 800$ A MCCB; $I_i = 8$ kA RMS – 12 kA RMS (10 kA setting ± 20 %); $C_1 = 125$ A MCCB.

Minimum tripping level of C_2 is $8 \times 1,414 = 11,3$ kA peak.

Let-through current of C_1 at 15 kA RMS prospective, due to the current limitation of C_1 , is 11 kA peak, from test data.

Therefore, the system is selective to at least 15 kA RMS prospective.

NOTE 2 The selectivity limit obtained by this method will be on the low side and the actual limit determined by test will be significantly higher in most cases.

b) MPD (C₁) with fuse as SCPD.

Selectivity in the fault-current (short-circuit) zone (see Figure Q.1) is determined from the I^2t characteristics. The selectivity limit current I_s is the maximum value at which let-through I^2t of the circuit-breaker is lower than the pre-arcing I^2t of the fuse. In the absence of an actual curve, the manufacturer's quoted I^2t pre-arc value for the fuse is taken.

Q.5.2.3 Determination of selectivity limit current for specific installation conditions

Data on selectivity limits may be supplied in tabulated form, graphically or as software media. Data obtained from either a desk study or tests, to this document, will be based on the prospective fault current level at the incoming device (C_2) and assumes that the coordinated devices are in close proximity. In practice the selectivity limit will be influenced by the impedance between the two devices. Therefore, in the practical situation taking the prospective fault current at the downstream MPD will give a more precise value for the selectivity limit.

Q.5.3 Selectivity determined by test

An example of the circuit diagram for the tests is shown in Figure Q.5, where:

- C_1 is a MPD;
- settings of C_1 and C_2 are adjusted to the maximum instantaneous setting, if applicable.

Tests at other release settings may be made at the discretion of the manufacturer, in which case the settings of the releases shall be recorded in the test report.

The connecting cables shall be included as specified in 9.3.4.1 and P.1 except the total length of the cables may be distributed between the supply side and the load side of C_1 and C_2 as convenient.

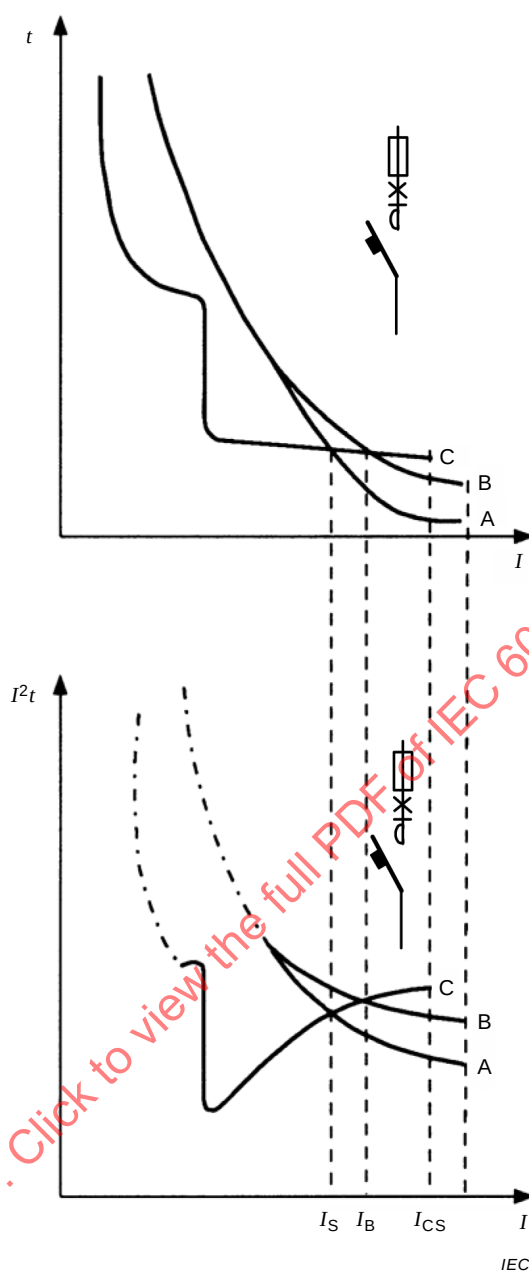
The test shall consist of an O – t – CO operation, the CO operation being made by closing the downstream device C_1 . If the downstream device is a fuse, the operation shall be made by closing C_2 .

The test is made at the level of prospective current for which the association of C_1 and C_2 is declared by the manufacturer to be selective.

Results to be obtained:

- 8.3.4.1.7 of IEC 60947-1:2007 applies;
- during each operation, C_1 shall operate and C_2 shall not trip. If the contacts of C_2 separate momentarily during the operations, the time between the beginning of short-circuit and the end of C_2 contact separation shall be less than or equal to 30 ms. The actual value shall be stated in the test report;
- in addition, it shall be verified that the contacts of C_2 are able to be opened by the normal operating means.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV



I prospective short-circuit current

I_{cs} rated service short-circuit breaking capacity (5.3.6.1)

I_s selectivity limit current (2.17.4 of IEC 60947-2:2016)

I_B take-over current (2.17.5 of IEC 60947-2:2016)

A pre-arcing characteristic of the fuse

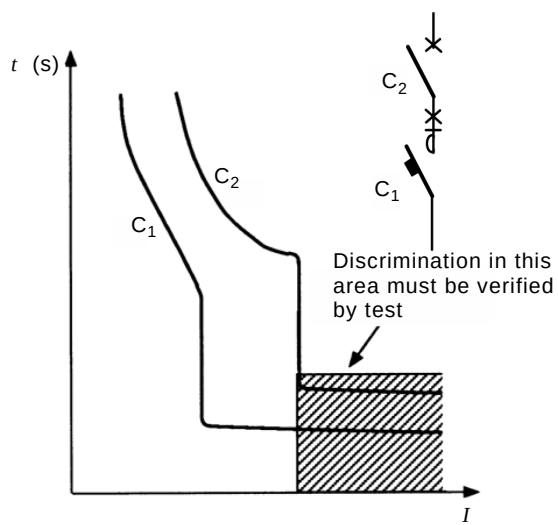
B operating characteristic of the fuse

C operating characteristic of the MPSD (break-time-current and I^2t / current)

NOTE 1 A is deemed to be the lower limit; B and C are deemed to be the upper limits.

NOTE 2 Non-adiabatic zone for I^2t shown chain-dotted.

Figure Q.1 – Over-current co-ordination between a MPSD and a fuse or back-up protection by a fuse: operating characteristics



IEC

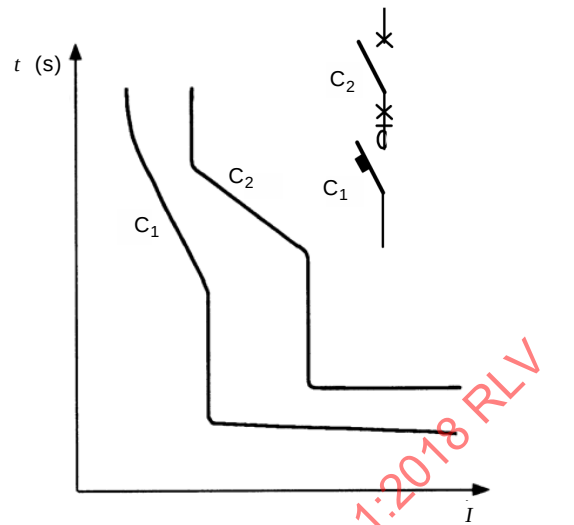
Key

C_1 current-limiting MPSD
(break-time characteristic)

C_2 non-current-limiting circuit-breaker
(tripping characteristic)

Values of I_{cu} (or I_{cs}) are not shown

**Figure Q.2 – Total selectivity between
MPSD and circuit-breakers – Case 1**



IEC

Key

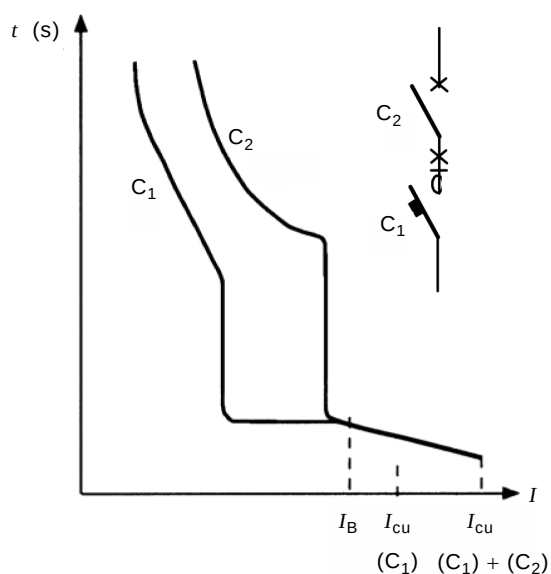
C_1 non-current-limiting MPSD
(break-time characteristic)

C_2 circuit-breaker with intentional short-time
delay (tripping characteristic)

Values of I_{cu} (or I_{cs}) are not shown

**Figure Q.3 – Total selectivity between
MPSD and circuit-breakers – Case 2**

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

**Key**

C_1 non current-limiting MPSPD/circuit-breaker

C_2 current-limiting circuit-breaker

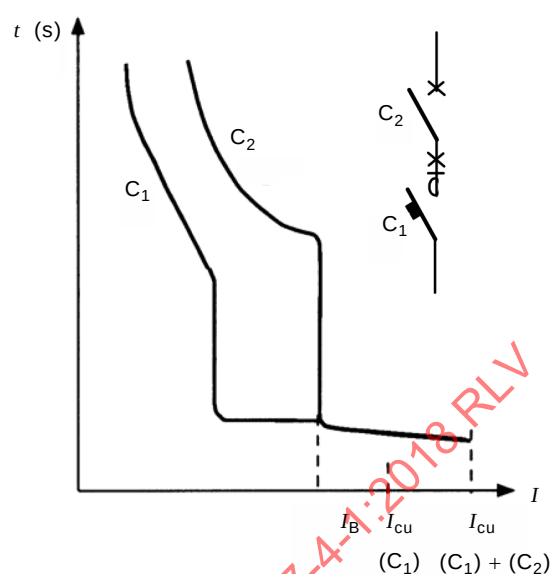
I_B take-over current

NOTE 1 Where applicable, restoration of supply by C_2 occurs.

NOTE 2 $I_{cu} (C_1 + C_2) \leq I_{cu} (C_2)$.

NOTE 3 For values of $I > I_B$, the curve is that of the association (shown in bold) for which data are obtained by tests.

**Figure Q.4 – Back-up protection
by a circuit-breaker –
Operating characteristics – Case 1**

**Key**

C_1 non current-limiting MPSPD/circuit-breaker

C_2 non current-limiting circuit-breaker

I_B take-over current

NOTE 1 Where applicable, restoration of supply by C_2 occurs.

NOTE 2 $I_{cu} (C_1 + C_2) \leq I_{cu} (C_2)$.

NOTE 3 For values of $I > I_B$, the curve is that of the association (shown in bold) for which data are obtained by tests.

**Figure Q.5 – Back-up protection
by a circuit-breaker –
Operating characteristics – Case 2**

Bibliography

IEC 60050-151:2001, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

IEC 60050-191:1990, *International Electrotechnical Vocabulary – Chapter 191: Dependability and quality of service*

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

IEC 60050-421:1990, *International Electrotechnical Vocabulary. Chapter 421: Power transformers and reactors*

IEC 60050-441:1984, *International Electrotechnical Vocabulary. Switchgear, controlgear and fuses*

IEC 60050-442:1998, *International Electrotechnical Vocabulary – Part 442: Electrical accessories*

IEC 60050-826:2004, *International Electrotechnical Vocabulary – Part 826: Electrical installations*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60072-1:1991, *Dimensions and output series for rotating electrical machines – Part 1: Frame numbers 56 to 400 and flange numbers 55 to 1080*

IEC 60079 (all parts), *Explosive atmospheres*

IEC 60079-7, *Explosive atmospheres – Part 7: Equipment protection by increased safety "e"*

IEC 60079-29-3, *Explosive atmospheres – Part 29-3: Gas detectors – Guidance on functional safety of fixed gas detection systems*

IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*

IEC 60269-2:2013, *Low-voltage fuses – Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) – Examples of standardized systems of fuses A to K*

IEC 60417, *Graphical symbols for use on equipment* (available at <http://www.graphical-symbols.info/equipment>)

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60812:2006, *Analysis techniques for system reliability – Procedure for failure mode and effects analysis (FMEA)*

IEC 60947-3, *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*

IEC 60947-8, *Low-voltage switchgear and controlgear – Part 8: Control units for built-in thermal protection (PTC) for rotating electrical machines*

IEC 60990:2016, *Methods of measurement of touch current and protective conductor current*

IEC 61000-6-5, *Electromagnetic compatibility (EMC) – Part 6-5: Generic standards – Immunity for equipment used in power station and substation environment*

IEC 61032, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 61095:2009, *Electromechanical contactors for household and similar purposes*

IEC 61508-2, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 2: Requirements for electrical/electronic/programmable electronic safety-related systems* (see <http://www.iec.ch/functionalsafety>)

IEC 61508-3, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 3: Software requirements* (see <http://www.iec.ch/functionalsafety>)

IEC 61508-4:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 4: Definitions and abbreviations* (see <http://www.iec.ch/functionalsafety>)

IEC 61508-6:2010, *Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 6: Guidelines on the application of IEC 61508-2 and IEC 61508-3* (see <http://www.iec.ch/functionalsafety>)

IEC 61649, *Weibull analysis*

IEC 61915-2:2011, *Low-voltage switchgear and controlgear – Device profiles for networked industrial devices – Part 2: Root device profiles for starters and similar equipment*

IEC 62061, *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*

IEC 62443 (all parts), *Security for industrial automation and control systems*

IEC 62477-1:2012, *Safety requirements for power electronic converter systems and equipment – Part 1: General*

IEC 62683-1, *Low-voltage switchgear and controlgear – Product data and properties for information exchange – Part 1: Catalogue data*

IEC TR 63054, *Low-voltage switchgear and controlgear – Fire risk analysis and risk reduction measures*

IEC TS 63058, *Environmental aspects for low-voltage switchgear and controlgear and their assemblies*²

IEC Guide 104:2010, *The preparation of safety publications and the use of basic safety publications and group safety publications*

ISO/IEC 80079-34, *Explosive atmospheres – Part 34: Application of quality systems for equipment manufacture*

² Under preparation. Stage at the time of publication: IEC/ACD TS 63058:2018.

ISO/IEC 82079-1, *Preparation of instructions for use – Structuring, content and presentation – Part 1: General principles and detailed requirements*

ISO/IEC Guide 51:2014, *Safety aspects – Guideline for their inclusion in standards*

ISO 3534-2:2006, *Statistics – Vocabulary and symbols – Part 2: Applied statistics*

CSA C22.1, *Canadian Electrical Code*

EN 50495, *Safety devices required for the safe functioning of equipment with respect to explosion risks*

NFPA 70, *National Electrical Code®*

PROFIEnergy profile test specification V1.1:2014

UL 508:2013, *Industrial control equipment*

UL 60947-1, *Low-Voltage Switchgear and Controlgear – Part 1: General rules*

UL 60947-4-1 *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

IEC 60947-4-1 Edition 4.0 2018-10

APPAREILLAGE A BASSE TENSION –

Partie 4-1: Contacteurs et démarreurs de moteurs – Contacteurs et démarreurs électromécaniques

FEUILLE D'INTERPRÉTATION 1

Cette feuille d'interprétation a été établie par le sous-comité 121A: Appareillage à basse tension, du comité d'études 121 de l'IEC: Appareillages et ensembles d'appareillages basse tension.

Le texte de cette feuille d'interprétation est issu des documents suivants:

DISH	Rapport de vote
121A/336/DISH	121A/342/RVDISH

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette feuille d'interprétation.

Interprétation du premier alinéa de 6.2

L'objectif de la référence à l'article 5.2 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 est de s'appliquer à l'ensemble du paragraphe alors que son premier alinéa peut en être écarté.

Plus particulièrement, le troisième alinéa de ce Paragraphe 5.2 imposant le marquage sur l'équipement du nom du fabricant ou de sa marque et de la désignation du type ou du numéro de série satisfait aux exigences des points a) et b) de 6.1.1 de l'IEC 60947-4-1:2018.

Interprétation des notes de bas de tableau ⁿ et ^o du Tableau 7

Les conditions normales d'établissement du courant pour la catégorie d'utilisation AC-3e sont définies par un rapport I / I_e égal à 12, avec la valeur correspondante du $\cos \phi$ telle que définie dans la note de bas de tableau ^o.

La note de bas de tableau ⁿ offre la possibilité de choisir une valeur du rapport I / I_e différente, comprise entre 12 et 13, et décrit l'équation associée permettant de déterminer la valeur de $\cos \phi$.

Interprétation du courant assigné d'emploi du Tableau 13 et du Tableau 14

Les Tableaux 13 et 14 sont applicables aux contacteurs et démarreurs pour les charges de type moteur. Si le contacteur ou le démarreur satisfait aux exigences de plusieurs catégories d'emploi (AC-2, AC-3, AC-3e ou AC-4), le courant assigné d'emploi I_e correspondant à la catégorie d'emploi AC-3 doit être choisi afin de déterminer la valeur présumée du courant " I " pour l'essai.

La catégorie d'emploi AC-3 est considérée comme le cas d'utilisation le plus représentatif, et est considérée couvrir les exigences des autres catégories d'emploi des moteurs.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 PLV

SOMMAIRE

AVANT-PROPOS	191
INTRODUCTION	194
1 Domaine d'application	195
2 Références normatives	196
3 Termes, définitions, symboles et abréviations	197
3.1 Généralités	197
3.2 Index alphabétique des termes	197
3.3 Termes et définitions relatifs aux contacteurs	199
3.4 Termes et définitions relatives aux démarreurs	200
3.5 Termes et définitions concernant les grandeurs caractéristiques	206
3.6 Termes et définitions relatifs aux aspects liés à la sécurité	207
3.7 Symboles et abréviations	208
4 Classification	209
5 Caractéristiques des contacteurs et des démarreurs	209
5.1 Énumération des caractéristiques	209
5.2 Type du matériel	210
5.2.1 Nature du matériel	210
5.2.2 Nombre de pôles	210
5.2.3 Nature du courant (alternatif ou continu)	210
5.2.4 Milieu de coupure (air, huile, gaz, vide, etc.)	210
5.2.5 Conditions de fonctionnement du matériel	210
5.3 Valeurs assignées et valeurs limites des circuits principaux	211
5.3.1 Tensions assignées	211
5.3.2 Courants ou puissances	212
5.3.3 Fréquence assignée	214
5.3.4 Services assignés	214
5.3.5 Caractéristiques en conditions normales de charge et de surcharge	215
5.3.6 Caractéristiques de court-circuit	217
5.3.7 Impédance de pôle d'un contacteur (Z)	218
5.4 Catégorie d'emploi	218
5.4.1 Généralités	218
5.4.2 Attribution des catégories d'emploi en fonction des résultats d'essais	218
5.5 Circuits de commande	220
5.6 Circuits auxiliaires	221
5.7 Caractéristiques du relais et du déclencheur des relais de surcharge et de l'appareil de connexion de protection des moteurs (ACPM)	221
5.7.1 Énumération des caractéristiques	221
5.7.2 Types du relais ou du déclencheur	221
5.7.3 Valeurs caractéristiques	222
5.7.4 Désignation et courants de réglage des relais de surcharge	223
5.7.5 Caractéristiques temps-courant des relais de surcharge	223
5.7.6 Influence de la température de l'air ambiant	224
5.8 Coordination avec les dispositifs de protection contre les courts-circuits	224
5.9 Vide	224
5.10 Types et caractéristiques des appareils de commande automatique de commutation et des appareils de commande automatique d'accélération	224

5.10.1	Types	224
5.10.2	Caractéristiques	224
5.11	Types et caractéristiques des autotransformateurs des démarreurs par autotransformateur à deux étapes.....	225
5.12	Types et caractéristiques des résistances de démarrage des démarreurs rotoriques à résistances	225
6	Informations sur le matériel	226
6.1	Nature des informations	226
6.1.1	Identification.....	226
6.1.2	Caractéristiques, valeurs assignées fondamentales et utilisation	226
6.2	Marquage	226
6.3	Instructions d'installation, de fonctionnement, de maintenance, de mise hors service et de démontage	228
6.4	Informations relatives à l'environnement	229
7	Conditions normales de service, de montage et de transport	229
8	Exigences relatives à la construction et au fonctionnement	229
8.1	Exigences relatives à la construction	229
8.1.1	Généralités	229
8.1.2	Matériaux	230
8.1.3	Parties conductrices et leurs connexions	230
8.1.4	Distances d'isolement et lignes de fuite	230
8.1.5	Organe de commande	231
8.1.6	Indication de la position des contacts	231
8.1.7	Exigences supplémentaires pour les matériels aptes au sectionnement.....	231
8.1.8	Bornes.....	232
8.1.9	Exigences supplémentaires pour les matériels équipés d'un pôle neutre	232
8.1.10	Dispositions pour assurer la mise à la terre de protection	232
8.1.11	Enveloppes pour le matériel	232
8.1.12	Degrés de protection du matériel sous enveloppe	232
8.1.13	Traction, torsion et flexion avec des conduits métalliques	232
8.1.14	Source d'énergie limitée	232
8.1.15	Circuit d'énergie de charge emmagasinée	235
8.1.16	Conditions de défaut et conditions anormales	235
8.1.17	Protection des accès contre les courts-circuits et les surcharges	236
8.2	Exigences relatives au fonctionnement	236
8.2.1	Conditions de fonctionnement.....	236
8.2.2	Échauffement	242
8.2.3	Propriétés diélectriques	244
8.2.4	Exigences de fonctionnement dans des conditions normales de charge et de surcharge	245
8.2.5	Coordination avec les dispositifs de protection contre les courts-circuits	251
8.3	Compatibilité électromagnétique (CEM)	254
8.3.1	Généralités	254
8.3.2	Immunité	254
8.3.3	Émission.....	255
9	Essais	256
9.1	Nature des essais	256
9.1.1	Généralités	256
9.1.2	Essais de type	256

9.1.3	Essais individuels de série.....	256
9.1.4	Essais sur prélèvement.....	256
9.1.5	Essais spéciaux.....	257
9.2	Conformité aux exigences de construction	258
9.2.1	Généralités.....	258
9.2.2	Performance électrique des organes de serrage sans vis	258
9.2.3	Essai de vieillissement pour organes de serrage sans vis.....	259
9.2.4	Essai de la source d'énergie limitée.....	259
9.2.5	Défaillance de composants.....	260
9.3	Conformité aux exigences relatives au fonctionnement	261
9.3.1	Séquences d'essais	261
9.3.2	Conditions générales pour les essais.....	261
9.3.3	Fonctionnement à vide et dans les conditions normales de charge et de surcharge	262
9.3.4	Fonctionnement en court-circuit.....	275
9.3.5	Capacité de tenue des contacteurs aux courants de surcharge.....	280
9.3.6	Essais individuels de série et essais sur prélèvement.....	280
9.4	Essais CEM	282
9.4.1	Généralités.....	282
9.4.2	Immunité	283
9.4.3	Émission.....	285
Annexe A (normative) Marquage et identification des bornes des contacteurs, des démarreurs et des relais de surcharge associés		287
A.1	Généralités	287
A.2	Marquage et identification des bornes des circuits principaux	287
A.3	Marquage et identification des bornes des relais de surcharge	287
Annexe B (normative) Essais spéciaux		289
B.1	Généralités	289
B.2	Durabilité mécanique.....	289
B.2.1	Généralités	289
B.2.2	Vérification de la durabilité mécanique	289
B.3	Durabilité électrique.....	291
B.3.1	Généralités.....	291
B.3.2	Résultats à obtenir	292
B.3.3	Analyse statistique des résultats d'essais pour les contacteurs ou les démarreurs	293
B.4	Coordination au courant d'intersection entre démarreur et DPCC associé.....	293
B.4.1	Généralités et définitions	293
B.4.2	Condition pour l'essai de vérification de la coordination au courant d'intersection par une méthode directe	294
B.4.3	Courants d'essai et circuits d'essai	294
B.4.4	Procédure d'essai et résultats à obtenir	294
B.4.5	Vérification de la coordination au courant d'intersection par une méthode indirecte	295
Annexe C (informative) Caractéristiques types des démarreurs		298
Annexe D (informative) Points faisant l'objet d'un accord entre le fabricant et l'utilisateur		305
Annexe E (Vide).....		306

Annexe F (normative) Exigences pour un contact auxiliaire lié à un contact de puissance (contact miroir).....	307
F.1 Application et objet	307
F.1.1 Application.....	307
F.1.2 Objet	307
F.2 Termes et définitions	307
F.3 Caractéristiques.....	307
F.4 Informations sur le matériel.....	307
F.5 Conditions normales de service, de montage et de transport.....	308
F.6 Exigences relatives à la construction et au fonctionnement.....	308
F.7 Essais.....	308
F.7.1 Généralités	308
F.7.2 Essais sur produits à l'état neuf.....	308
F.7.3 Essai après le fonctionnement conventionnel en service (défini dans le Tableau 12)	309
Annexe G (informative) Courants assignés d'emploi et puissances assignées d'emploi des appareils de connexion pour moteurs électriques	310
G.1 Généralités	310
G.2 Puissances assignées d'emploi et courants assignés d'emploi.....	310
Annexe H (normative) Fonctions étendues des relais électroniques de surcharge	314
H.1 Généralités	314
H.2 Termes et définitions	314
H.3 Limites d'action des fonctions de commande.....	314
H.3.1 Généralités	314
H.3.2 Limites du relais électronique de surcharge avec fonction de redémarrage à minimum de tension du circuit principal.....	315
H.4 Essai des fonctions de commande	315
Annexe I (informative) Contacteurs AC-1 pour utilisation avec des moteurs commandés par des appareils à semiconducteurs	316
Annexe J (Vide)	317
Annexe K (normative) Procédure de détermination des données des contacteurs électromécaniques utilisés dans des applications de sécurité fonctionnelle.....	318
K.1 Généralités	318
K.2 Exigences d'essais	318
K.3 Caractérisation d'un mode de défaillance.....	318
K.4 Rapports de défaillance d'un contacteur.....	318
Annexe L (normative) Procédure d'évaluation de la protection électromécanique contre les surcharges utilisée dans des applications de sécurité, et plus particulièrement dans des atmosphères explosives.....	320
L.1 Application et objet	320
L.1.1 Application.....	320
L.1.2 Objet	320
L.2 Termes, définitions et symboles.....	320
L.2.1 Termes et définitions	320
L.2.2 Symboles et abréviations.....	322
L.3 Procédure	322
L.3.1 Généralités	322
L.3.2 Processus de conception de sécurité.....	322
L.4 Exigences	323

L.4.1	Généralités	323
L.4.2	Plan de sécurité	324
L.4.3	Conception	324
L.4.4	Analyse des modes de défaillance et de leurs effets de la fonction de sécurité	325
L.4.5	Plan de conception	325
L.4.6	Vérification	325
L.4.7	Fonction évaluée	326
L.5	Documentation	326
L.5.1	Documentation de sécurité technique	326
L.5.2	Instructions de sécurité	326
L.6	Exemple	326
L.6.1	Description de l'architecture	326
L.6.2	AMDE	328
Annexe M (normative) Contacteurs à courant continu utilisés dans des applications photovoltaïques (PV)		338
M.1	Application	338
M.2	Objet	338
M.3	Termes et définitions	338
M.4	Classification	339
M.5	Caractéristiques	339
M.5.1	Généralités	339
M.5.2	Tension assignée de tenue aux chocs	339
M.5.3	Catégorie d'emploi	339
M.6	Informations sur le matériel	340
M.7	Conditions normales de service, de montage et de transport	340
M.7.1	Généralités	340
M.7.2	Température de l'air ambiant	340
M.7.3	Altitude	341
M.8	Exigences relatives à la construction et au fonctionnement	341
M.8.1	Exigences relatives à la construction	341
M.8.2	Exigences relatives au fonctionnement	341
M.8.3	Compatibilité électromagnétique (CEM)	342
M.9	Essais	343
M.9.1	Généralités	343
M.9.2	Essais de type	343
M.9.3	Pouvoirs de fermeture et de coupure et performance de fonctionnement conventionnel en service	343
M.9.4	Essai de cycles thermiques	343
M.9.5	Essai climatique	344
M.9.6	Essai diélectrique	344
M.9.7	Essai du courant critique de charge	344
M.9.8	Propriétés mécaniques	346
M.9.9	Degré de protection des contacteurs sous enveloppe	346
M.9.10	CEM	346
M.9.11	Distances d'isolement et lignes de fuite	346
Annexe N (normative) Exigences supplémentaires et essais pour le matériel avec séparation de protection		347
N.1	Généralités	347

N.2	Définitions.....	347
N.3	Exigences	347
N.3.1	Méthode d'essai de mise en œuvre de l'impédance de protection	347
N.3.2	Mesurage du courant de contact.....	348
Annexe O (informative)	Indicateurs de surveillance de charge	350
O.1	Généralités	350
O.2	Liste des indicateurs	350
O.3	Incertitude.....	352
O.4	Essais.....	353
O.4.1	Essais individuels de série.....	353
O.4.2	Essais de type	353
Annexe P (normative)	Essais de coupure en court-circuit de l'ACPM	355
P.1	Conditions générales d'essai	355
P.2	Pouvoir de coupure de service en court-circuit assigné.....	356
P.2.1	Généralités.....	356
P.2.2	Essai du pouvoir de coupure de service en court-circuit assigné.....	356
P.2.3	Vérification de l'aptitude au fonctionnement en service.....	356
P.2.4	Vérification de la rigidité diélectrique	356
P.2.5	Vérification de l'échauffement.....	357
P.2.6	Vérification des déclencheurs de surcharge.....	357
P.3	Pouvoir de coupure ultime en court-circuit assigné	357
P.3.1	Généralités.....	357
P.3.2	Vérification des déclencheurs de surcharge.....	357
P.3.3	Essai du pouvoir de coupure ultime en court-circuit assigné	358
P.3.4	Vérification de la rigidité diélectrique	358
P.3.5	Vérification des déclencheurs de surcharge.....	358
P.4	Essai de l'ACPM pour les schémas de mise à la terre de type IT	358
P.4.1	Généralités.....	358
P.4.2	Court-circuit du pôle individuel.....	359
P.4.3	Vérification de la rigidité diélectrique	359
P.4.4	Vérification des déclencheurs de surcharge.....	359
P.4.5	Marquage	359
Annexe Q (normative)	Coordination dans les conditions de court-circuit entre un ACPM et un autre dispositif de protection contre les courts-circuits associés dans le même circuit.....	361
Q.1	Application	361
Q.2	Objet.....	362
Q.3	Exigences générales relatives à la coordination d'un ACPM avec un autre DPCC	362
Q.3.1	Généralités.....	362
Q.3.2	Comportement de C_1 en association avec un autre DPCC.....	362
Q.4	Type et caractéristiques du DPCC associé.....	363
Q.5	Vérification de la sélectivité	363
Q.5.1	Généralités.....	363
Q.5.2	Prise en compte de la sélectivité par étude théorique	363
Q.5.3	Sélectivité déterminée par essai	365
Bibliographie.....		369

Figure 1 – Limites des multiples de la valeur du courant de réglage des relais de surcharge à fonctionnement différé compensés pour la température de l'air ambiant	239
Figure 2 – Essai de mémoire thermique	240
Figure 3 – Exemples de caractéristiques de coordination d'un démarreur	253
Figure 4 – Mesurage de chute de tension au point de contact de la borne de contact	259
Figure 5 – Exemple de mesurage d'impédance de pôles pour un contacteur tripolaire	265
Figure A.1 – Circuit principal	287
Figure A.2 – Relais de surcharge	288
Figure B.1 – Exemples de caractéristique de tenue temps-courant	297
Figure C.1 – Courbes types de courants et de couples au cours d'un démarrage étoile-triangle (voir 3.4.4.1)	298
Figure C.2 – Courbes types de courants et de couples au cours d'un démarrage par autotransformateur (voir 3.4.4.2)	299
Figure C.3 – Variantes types de démarreurs protégés, de combinés de démarrage, d'appareils de connexion protégés et de combinés d'appareils de connexion	300
Figure C.4 – Exemple de schéma en triphasé d'un démarreur rotorique à résistances à trois étapes de démarrage et à un seul sens de marche (dans le cas dans lequel tous les appareils mécaniques de connexion sont des contacteurs)	301
Figure C.5 – Méthodes et schémas types de démarrage, au moyen d'autotransformateurs, de moteurs à induction à courant alternatif	303
Figure C.6 – Exemples de courbes vitesses/temps correspondant aux cas a), b), c), d), e) et f) de 5.3.5.6.1	304
Figure F.1 – Contact miroir	308
Figure L.1 – Processus de conception de sécurité	323
Figure L.2 – Structure type d'un relais thermique de surcharge	327
Figure L.3 – Structure type d'un ACPM	328
Figure M.1 – Courant critique	345
Figure N.1 – Protection au moyen de l'impédance de protection	348
Figure N.2 – Instrument de mesure	349
Figure O.1 – Exemple de quantification d'une modification de procédé	352
Figure Q.1 – Coordination à maximum de courant entre un ACPM et un fusible ou protection d'accompagnement par un fusible: caractéristiques de fonctionnement	366
Figure Q.2 – Sélectivité totale entre l'ACPM et les disjoncteurs – Cas 1	367
Figure Q.3 – Sélectivité totale entre l'ACPM et les disjoncteurs – Cas 2	367
Figure Q.4 – Protection d'accompagnement par un disjoncteur – Caractéristiques de fonctionnement – Cas 1	368
Figure Q.5 – Protection d'accompagnement par un disjoncteur – Caractéristiques de fonctionnement – Cas 2	368
Tableau 1 – Catégories d'emploi	220
Tableau 2 – Classes de déclenchement des relais de surcharge	223
Tableau 3 – Limites de fonctionnement des relais de surcharge à fonctionnement différé alimentés sur tous leurs pôles	238
Tableau 4 – Limites de fonctionnement des relais de surcharge tripolaires à fonctionnement différé alimentés sur deux pôles seulement	241
Tableau 5 – Limites d'échauffement pour les bobines isolées dans l'air et dans l'huile	243
Tableau 6 – Données pour les cycles d'essai de service intermittent	244

Tableau 7 – Pouvoirs de fermeture et de coupure – Conditions de fermeture et de coupure correspondant aux catégories d'emploi.....	246
Tableau 8 – Relation entre le courant d'essai et la durée à l'état non passant pour la vérification des pouvoirs assignés de fermeture et de coupure.....	248
Tableau 9 – Détermination du courant d'emploi pour les catégories d'emploi AC-6a et AC-6b à partir des caractéristiques assignées pour AC-3.....	248
Tableau 10 – Fonctionnement conventionnel en service – Conditions de fermeture et de coupure en fonction de la catégorie d'emploi.....	249
Tableau 11 – Exigences de tenue aux courants de surcharge	251
Tableau 12 – Critères d'acceptation spécifiques pour les essais d'immunité	255
Tableau 13 – Valeur du courant d'essai présumé en fonction du courant assigné d'emploi.....	277
Tableau 14 – Valeur du courant d'essai présumé en fonction du courant assigné d'emploi (tableau harmonisé).....	278
Tableau 15 – Procédure d'essai pour I_{cd}	253
Tableau 16 – Essais d'immunité CEM	283
Tableau 17 – Limites de la tension perturbatrice aux bornes pour les émissions conduites aux fréquences radioélectriques (pour les accès principaux).....	285
Tableau 18– Limites d'essai d'émission rayonnée	286
Tableau 19 – Limites pour les sources d'énergie limitée sans dispositif de protection contre les surintensités	233
Tableau 20 – Limites pour les sources d'énergie limitée avec dispositif de protection contre les surintensités	234
Tableau 21 – Limites pour la source d'énergie limitée avec impédance de limitation de courant	235
Tableau B.1 – Vérification du nombre de cycles de manœuvres en charge – Conditions d'établissement et de coupure correspondant aux diverses catégories d'emploi.....	292
Tableau B.2 – Conditions d'essai.....	295
Tableau F.1 – Tension d'essai selon l'altitude.....	309
Tableau G.1 – Puissances assignées d'emploi et courants assignés d'emploi des moteurs	311
Tableau K.1 – Mode de défaillance des contacteurs	318
Tableau K.2 – Rapports types de défaillance pour les contacteurs normalement ouverts	319
Tableau L.1 – Sévérité.....	328
Tableau L.2 – Occurrence.....	329
Tableau L.3 – Niveaux de détection	329
Tableau L.4 – Conclusion	330
Tableau L.5 – Exemple d'analyse des modes de défaillance et de leurs effets pour relais thermique de surcharge.....	331
Tableau M.1 – Niveaux de tension de choc assignée des contacteurs PV.....	339
Tableau M.2 – Catégories d'emploi	339
Tableau M.3 – Conditions de température de l'air ambiant.....	341
Tableau M.4 – Vérification des pouvoirs assignés de fermeture et de coupure – Conditions de fermeture et de coupure correspondant à la catégorie d'emploi DC-PV.....	342
Tableau M.5 – Fonctionnement conventionnel en service – Conditions de fermeture et de coupure correspondant à la catégorie DC-PV.....	342
Tableau M.6 – Description générale des séquences d'essais.....	343

Tableau M.7 – Nombre de cycles de manœuvres correspondant au courant critique de charge	345
Tableau M.8 – Performances du courant critique de charge	346
Tableau O.1 – Liste des indicateurs de surveillance en courant alternatif.....	351
Tableau O.2 – Différentes possibilités admises pour vérifier les indicateurs	353
Tableau O.3 – Référence pour les conditions de vérification	354
Tableau O.4 – Niveaux d'harmoniques	354

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

APPAREILLAGE À BASSE TENSION –

**Partie 4-1: Contacteurs et démarreurs de moteurs –
Contacteurs et démarreurs électromécaniques**

AVANT-PROPOS

- 1) La Commission Électrotechnique Internationale (IEC) est une organisation mondiale de normalisation composée de l'ensemble des comités électrotechniques nationaux (Comités nationaux de l'IEC). L'IEC a pour objet de favoriser la coopération internationale pour toutes les questions de normalisation dans les domaines de l'électricité et de l'électronique. À cet effet, l'IEC – entre autres activités – publie des Normes internationales, des Spécifications techniques, des Rapports techniques, des Spécifications accessibles au public (PAS) et des Guides (ci-après dénommés "Publication(s) de l'IEC"). Leur élaboration est confiée à des comités d'études, aux travaux desquels tout Comité national intéressé par le sujet traité peut participer. Les organisations internationales, gouvernementales et non gouvernementales, en liaison avec l'IEC, participent également aux travaux. L'IEC collabore étroitement avec l'Organisation Internationale de Normalisation (ISO), selon des conditions fixées par accord entre les deux organisations.
- 2) Les décisions ou accords officiels de l'IEC concernant les questions techniques représentent, dans la mesure du possible, un accord international sur les sujets étudiés, étant donné que les Comités nationaux de l'IEC intéressés sont représentés dans chaque comité d'études.
- 3) Les Publications de l'IEC se présentent sous la forme de recommandations internationales et sont agréées comme telles par les Comités nationaux de l'IEC. Tous les efforts raisonnables sont entrepris afin que l'IEC s'assure de l'exactitude du contenu technique de ses publications; l'IEC ne peut pas être tenue responsable de l'éventuelle mauvaise utilisation ou interprétation qui en est faite par un quelconque utilisateur final.
- 4) Dans le but d'encourager l'uniformité internationale, les Comités nationaux de l'IEC s'engagent, dans toute la mesure possible, à appliquer de façon transparente les Publications de l'IEC dans leurs publications nationales et régionales. Toutes divergences entre toutes Publications de l'IEC et toutes publications nationales ou régionales correspondantes doivent être indiquées en termes clairs dans ces dernières.
- 5) L'IEC elle-même ne fournit aucune attestation de conformité. Des organismes de certification indépendants fournissent des services d'évaluation de conformité et, dans certains secteurs, accèdent aux marques de conformité de l'IEC. L'IEC n'est responsable d'aucun des services effectués par les organismes de certification indépendants.
- 6) Tous les utilisateurs doivent s'assurer qu'ils sont en possession de la dernière édition de cette publication.
- 7) Aucune responsabilité ne doit être imputée à l'IEC, à ses administrateurs, employés, auxiliaires ou mandataires, y compris ses experts particuliers et les membres de ses comités d'études et des Comités nationaux de l'IEC, pour tout préjudice causé en cas de dommages corporels et matériels, ou de tout autre dommage de quelque nature que ce soit, directe ou indirecte, ou pour supporter les coûts (y compris les frais de justice) et les dépenses découlant de la publication ou de l'utilisation de cette Publication de l'IEC ou de toute autre Publication de l'IEC, ou au crédit qui lui est accordé.
- 8) L'attention est attirée sur les références normatives citées dans cette publication. L'utilisation de publications référencées est obligatoire pour une application correcte de la présente publication.
- 9) L'attention est attirée sur le fait que certains des éléments de la présente Publication de l'IEC peuvent faire l'objet de droits de brevet. L'IEC ne saurait être tenue pour responsable de ne pas avoir identifié de tels droits de brevets et de ne pas avoir signalé leur existence.

La Norme internationale IEC 60947-4-1 a été établie par le sous-comité 121A: Appareillage à basse tension, du comité d'études 121 de l'IEC: Appareillages et ensembles d'appareillages basse tension.

Cette quatrième édition annule et remplace la troisième édition parue en 2009, ainsi que son Amendement 1:2012. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- Structure du domaine d'application et exclusions
- Corrections rédactionnelles des notes et des alinéas suspendus

- Référence à l'IEC 62683-1
- Appareil de connexion de protection des moteurs (ACPM) accompagné de ses exigences
- Aspects relatifs à la sécurité:
 - Aspects généraux;
 - Circuits limités en énergie;
 - Circuits électroniques;
 - Procédure d'évaluation de la protection électromécanique contre les surcharges utilisée dans des applications de sécurité (nouvelle Annexe L)
- Introduction des dispositions relatives à l'impact du courant rotor bloqué plus élevé afin d'atteindre une classe de rendement supérieure
- Mention des accessoires de câblage dédiés
- Mesurage de la puissance d'appel
- Alignement avec l'IEC 60947-1:2007, l'IEC 60947-1:2007/AMD1:2010, et l'IEC 60947-1:2007/AMD2:2014
- Exigences en matière de courant continu pour couvrir les applications photovoltaïques (nouvelle Annexe M)
- Indicateurs de surveillance de charge (nouvelle Annexe O)
- Essais de coupure en court-circuit de l'ACPM (nouvelle Annexe P)
- Coordination dans les conditions de court-circuit entre un ACPM et un autre dispositif de protection contre les courts-circuits associés dans le même circuit (nouvelle Annexe Q)

Le texte de cette Norme internationale est issu des documents suivants:

FDIS	Rapport de vote
121A/224/FDIS	121A/233/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 60947, publiées sous le titre général *Appareillage à basse tension*, peut être consultée sur le site web de l'IEC.

Le présent document doit être lu conjointement avec l'IEC 60947-1:2007, l'IEC 60947-1:2007/AMD1:2010, l'IEC 60947-1:2007/AMD2:2014, *Appareillage à basse tension – Partie 1: Règles générales*. Les dispositions des règles générales sont applicables au présent document, lorsque cela est spécifiquement mentionné.

Les dispositions des règles générales présentées dans l'IEC 60947-1 sont applicables à la présente partie de la série IEC 60947, lorsque cela est spécifiquement mentionné. Les articles et paragraphes, les tableaux, les figures et les annexes des règles générales qui sont donc applicables sont identifiés en référence à l'IEC 60947-1:2007, à l'IEC 60947-1:2007/AMD1:2010 et à l'IEC 60947-1:2007/AMD2:2014. Par exemple, 4.3.4.1 de l'IEC 60947-1:2007, Tableau 4 de l'IEC 60947-1:2007 ou Annexe A de l'IEC 60947-1:2007.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous «<http://webstore.iec.ch>» dans les données relatives au document recherché. À cette date, le document sera

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

Le contenu de la feuille d'interprétation de mars 2020 a été pris en considération dans cet exemplaire.

Le contenu des corrigenda 1 (2020-04) et 2 (2021-04) a été pris en considération dans cet exemplaire.

IMPORTANT – Le logo «*colour inside*» qui se trouve sur la page de couverture de cette publication indique qu'elle contient des couleurs qui sont considérées comme utiles à une bonne compréhension de son contenu. Les utilisateurs devraient, par conséquent, imprimer cette publication en utilisant une imprimante couleur.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

INTRODUCTION

Ce document introduit les exigences relatives aux appareils de connexion de protection des moteurs (ACPM).

Les ACPM sont disponibles sur le marché depuis de nombreuses années. Ils sont présentés dans ce document pour couvrir les exigences minimales de sécurité et de performances d'un démarreur moteur à main comportant une protection intégrale, électromécanique ou électronique, contre les courts-circuits. Cet appareil satisfait à toutes les exigences d'un démarreur et aux exigences spécifiques d'un disjoncteur conformément à l'IEC 60947-2 (plus particulièrement I_{cu} et I_{cs}) pour la protection du moteur et de ses circuits avec des appareils de commande (un contacteur, par exemple). Un ACPM n'a pas vocation à prendre en charge les exigences en matière de pôle neutre, de courants continus assignés, de courant assigné ininterrompu I_u , de protection de secours, de retard de déclenchement de court-circuit, de catégorie de sélectivité, de capacité débrochable, de dispositif à courant différentiel résiduel, de disjoncteur à réenclenchement et de CEM de l'IEC 60947-2, etc.

Les disjoncteurs conformes à l'Annexe O de l'IEC 60947-2:2016 présentant des caractéristiques de protection du moteur contre les surcharges selon le présent document, mais sans caractéristiques assignées de démarreur (AC-3, par exemple), sont également disponibles sur le marché. Ces appareils ne sont pas couverts par le présent document.

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 PDF

APPAREILLAGE À BASSE TENSION –

Partie 4-1: Contacteurs et démarreurs de moteurs – Contacteurs et démarreurs électromécaniques

1 Domaine d'application

La présente partie de l'IEC 60947 s'applique aux équipements suivants:

- contacteurs électromécaniques et démarreurs, y compris les appareils de connexion de protection des moteurs (ACPM);
- organes de commande de contacteurs auxiliaires;
- contacts destinés exclusivement au circuit de la bobine de ce contacteur ou ce contacteur auxiliaire;
- accessoires dédiés (câblage dédié, accessoires d'accrochage dédié, par exemple);

destinés à être connectés à des circuits de distribution, des circuits de moteur et à d'autres circuits de charge, dont la tension assignée ne dépasse pas 1 000 V en courant alternatif ou 1 500 V en courant continu.

Le présent document couvre également la procédure d'évaluation de la protection électromécanique contre les surcharges utilisée dans des applications de sécurité, telle que la protection d'un moteur situé dans une atmosphère explosive provenant de l'atmosphère extérieure. Voir l'Annexe L.

Le présent document ne s'applique pas:

- aux démarreurs de moteurs en courant continu¹;

NOTE 1 Des exigences relatives aux démarreurs moteurs en courant continu sont à l'étude pour le prochain cycle de maintenance.

- aux contacts auxiliaires des contacteurs et aux contacts des contacteurs auxiliaires. Ils sont couverts par l'IEC 60947-5-1;
- aux démarreurs utilisés en aval d'un entraînement à fréquence variable¹;

NOTE 2 Des exigences supplémentaires relatives aux démarreurs utilisés en aval d'un entraînement à fréquence variable sont à l'étude pour le prochain cycle de maintenance.

- aux dispositifs de protection contre les courts-circuits intégrés dans les démarreurs autres que des ACPM. Ils sont couverts par l'IEC 60947-2 et l'IEC 60947-3;
- à l'utilisation du produit avec des dispositifs supplémentaires en atmosphères explosives. Elle est spécifiée par la série IEC 60079;
- aux règles de conception de logiciels intégrés¹;
- aux aspects liés à la cybersécurité. Ils sont couverts par la série IEC 62443.

Le présent document a pour objet de fixer:

- a) les caractéristiques du matériel;
- b) les conditions applicables au matériel relativement:
 - 1) à son fonctionnement et son comportement,

¹ À ce sujet, le fabricant est chargé de prendre des mesures de sécurité supplémentaires.

- 2) à ses propriétés diélectriques,
- 3) à son degré de protection,
- 4) à sa construction, y compris les mesures de sécurité contre les chocs électriques, les dangers d'incendie et les dangers mécaniques;
- c) les essais destinés à vérifier si ces conditions sont réalisées, ainsi que les méthodes à adopter pour ces essais;
- d) les renseignements à fournir avec les matériels ou dans la documentation du fabricant.

2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60034-1:2017, *Machines électriques tournantes – Partie 1: Caractéristiques assignées et caractéristiques de fonctionnement*

IEC 60034-12:2016, *Machines électriques tournantes – Partie 12: Caractéristiques de démarrage des moteurs triphasés à induction à cage à une seule vitesse*

IEC 60034-30-1, *Machines électriques tournantes – Partie 30-1: Classes de rendement pour les moteurs à courant alternatif alimentés par le réseau (code IE)*

IEC 60038, *Tensions normales de la CEI*

IEC 60068-2-14:2009, *Essais d'environnement – Partie 2-14: Essais – Essai N: Variation de température*

IEC 60079-14, *Atmosphères explosives – Partie 14: Conception, sélection et construction des installations électriques*

IEC 60085:2007, *Isolation électrique – Evaluation et désignation thermiques*

IEC 60364-1:2005, *Installations électriques à basse tension – Partie 1: Principes fondamentaux, détermination des caractéristiques générales, définitions*

IEC 60364-7-712, *Installations électriques à basse tension – Partie 7-712: Exigences applicables aux installations ou emplacements spéciaux – Installations d'énergie solaire photovoltaïque (PV)*

IEC 60715:2017, *Dimensions de l'appareillage à basse tension – Montage normalisé sur profilés-soutiens pour le support mécanique des appareillages et de leurs accessoires*

IEC 60730-1, *Dispositifs de commande électrique automatiques – Partie 1: Exigences générales*

IEC 60947-1:2007, *Appareillage à basse tension – Partie 1: Règles générales*

IEC 60947-1:2007/AMD1:2010

IEC 60947-1:2007/AMD2:2014

IEC 60947-2:2016, *Appareillage à basse tension – Partie 2: Disjoncteurs*

IEC 60947-5-1:2016, *Appareillage à basse tension – Partie 5-1: Appareils et éléments de commutation pour circuits de commande – Appareils électromécaniques pour circuits de commande*

IEC 61000-6-2, *Compatibilité électromagnétique (CEM) – Partie 6-2: Normes génériques – Norme d'immunité pour les environnements industriels*

IEC 61051-2, *Varistances utilisées dans les équipements électroniques – Deuxième partie: Spécification intermédiaire pour varistances pour limitations de surtensions transitoires*

IEC 61140:2016, *Protection contre les chocs électriques – Aspects communs aux installations et aux matériels*

IEC 61439 (toutes les parties), *Ensembles d'appareillage à basse tension*

IEC 61810-1, *Relais électromécaniques élémentaires – Partie 1: Exigences générales et de sécurité*

CISPR 11:2015, *Appareils industriels, scientifiques et médicaux – Caractéristiques de perturbations radioélectriques – Limites et méthodes de mesure*
CISPR 11:2015/AMD1:2016

ISO 2859-1:1999, *Règles d'échantillonnage pour les contrôles par attributs – Partie 1: Procédures d'échantillonnage pour les contrôles lot par lot, indexés d'après le niveau de qualité acceptable (NQA)*

ISO 3864-2, *Symboles graphiques – Couleurs de sécurité et signaux de sécurité – Partie 2: Principes de conception pour l'étiquetage de sécurité des produits*

3 Termes, définitions, symboles et abréviations

3.1 Généralités

Pour les besoins du présent document, les termes et définitions de l'Article 2 de l'IEC 60947-1:2007/AMD1:2010/AMD2:2014 ainsi que les termes, définitions, symboles et abréviations suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse <http://www.electropedia.org/>
- ISO Online browsing platform: disponible à l'adresse <http://www.iso.org/obp>

3.2 Index alphabétique des termes

Référence

A

accessoire d'accrochage	3.4.33
accessoire de câblage dédié	3.4.32
appareil de connexion de protection des moteurs (abréviation: ACPM)	3.4.31
appareil de connexion protégé	3.4.25
autotransformateur	3.4.4.3

B

bobine d'électro-aimant commandée électroniquement	3.3.8

C

caractéristique I^2t d'un disjoncteur ou d'un ACPM	3.5.6
combiné d'appareils de connexion	3.4.26
combiné de démarrage	3.4.7
condition de premier défaut	3.6.7
conditions anormales de fonctionnement	3.6.1
contact miroir	F.2.1
contacteur (mécanique)	3.3.1
contacteur à accrochage	3.3.5
contacteur électromagnétique	3.3.2
contacteur électropneumatique	3.3.4
contacteur pneumatique	3.3.3
contacteur (ou démarreur) sous vide	3.3.6
courant I_{cd}	3.5.4
courant assigné instantané de réglage de court-circuit (abréviation: I_f)	3.5.7
courant de réglage de surcharge (abréviation: I_r)	3.5.8

D

démarreur	3.4.1
démarreur à deux étapes	3.4.14
démarreur à main	3.4.8
démarreur à n étapes	3.4.15
démarreur à résistances	3.4.5
démarreur à une étape	3.4.13
démarreur actionné par un moteur	3.4.10
démarreur moteur	3.4.1
démarreur direct	3.4.2
démarreur électromagnétique	3.4.9
démarreur électropneumatique	3.4.12
démarreur étoile-triangle	3.4.4.1
démarreur-inverseur	3.4.3
démarreur par autotransformateur	3.4.4.2
démarreur pneumatique	3.4.11
démarreur protégé	3.4.6
démarreur rotorique à résistances	3.4.5.2
démarreur sous tension réduite	3.4.4
démarreur statorique à résistances	3.4.5.1
durée de démarrage (d'un démarreur à résistances)	3.4.19
durée de démarrage (d'un démarreur par autotransformateur)	3.4.20
durée de réarmement	3.5.5

F

fonctionnement CO	3.5.2
fonctionnement O	3.5.3

I

impédance de protection	3.6.5
inversion de marche	3.4.24

M

marche par à-coups	3.4.23
mauvais usage raisonnablement prévisible	3.6.6

O

ouverture galvanique (d'un circuit)	3.5.9

P

partie accessible	3.6.2

partie active dangereuse.....	3.6.3
passage avec coupure du moteur (avec un démarreur étoile-triangle ou par autotransformateur)	3.4.21
passage sans coupure du moteur (avec un démarreur étoile-triangle ou par autotransformateur)	3.4.22
puissance d'appel (d'un contacteur).....	3.3.10
puissance de maintien (d'un contacteur)	3.3.9
position de repos (d'un contacteur)	3.3.7

R

relais (ou déclencheur) de blocage	3.4.28
relais (ou déclencheur) de calage	3.4.27
relais ou déclencheur à minimum de courant	3.4.17
relais ou déclencheur à minimum de tension.....	3.4.18
relais ou déclencheur de surcharge sensible à une perte de phase.....	3.4.16

S

séparation galvanique	3.5.10
source d'énergie limitée	3.6.4
système de gestion de moteurs.....	3.4.30

T

temps d'inhibition.....	3.4.29
tension transitoire de rétablissement (abréviation: TTR)	3.5.1

3.3 Termes et définitions relatifs aux contacteurs

3.3.1

contacteur (mécanique)

appareil mécanique de connexion ayant une seule position de repos, commandé autrement qu'à la main, capable d'établir, de supporter et d'interrompre des courants dans les conditions normales du circuit, y compris les conditions de surcharge en service

Note 1 à l'article: Les contacteurs mécaniques peuvent être désignés suivant la façon dont est fourni l'effort nécessaire à la fermeture des contacts principaux.

Note 2 à l'article: L'expression «commandé autrement qu'à la main» signifie que l'appareil est destiné à être commandé et maintenu en position de fonctionnement à partir d'une ou de plusieurs sources d'énergie extérieures.

Note 3 à l'article: Un contacteur dont les contacts principaux sont fermés dans la position de repos est généralement appelé en français «rupteur». Le mot «rupteur» n'a pas d'équivalent dans la langue anglaise.

Note 4 à l'article: Un contacteur est généralement prévu pour fonctionner fréquemment.

Note 5 à l'article: Un contacteur mécanique peut assurer une ouverture galvanique (3.5.9), mais il n'est pas adapté au sectionnement, sauf si les exigences supplémentaires définies en 8.1.7 sont satisfaites. Dans ce cas, le matériel peut être marqué selon l'IEC 60417-6169-1 «sectionneur; isolateur».

[SOURCE: IEC 60050-441:2000, 441-14-33, modifiée – Terme «mécanique» entre parenthèses; Notes à l'article 2 à 5 ajoutées]

3.3.2

contacteur électromagnétique

contacteur pour lequel l'effort nécessaire à la fermeture des contacts principaux normalement ouverts ou à l'ouverture des contacts principaux normalement fermés est fourni par un électro-aimant

Note 1 à l'article: L'électro-aimant peut être commandé électroniquement.

3.3.3**contacteur pneumatique**

contacteur pour lequel l'effort nécessaire à la fermeture des contacts principaux normalement ouverts ou à l'ouverture des contacts principaux normalement fermés est fourni par un dispositif utilisant de l'air comprimé sans utilisation de moyens électriques

3.3.4**contacteur électropneumatique**

contacteur pour lequel l'effort nécessaire à la fermeture des contacts principaux normalement ouverts ou à l'ouverture des contacts principaux normalement fermés est fourni par un dispositif utilisant de l'air comprimé, la commande s'effectuant au moyen d'électrovalves

3.3.5**contacteur à accrochage**

contacteur muni d'un dispositif d'accrochage empêchant ses éléments mobiles de retourner à leur position de repos quand on cesse d'actionner le dispositif de commande

Note 1 à l'article: L'accrochage et le déclencheur d'accrochage peuvent être mécaniques, électromagnétiques, pneumatiques, etc.

Note 2 à l'article: Du fait de son accrochage, le contacteur à accrochage possède en fait une seconde position de repos et, d'après la définition du contacteur, n'est pas à proprement parler un contacteur. Cependant, étant donné que le contacteur à accrochage, tant par son utilisation que par sa conception, se rapproche davantage d'un contacteur en général que de toute autre sorte d'appareil de connexion, il est admis qu'il réponde aux spécifications des contacteurs dans la mesure du possible.

[SOURCE: IEC 60050-441:2000, 441-14-34]

3.3.6**contacteur (ou démarreur) sous vide**

contacteur (ou démarreur) dont les contacts principaux s'ouvrent et se ferment dans une enceinte où règne un vide poussé

3.3.7**position de repos (d'un contacteur)**

position que prennent les organes mobiles du contacteur quand son électro-aimant ou son dispositif à air comprimé n'est pas alimenté

[SOURCE: IEC 60050-441:2000, 441-16-24]

3.3.8**bobine d'électro-aimant commandée électroniquement**

électro-aimant dont la bobine est commandée par un circuit comprenant des éléments électroniques actifs

3.3.9**puissance de maintien (d'un contacteur)**

puissance nécessaire pour maintenir le fonctionnement de l'électro-aimant

3.3.10**puissance d'appel (d'un contacteur)**

puissance nécessaire pour faire passer le contacteur de l'état non alimenté à l'état alimenté

3.4 Termes et définitions relatives aux démarreurs**3.4.1****démarreur moteur**

combinaison de tous les moyens de mise sous et hors tension nécessaires pour provoquer le démarrage et l'arrêt d'un moteur tout en assurant une protection appropriée contre les surcharges

[SOURCE: IEC 60050-441:2000, 441-14-38, modifiée – «moteur» a été ajouté au terme et la Note 1 à l'article a été supprimée]

3.4.2

démarreur direct

démarreur qui applique la tension d'alimentation sur les bornes du moteur en une seule manœuvre

[SOURCE: IEC 60050-441:2000, 441-14-40]

3.4.3

démarreur-inverseur

démarreur destiné à provoquer l'inversion du sens de rotation d'un moteur par inversion des connexions principales lorsque celui-ci ne tourne pas

Note 1 à l'article: Une application dans laquelle les connexions principales du moteur sont inversées pendant que le moteur tourne est dite à inversion de marche (voir 3.4.24).

3.4.4

démarreur sous tension réduite

démarreur qui applique la tension d'alimentation aux bornes du moteur en plus d'une étape ou par élévation progressive de la tension aux bornes

3.4.4.1

démarreur étoile-triangle

démarreur pour un moteur à induction triphasé tel que les enroulements du stator soient connectés en étoile en position de démarrage et en triangle en position de marche

Note 1 à l'article: Un démarreur étoile-triangle n'est pas prévu pour inverser le sens de marche du moteur tournant et, en conséquence, la catégorie d'emploi AC-4 ne lui est pas applicable.

Note 2 à l'article: Dans la position en étoile, le courant de démarrage en ligne et le couple du moteur sont égaux environ au tiers des valeurs correspondantes dans la position en triangle. En conséquence, les démarreurs étoile-triangle sont utilisés lorsque le courant d'appel provoqué par le démarrage doit être limité ou lorsque la machine entraînée a besoin d'un couple limité pour démarrer. Voir la Figure C.1a) et la Figure C.1b).

[SOURCE: IEC 60050-441:2000, 441-14-44, modifiée – Les Notes à l'article ont été ajoutées]

3.4.4.2

démarreur par autotransformateur

démarreur pour moteur à induction qui utilise pour le démarrage une ou plusieurs tensions réduites prélevées sur un autotransformateur

Note 1 à l'article: Le démarreur par autotransformateur n'est pas prévu pour la marche par à-coups ni pour inverser le sens de marche d'un moteur tournant et, en conséquence, la catégorie d'emploi AC-4 ne lui est pas applicable.

Note 2 à l'article: En position de démarrage, le courant du circuit et le couple occasionné par le démarrage du moteur à la tension assignée sont réduits à peu près comme le carré du rapport (tension de démarrage)/(tension assignée). En conséquence, les démarreurs par autotransformateur sont utilisés lorsque le courant d'appel provoqué par le démarrage doit être limité ou lorsque la machine entraînée a besoin d'un couple limité pour démarrer. Voir la Figure C.2a) et la Figure C.2b).

[SOURCE: IEC 60050-441:2000, 441-14-45, modifiée – Les Notes à l'article ont été ajoutées]

3.4.4.3

autotransformateur

transformateur dont au moins deux enroulements ont une partie commune

[SOURCE: IEC 60050-421:1990, 421-01-11]

3.4.5

démarreur à résistances

démarreur utilisant une ou plusieurs résistances pour obtenir au cours du démarrage des caractéristiques données de couple de démarrage et pour limiter le courant

Note 1 à l'article: Un démarreur à résistances est généralement composé de trois parties principales qui peuvent soit être fournies dans le même ensemble, soit être fournies séparément pour être raccordées entre elles sur le lieu d'utilisation:

- les appareils mécaniques de connexion pour alimentation du stator (généralement associés à un dispositif de protection contre les surcharges);
- la ou les résistances insérées dans le circuit du stator ou du rotor;
- les appareils mécaniques de connexion pour l'élimination successive de la ou des résistances.

Note 2 à l'article: Il s'applique également aux démarreurs à deux sens de rotation lorsque la permutation des connexions s'effectue à l'arrêt.

[SOURCE: IEC 60050-441:2000, 441-14-42, modifiée – Les Notes à l'article ont été ajoutées]

3.4.5.1

démarreur statorique à résistances

démarreur à résistances pour moteur à cage d'écureuil qui, au cours de la période de démarrage, élimine successivement une ou plusieurs résistances préalablement insérées dans le circuit du stator

3.4.5.2

démarreur rotorique à résistances

démarreur à résistances pour moteur asynchrone à rotor bobiné qui, pendant la période de démarrage, élimine successivement une ou plusieurs résistances préalablement insérées dans le circuit du rotor

[SOURCE: IEC 60050-441:2000, 441-14-43]

3.4.6

démarreur protégé

matériel comprenant un démarreur, un appareil de connexion à commande manuelle et un dispositif de protection contre les courts-circuits, caractérisé comme une unité par le fabricant

Note 1 à l'article: Le démarreur protégé peut ou non être sous enveloppe.

Note 2 à l'article: Dans le contexte du présent document, le terme «fabricant» signifie toute personne, entreprise ou organisation ayant la responsabilité ultime:

- de vérifier la conformité à la norme appropriée;
- de fournir les informations sur le matériel selon l'Article 6.

Note 3 à l'article: Un démarreur protégé manuellement en tant qu'unité peut être un ACPM.

3.4.7

combiné de démarrage

matériel comprenant un démarreur protégé incorporant une fonction de sectionnement

Note 1 à l'article: Également appelé «combiné contrôleur de moteur».

Note 2 à l'article: Voir la Figure C.3.

3.4.8

démarreur à main

démarreur pour lequel l'effort nécessaire à la fermeture des contacts principaux est fourni exclusivement par une énergie manuelle

[SOURCE: IEC 60050-441:2000, 441-14-39]

3.4.9**démarreur électromagnétique**

démarreur pour lequel l'effort nécessaire à la fermeture des contacts principaux est fourni par un électro-aimant

3.4.10**démarreur actionné par un moteur**

démarreur pour lequel l'effort nécessaire à la fermeture des contacts principaux est fourni par un moteur électrique

3.4.11**démarreur pneumatique**

démarreur pour lequel l'effort nécessaire à la fermeture des contacts principaux est fourni par de l'air comprimé, sans utilisation de moyens électriques

3.4.12**démarreur électropneumatique**

démarreur pour lequel l'effort nécessaire à la fermeture des contacts principaux est fourni par de l'air comprimé, la commande s'effectuant au moyen d'électrovalves

3.4.13**démarreur à une étape**

démarreur pour lequel il n'existe pas de position intermédiaire d'accélération entre la position ARRÊT et la position MARCHE

Note 1 à l'article: Ce démarreur est un démarreur direct.

3.4.14**démarreur à deux étapes**

démarreur dans lequel il n'existe qu'une seule position intermédiaire d'accélération entre la position ARRÊT et la position MARCHE

EXEMPLE Un démarreur étoile-triangle est un démarreur à deux étapes.

3.4.15**démarreur à n étapes**

démarreur dans lequel il y a $(n-1)$ positions intermédiaires d'accélération entre la position ARRÊT et la position MARCHE

Note 1 à l'article: Voir la Figure C.4.

EXEMPLE Un démarreur à résistances à trois étapes possède deux sections de résistances utilisées pour le démarrage.

[SOURCE: IEC 60050-441:2000, 441-14-41, modifiée – «MARCHE» et «ARRÊT» en majuscules; Exemple et Note 1 à l'article ajoutés]

3.4.16**relais ou déclencheur de surcharge sensible à une perte de phase**

relais ou déclencheur multipolaire de surcharge qui fonctionne en cas de surcharge et aussi dans le cas d'une perte de phase selon des exigences spécifiées

3.4.17**relais ou déclencheur à minimum de courant**

relais de mesure ou déclencheur qui fonctionne automatiquement lorsque le courant qui le traverse devient inférieur à une valeur prédéterminée

3.4.18

relais ou déclencheur à minimum de tension

relais de mesure ou déclencheur qui fonctionne automatiquement lorsque la tension qui lui est appliquée devient inférieure à une valeur prédéterminée

3.4.19

durée de démarrage (d'un démarreur à résistances)

laps de temps pendant lequel les résistances de démarrage ou une partie d'entre elles sont parcourues par du courant

Note 1 à l'article: La durée de démarrage d'un démarreur est plus courte que la durée totale de démarrage du moteur qui tient compte aussi de la dernière période d'accélération suivant la manœuvre de passage en position MARCHE.

3.4.20

durée de démarrage (d'un démarreur par autotransformateur)

laps de temps pendant lequel l'autotransformateur est parcouru par du courant

Note 1 à l'article: La durée de démarrage d'un démarreur est plus courte que la durée totale de démarrage du moteur qui tient compte aussi de la dernière période d'accélération suivant la manœuvre de passage en position MARCHE.

3.4.21

passage avec coupure du moteur (avec un démarreur étoile-triangle ou par autotransformateur)

disposition de circuits telle que le courant dans le moteur est interrompu et rétabli lors du passage d'une étape à une autre

Note 1 à l'article: L'état de passage n'est pas considéré comme une étape supplémentaire.

3.4.22

passage sans coupure du moteur (avec un démarreur étoile-triangle ou par autotransformateur)

disposition de circuits telle que le courant dans le moteur n'est pas interrompu (même momentanément) lors du passage d'une étape à une autre

Note 1 à l'article: L'état de passage n'est pas considéré comme une étape supplémentaire.

3.4.23

marche par à-coups

mise sous tension répétitive, durant de courts intervalles de temps, d'un moteur ou d'un solénoïde, afin de provoquer des mouvements de faible amplitude du mécanisme entraîné

3.4.24

inversion de marche

arrêt ou inversion rapide du sens de rotation d'un moteur par permutation des connexions principales du moteur pendant que celui-ci tourne

3.4.25

appareil de connexion protégé

matériel (pour charges autres que des moteurs) comprenant un contacteur ou un gradateur à semi-conducteurs, une protection contre les surcharges, un appareil de connexion à commande manuelle et un dispositif de protection contre les courts-circuits, caractérisé comme une unité par le fabricant

Note 1 à l'article: L'appareil de connexion protégé peut ou non être sous enveloppe.

Note 2 à l'article: Dans le contexte du présent document, le terme «fabricant» signifie toute personne, entreprise ou organisation ayant la responsabilité ultime:

- de vérifier la conformité à la norme appropriée;
- de fournir les informations sur le matériel selon l'Article 6.

Note 3 à l'article: L'appareil de connexion à commande manuelle et le dispositif de protection contre les courts-circuits peuvent être seulement un appareil et peuvent également incorporer la protection contre les surcharges.

3.4.26

combiné d'appareils de connexion

matériel comprenant un appareil de connexion protégé incorporant une fonction de sectionnement

3.4.27

relais (ou déclencheur) de calage

relais ou déclencheur électronique de surcharge qui fonctionne lorsque le courant n'a pas diminué en dessous d'une valeur prédéterminée pendant un laps de temps spécifique durant le démarrage ou lorsque le relais ou le déclencheur reçoit une information lui indiquant qu'il n'y a pas rotation du moteur après un temps prédéterminé, conformément aux exigences spécifiées

Note 1 à l'article: Explication de calage: rotor bloqué pendant le démarrage.

Note 2 à l'article: Avec le réglage approprié des valeurs de courant et de durée de démarrage, un tel relais ou déclencheur peut être utilisé pour détecter les démarrages exigeant des durées supérieures à celles spécifiées.

3.4.28

relais (ou déclencheur) de blocage

relais ou déclencheur électronique de surcharge qui fonctionne dans le cas d'une surcharge et aussi lorsque le courant a augmenté au-dessus d'une valeur prédéterminée pendant un laps de temps spécifique durant le fonctionnement, conformément aux exigences spécifiées

Note 1 à l'article: Un blocage est une surcharge élevée survenant après achèvement du démarrage qui provoque une augmentation du courant atteignant la valeur correspondant au rotor bloqué du moteur commandé.

3.4.29

temps d'inhibition

temporisation pendant laquelle la fonction de déclenchement du relais est inhibée (peut être réglable)

3.4.30

système de gestion de moteurs

démarrateur incluant des fonctions étendues avec possibilité de communication

Note 1 à l'article: Des profils d'appareils interopérables pour le système de gestion de moteurs sont définis dans l'IEC 61915-2:2011.

3.4.31

appareil de connexion de protection des moteurs

ACPM

démarrateur moteur à commande manuelle assurant en plus une protection réarmable contre les courts-circuits du moteur et du circuit

Note 1 à l'article: Un ACPM peut également être utilisé comme démarreur à main, démarreur protégé ou combiné de démarrage.

Note 2 à l'article: Un ACPM peut être utilisé comme DPCC dans la branche du moteur.

Note 3 à l'article: En Amérique du Nord, cet appareil est appelé contrôleur de moteur manuel, apte à la protection du conducteur dérivé.

3.4.32

accessoire de câblage dédié

système de câble à connexion préfabriquée spécifiquement destiné aux appareillages identifiés

Note 1 à l'article: Un accessoire de câblage dédié peut être intégré dans l'appareillage ou livré séparément.

Note 2 à l'article: Une barrette de couplage est un accessoire de câblage dédié.

3.4.33

accessoire d'accrochage

dispositif mécanique fixé à un contacteur dont les éléments mobiles sont dans l'impossibilité de retourner à leur position de repos quand on cesse d'actionner le dispositif de commande

Note 1 à l'article: L'accrochage et le déclencheur d'accrochage peuvent être mécaniques, électromagnétiques, pneumatiques, etc.

[SOURCE: IEC 60050-441:2000, 441-14-34, modifiée – Adaptée aux accessoires, Note 2 à l'article supprimée]

3.5 Termes et définitions concernant les grandeurs caractéristiques

3.5.1

tension transitoire de rétablissement

TTR

tension de rétablissement pendant la durée où elle présente un caractère transitoire appréciable

Note 1 à l'article: Pour un contacteur ou un démarreur sous vide, la tension de rétablissement la plus élevée peut apparaître sur un autre pôle que le premier pôle qui coupe.

[SOURCE: IEC 60947-1:2007, 2.5.34, modifiée – La Note 1 à l'article a été modifiée]

3.5.2

fonctionnement CO

interruption du circuit par le DPCC résultant de la fermeture du circuit par le matériel en essai

3.5.3

fonctionnement O

interruption du circuit par le DPCC résultant de la fermeture du circuit par le matériel en essai qui est en position de fermeture

Note 1 à l'article: Le DPCC est normalement en position de fermeture avant de fermer le circuit; dans certains cas, le DPCC doit fermer le circuit (voir 9.3.4.2.2, point b)).

3.5.4

courant I_{cd}

courant représentant un courant de défaut supérieur ou égal au courant correspondant au point d'intersection de la valeur moyenne des courbes publiées représentant respectivement les caractéristiques temps-courant du relais de surcharge et du DPCC

3.5.5

durée de réarmement

temps écoulé entre le déclenchement du disjoncteur (ACPM) provoqué par une surintensité et l'instant où les conditions sont atteintes pour qu'il puisse être refermé

[SOURCE: IEC 60947-2:2016, 2.19, modifiée – Insertion de «(ACPM)» dans la définition]

3.5.6

caractéristique I^2t d'un disjoncteur ou d'un ACPM

information (généralement une courbe) donnant les valeurs maximales de I^2t correspondant à la durée de coupure en fonction du courant présumé (valeur efficace de la composante périodique en courant alternatif) jusqu'à la valeur maximale du courant présumé correspondant au pouvoir assigné de coupure de service en court-circuit à la tension correspondante

[SOURCE: IEC 60947-2:2016, 2.18, modifiée – «ou d'un ACPM» inséré dans le terme]

3.5.7**courant assigné instantané de réglage de court-circuit** I_i

valeur assignée du courant provoquant le fonctionnement d'un déclencheur sans retard intentionnel

[SOURCE: IEC 60947-2:2016, 2.20]

3.5.8**courant de réglage de surcharge** I_r

courant de réglage pour un déclencheur de surcharge réglable

[SOURCE: IEC 60947-2:2016, 2.21, modifiée – La Note 1 à l'article a été supprimée]

3.5.9**ouverture galvanique (d'un circuit)**

action ou moyen d'empêcher la conduction électrique dans un circuit électrique prévu pour fournir la puissance et/ou des signaux

Note 1 à l'article: Une ouverture galvanique peut être obtenue, par exemple, au moyen d'un commutateur ou d'un contacteur.

3.5.10**séparation galvanique**

action ou moyen d'empêcher la conduction électrique entre deux circuits électriques prévus pour échanger de la puissance ou des signaux

Note 1 à l'article: Une séparation galvanique peut être obtenue, par exemple, au moyen d'un transformateur de séparation (de circuits) ou d'un optocoupleur.

[SOURCE: IEC 60050-151:2001, 151-12-26]

3.6 Termes et définitions relatifs aux aspects liés à la sécurité**3.6.1****conditions anormales de fonctionnement**

conditions temporaires de fonctionnement qui ne sont ni les conditions normales de fonctionnement ni les conditions de premier défaut du matériel proprement dit

Note 1 à l'article: Une condition anormale de fonctionnement est une condition temporaire qui peut être introduite par le matériel ou par une personne, et qui peut se traduire par la défaillance d'un composant, d'un appareil ou d'une protection.

Note 2 à l'article: Cette définition est utilisée dans le contexte d'une analyse des risques de défaillance d'un composant.

3.6.2**partie accessible**

partie pouvant être touchée au moyen du doigt d'épreuve normalisé

[SOURCE: IEC 60050-442:1998, 442-01-15]

3.6.3**partie active dangereuse**

partie active qui peut provoquer, dans certaines conditions, un choc électrique nuisible

[SOURCE: IEC 60050-195:1998, 195-06-05]

3.6.4

source d'énergie limitée

source conçue et protégée de manière à ce que, dans des conditions normales de fonctionnement et dans des conditions de premier défaut, le courant qui peut être délivré ne soit pas dangereux eu égard aux dangers d'incendie

3.6.5

impédance de protection

impédance connectée entre des parties actives dangereuses et des parties conductrices accessibles, d'une valeur telle que le courant, en condition normale d'utilisation et sous des conditions de défaut vraisemblables, est limité à une valeur de sécurité, et qui est construite de telle sorte que sa fiabilité est maintenue tout au long de la durée de vie du matériel

[SOURCE: IEC 62477-1:2012, 3.42]

3.6.6

mauvais usage raisonnablement prévisible

utilisation d'un produit ou d'un système dans des conditions ou à des fins non prévues par le fournisseur, mais qui peut provenir d'un comportement humain envisageable

[SOURCE: ISO/IEC Guide 51:2014, 3.7, modifiée – Les Notes à l'article ont été supprimées]

3.6.7

condition de premier défaut

condition dans laquelle il existe un défaut d'une protection simple (mais pas d'une protection renforcée) d'un composant ou d'un appareil unique

Note 1 à l'article: Si une condition de premier défaut engendre une ou plusieurs autres conditions de défaut, toutes sont considérées comme une seule condition de premier défaut.

3.7 Symboles et abréviations

NQA	Niveau de qualité acceptable
CEM	Compatibilité électromagnétique
DPCC	Dispositif de protection contre les courts-circuits
$\hat{I}$	Valeur crête maximale du courant d'attraction d'une bobine d'électro-aimant commandée électroniquement
I_c	Courant établi et coupé (Tableau 7)
I_{cs}	Pouvoir de coupure de service en court-circuit assigné (5.3.6.2)
I_{cs}	Pouvoir de coupure ultime en court-circuit assigné (5.3.6.1)
I_e	Courant assigné d'emploi (5.3.2.5)
I_{er}	Courant assigné rotorique d'emploi (5.3.2.7)
I_{es}	Courant assigné statorique d'emploi (5.3.2.6)
I_i	Courant de réglage de court-circuit instantané
I_{IT}	Courant d'essai de court-circuit pour schéma de mise à la terre de type IT
I_q	Courant maximal d'essai de court-circuit conditionnel
I_{th}	Courant thermique conventionnel à l'air libre (5.3.2.1)
I_{the}	Courant thermique conventionnel sous enveloppe (5.3.2.2)
I_{thr}	Courant thermique conventionnel rotorique (5.3.2.4)
I_{ths}	Courant thermique conventionnel statorique (5.3.2.3)
I_u	Courant assigné ininterrompu (5.3.2.8)

P_c	Puissance nominale de maintien/d'appel d'un électro-aimant conventionnel commandé par un courant continu ou puissance de maintien d'un électro-aimant commandé électroniquement par un courant continu
P_p	Puissance d'appel d'un contacteur commandé par un courant continu avec enroulements séparés d'appel et de maintien
«r»	Courant minimal d'essai de court-circuit
S_h	Puissance de maintien d'un électro-aimant commandé par un courant alternatif
S_p	Puissance d'appel d'un électro-aimant commandé par un courant alternatif
T_p	Temps de déclenchement (Tableau 2)
U_c	Tension assignée du circuit de commande (5.5)
U_d	Chute de tension d'un pôle de contacteur
U_e	Tension assignée d'emploi (5.3.1.1)
U_{er}	Tension assignée rotorique d'emploi (5.3.1.1.3)
U_{es}	Tension assignée statorique d'emploi (5.3.1.1.2)
U_i	Tension assignée d'isolement (5.3.1.2)
U_{imp}	Tension assignée de tenue aux chocs (5.3.1.3)
U_{ir}	Tension assignée rotorique d'isolement (5.3.1.2.3)
U_{is}	Tension assignée statorique d'isolement (5.3.1.2.2)
U_r	Tension de rétablissement à fréquence industrielle ou en courant continu (Tableau 7)
U_s	Tension d'alimentation assignée du circuit de commande (5.5)
Z	Impédance de pôle d'un contacteur (5.3.7)

4 Classification

Le 5.2 donne toutes les données qui peuvent servir de critères de classification.

5 Caractéristiques des contacteurs et des démarreurs

5.1 Énumération des caractéristiques

Les caractéristiques d'un contacteur ou d'un démarreur doivent, chaque fois que cela est possible, être indiquées de la façon suivante:

- type du matériel (5.2);
- valeurs assignées et valeurs limites des circuits principaux (5.3);

NOTE 1 Les valeurs assignées relatives à un démarreur rotorique à résistances sont indiquées conformément à 5.3.1.1.2, 5.3.1.1.3, 5.3.1.2.2, 5.3.1.2.3, 5.3.2.3, 5.3.2.4, 5.3.2.6, 5.3.2.7 et 5.3.5.6, mais il n'est pas nécessaire de spécifier toutes les valeurs énumérées.

- catégorie d'emploi (5.4);
- circuits de commande (5.5);
- circuits auxiliaires (5.6);
- types et caractéristiques des relais et des déclencheurs (5.7);
- coordination avec les dispositifs de protection contre les courts-circuits (5.8);
- types et caractéristiques des appareils de commande automatique de commutation et des appareils de commande automatique d'accélération (5.10);
- types et caractéristiques des autotransformateurs des démarreurs par autotransformateur à deux étapes (5.11);

- types et caractéristiques des résistances de démarrage pour démarreurs rotoriques à résistances (5.12);
- points faisant l'objet d'un accord entre le fabricant et l'utilisateur; voir l'Annexe D.

Pour les échanges d'informations au format électronique (catalogue électronique, par exemple), l'IEC 62683-1 donne le format de données des caractéristiques essentielles des démarreurs moteurs, des contacteurs et de leurs accessoires.

NOTE 2 Dans le cas d'un démarreur étoile-triangle, ces courants se rapportent à la position en triangle et, dans le cas d'un démarreur par autotransformateur à deux étapes ou d'un démarreur rotorique à résistances, à la position MARCHE.

5.2 Type du matériel

5.2.1 Nature du matériel

- contacteur;
- démarreur direct en courant alternatif;
- démarreur étoile-triangle;
- démarreur par autotransformateur à deux étapes;
- démarreur rotorique à résistances;
- combiné de démarrage ou démarreur protégé.

5.2.2 Nombre de pôles

5.2.3 Nature du courant (alternatif ou continu)

5.2.4 Milieu de coupure (air, huile, gaz, vide, etc.)

5.2.5 Conditions de fonctionnement du matériel

5.2.5.1 Méthode de fonctionnement

Par exemple: manuel, électromagnétique, commande par moteur, pneumatique, électropneumatique.

5.2.5.2 Mode de commande

Par exemple:

- automatique (par auxiliaire automatique de commande ou commande séquentielle);
- non automatique (telle que commande manuelle ou par boutons-poussoirs);
- semi-automatique (c'est-à-dire en partie automatique, en partie non automatique).

5.2.5.3 Mode de commutation pour des types particuliers de démarreurs

La commutation pour les démarreurs étoile-triangle, les démarreurs rotoriques à résistances ou les démarreurs par autotransformateur peut être automatique, non automatique ou semi-automatique (voir Figure C.4 et Figure C.5).

5.2.5.4 Mode de connexion pour des types particuliers de démarreurs

Par exemple: démarreur avec coupure du moteur, démarreur sans coupure du moteur (voir Figure C.5).

5.3 Valeurs assignées et valeurs limites des circuits principaux

5.3.1 Tensions assignées

5.3.1.1 Tension assignée d'emploi (U_e)

5.3.1.1.1 Généralités

Le 4.3.1.1 de l'IEC 60947-1:2007 s'applique.

La valeur de la tension assignée d'emploi doit clairement indiquer pour quel système triphasé (en étoile ou en triangle) elle est valable, selon l'IEC 60038 (230/400 V ou 400 V (50 Hz), 277/480 V ou 480 V (60 Hz), par exemple). Lorsqu'elles sont exprimées dans le format X/Y V, la valeur la plus faible est la tension efficace par rapport au neutre, et la plus élevée est la tension efficace entre phases. Lorsqu'une seule valeur est indiquée, il s'agit de la tension efficace entre phases et neutre.

5.3.1.1.2 Tension assignée statorique d'emploi (U_{es})

Une tension assignée statorique d'emploi d'un démarreur rotorique à résistances est une valeur de tension qui, combinée avec un courant assigné statorique d'emploi, détermine l'emploi du circuit statorique, y compris ses appareils mécaniques de connexion, et à laquelle se rapportent les pouvoirs de fermeture et de coupure, le type de service et les caractéristiques de démarrage. En aucun cas la tension assignée statorique d'emploi maximale ne doit être supérieure à la tension assignée d'isolement correspondante.

NOTE La tension assignée statorique d'emploi s'exprime par la tension entre phases.

5.3.1.1.3 Tension assignée rotorique d'emploi (U_{er})

Pour les démarreurs rotoriques à résistances, la valeur de la tension assignée rotorique d'emploi est celle de la tension qui, combinée avec un courant assigné rotorique d'emploi, détermine l'emploi du circuit rotorique, y compris ses appareils mécaniques de connexion, et à laquelle se rapportent les pouvoirs de fermeture et de coupure, le type de service et les caractéristiques de démarrage.

Cette tension est prise égale à la tension mesurée entre bagues, le moteur étant arrêté et le circuit du rotor étant ouvert, le stator étant alimenté à sa tension assignée.

La tension assignée d'isolement des appareils de connexion insérés dans le circuit du rotor doit être au moins égale à 50 % de la tension la plus élevée entre bagues ouvertes.

NOTE Dans le rotor, les contraintes électriques sont plus petites et plus courtes que dans le stator.

La tension assignée rotorique d'emploi n'est appliquée que pendant un court laps de temps durant la période de démarrage. C'est pourquoi il est admis que la tension assignée rotorique d'emploi excède de 100 % la tension assignée rotorique d'isolement.

La tension maximale entre les différentes parties actives (par exemple, les appareils de connexion, les résistances, les connexions, etc.) du circuit rotorique du démarreur varie, et ce fait peut être pris en considération lors du choix du matériel et de sa disposition.

5.3.1.2 Tension assignée d'isolement (U_i)

5.3.1.2.1 Généralités

Le 4.3.1.2 de l'IEC 60947-1:2007 s'applique.

5.3.1.2.2 Tension assignée statorique d'isolement (U_{is})

La tension assignée statorique d'isolement d'un démarreur rotorique à résistances est la valeur de la tension qui est prévue pour les appareils placés dans l'alimentation du stator et l'ensemble dont ils font partie, et à laquelle se rapportent les essais diélectriques et les lignes de fuite.

Sauf indication contraire, la tension assignée statorique d'isolement est la valeur de la tension assignée statorique d'emploi la plus élevée du démarreur.

5.3.1.2.3 Tension assignée rotorique d'isolement (U_{ir})

Pour les démarreurs rotoriques à résistances, la tension assignée rotorique d'isolement est la valeur de la tension qui sert à désigner les appareils placés dans le circuit du rotor et l'ensemble dont ils font partie (conducteurs de liaison, résistances, enveloppe) et à laquelle se rapportent les essais diélectriques et les lignes de fuite.

5.3.1.3 Tension assignée de tenue aux chocs (U_{imp})

Le 4.3.1.3 de l'IEC 60947-1:2007 s'applique.

5.3.1.4 Tension assignée de démarrage d'un démarreur par autotransformateur

La tension assignée de démarrage d'un démarreur par autotransformateur est la tension réduite prélevée sur le transformateur.

Les valeurs préférentielles de la tension assignée de démarrage sont 50 %, 65 % ou 80 % de la tension assignée d'emploi.

5.3.2 Courants ou puissances

5.3.2.1 Courant thermique conventionnel à l'air libre (I_{th})

Le 4.3.2.1 de l'IEC 60947-1:2007 s'applique.

5.3.2.2 Courant thermique conventionnel sous enveloppe (I_{the})

Le 4.3.2.2 de l'IEC 60947-1:2007 s'applique.

5.3.2.3 Courant thermique conventionnel statorique (I_{ths})

Le courant thermique conventionnel statorique d'un démarreur peut être soit un courant à l'air libre I_{ths} soit un courant sous enveloppe I_{thes} , conformément à 5.3.2.1 et 5.3.2.2.

Pour un démarreur rotorique à résistances, le courant thermique statorique est le courant maximal qu'il peut supporter en service de 8 h (voir 5.3.4.1) sans que l'échauffement de ses diverses parties dépasse les limites spécifiées en 8.2.2 quand l'appareil est soumis à l'essai conformément à 9.3.3.3.

5.3.2.4 Courant thermique conventionnel rotorique (I_{thr})

Le courant thermique conventionnel rotorique d'un démarreur peut être soit un courant à l'air libre I_{thr} soit un courant sous enveloppe I_{ther} , conformément à 5.3.2.1 et 5.3.2.2.

Le courant thermique rotorique d'un démarreur rotorique à résistances est le courant maximal que les éléments du démarreur parcourus par le courant rotorique en position MARCHE, c'est-à-dire après élimination des résistances, peuvent supporter en service de 8 h (voir 5.3.4.1) sans que l'échauffement de ces éléments dépasse les limites spécifiées en 8.2.2 quand l'appareil est soumis à l'essai conformément à 9.3.3.3.

NOTE 1 Pour les éléments (appareils de connexion, conducteurs de liaison, résistances) qui sont parcourus par un courant pratiquement nul en position MARCHE, il peut être vérifié que, pour les services assignés (voir 5.3.4) indiqués par le fabricant, la valeur de l'intégrale

$$\int_0^t i^2 dt$$

ne conduit pas à des échauffements supérieurs à ceux prévus en 8.2.2.

NOTE 2 Lorsque les résistances sont incorporées au démarreur, l'échauffement peut être pris en compte.

5.3.2.5 Courants assignés d'emploi (I_e) ou puissances assignées d'emploi

Le courant assigné d'emploi d'un contacteur ou d'un démarreur est défini par le fabricant et tient compte de la tension assignée d'emploi (voir 5.3.1.1), du courant thermique conventionnel à l'air libre ou sous enveloppe, du courant assigné du relais de surcharge, de la fréquence assignée (voir 5.3.3), du service assigné (voir 5.3.4), de la catégorie d'emploi (voir 5.4) et du type d'enveloppe de protection, s'il y a lieu.

Dans le cas de matériels pour commande directe d'un seul moteur, l'indication d'un courant assigné d'emploi peut être remplacée ou complétée par celle de la puissance assignée maximale disponible, à la tension assignée d'emploi prise en considération, du moteur pour lequel le matériel est prévu. Le fabricant doit être en mesure de préciser la relation qui est admise entre le courant et la puissance.

NOTE L'Annexe G donne des valeurs concernant la relation entre les courants assignés d'emploi et les puissances assignées d'emploi.

Pour les démarreurs, le courant assigné d'emploi (I_e) est le courant des démarreurs en position MARCHE.

5.3.2.6 Courant assigné statorique d'emploi (I_{es}) ou puissance assignée statorique d'emploi

Un courant assigné statorique d'emploi d'un démarreur rotorique à résistances est défini par le fabricant et tient compte du courant assigné du relais de surcharge installé dans ce démarreur, de la tension assignée statorique d'emploi (voir 5.3.1.1.1), du courant thermique conventionnel à l'air libre ou sous enveloppe, de la fréquence assignée (voir 5.3.3), du service assigné (voir 5.3.4), des caractéristiques de démarrage (voir 5.3.5.6) et du type d'enveloppe de protection.

L'indication d'un courant assigné statorique d'emploi peut être remplacée par celle de la puissance assignée maximale disponible, à la tension assignée statorique d'emploi prise en considération, du moteur pour lequel les éléments statoriques du démarreur sont prévus. Le fabricant doit être en mesure de préciser la relation qui est admise entre la puissance du moteur et le courant statorique.

5.3.2.7 Courant assigné rotorique d'emploi (I_{er})

Le courant assigné rotorique d'emploi d'un démarreur rotorique à résistances est défini par le fabricant et tient compte de la tension assignée rotorique d'emploi (voir 5.3.1.1.2), du courant thermique conventionnel rotorique à l'air libre ou sous enveloppe, de la fréquence assignée (voir 5.3.3), du service assigné (voir 5.3.4), des caractéristiques de démarrage (voir 5.3.5.6) et du type d'enveloppe de protection.

Il est pris égal au courant qui parcourt les connexions au rotor quand ce dernier est court-circuité, que le moteur tourne à sa pleine charge et que le stator est alimenté à sa tension assignée et à sa fréquence assignée.

Si la partie rotorique d'un démarreur rotorique à résistances présente des caractéristiques assignées distinctes, l'indication d'un courant assigné rotorique d'emploi peut être complétée par celle de la puissance assignée maximale disponible, pour des moteurs de la tension assignée rotorique d'emploi prise en considération, du moteur pour lequel cette partie du démarreur (appareils de connexion, conducteurs de liaison, relais, résistances) est prévue. Cette puissance varie notamment en fonction du couple de démarrage prévu et tient compte en conséquence des caractéristiques de démarrage (voir 5.3.5.6).

5.3.2.8 Courant assigné ininterrompu (I_U)

Le 4.3.2.4 de l'IEC 60947-1:2007 s'applique.

5.3.3 Fréquence assignée

Le 4.3.3 de l'IEC 60947-1:2007 s'applique.

5.3.4 Services assignés

5.3.4.1 Service de huit heures (service continu)

Le 4.3.4.1 de l'IEC 60947-1:2007 s'applique avec les ajouts suivants:

Pour un démarreur étoile-triangle, un démarreur par autotransformateur à deux étapes ou un démarreur rotorique à résistances, le service continu est le service dans lequel le démarreur est dans la position MARCHE et les contacts principaux des appareils de connexion le constituant, qui sont fermés dans cette position, demeurent fermés, chacun d'eux étant parcouru par un courant constant pendant une durée assez longue pour que le démarreur atteigne l'équilibre thermique, cette durée ne dépassant pas 8 h sans interruption.

5.3.4.2 Service ininterrompu

Le 4.3.4.2 de l'IEC 60947-1:2007 s'applique avec les ajouts suivants.

Pour un démarreur étoile-triangle, un démarreur par autotransformateur à deux étapes ou un démarreur rotorique à résistances, le service ininterrompu est le service dans lequel le démarreur est dans la position MARCHE et les contacts principaux des appareils de connexion le constituant, qui sont fermés dans cette position, demeurent fermés sans interruption, chacun d'eux étant parcouru par un courant constant pendant des durées supérieures à 8 h (des semaines, des mois ou même des années).

5.3.4.3 Service intermittent périodique ou service intermittent

Le 4.3.4.3 de l'IEC 60947-1:2007 s'applique avec les ajouts suivants.

Pour un démarreur sous tension réduite, le service intermittent est le service dans lequel le démarreur est dans la position MARCHE et les contacts principaux des appareils de connexion le constituant demeurent fermés pendant des durées ayant une relation définie par rapport aux durées pendant lesquelles ils ne sont parcourus par aucun courant, chacune de ces durées étant trop courte pour permettre au démarreur d'atteindre l'équilibre thermique.

Les classes préférentielles de service intermittent sont:

- pour les contacteurs: 1, 3, 12, 30, 120, 300 et 1 200 (cycles de manœuvres par heure);
- pour les démarreurs: 1, 3, 12 et 30 (cycles de manœuvres par heure).

Il est rappelé qu'un cycle de manœuvres est un cycle complet de fonctionnement comprenant une fermeture et une ouverture.

Pour les démarreurs, un cycle de manœuvres comprend le démarrage, le fonctionnement à pleine vitesse et la mise hors tension du moteur.

NOTE Dans le cas de démarreurs pour service intermittent, la différence entre la constante de temps thermique du relais de surcharge et celle du moteur peut rendre un relais thermique mal adapté à la protection contre les surcharges. Pour les installations prévues pour un service intermittent, la question de la protection contre les surcharges fait l'objet d'un accord entre le fabricant et l'utilisateur.

5.3.4.4 Service temporaire

Le 4.3.4.4 de l'IEC 60947-1:2007 s'applique.

5.3.4.5 Service périodique

Le 4.3.4.5 de l'IEC 60947-1:2007 s'applique.

5.3.5 Caractéristiques en conditions normales de charge et de surcharge

5.3.5.1 Généralités

Le 4.3.5 de l'IEC 60947-1:2007 s'applique avec les ajouts suivants:

5.3.5.2 Aptitude à supporter les courants de surcharge occasionnés par le démarrage de moteurs

Les exigences à satisfaire sont données en 8.2.4.4 pour les contacteurs.

5.3.5.3 Pouvoir assigné de fermeture

Les exigences concernant les différentes catégories d'emploi (voir 5.4) sont données en 8.2.4.1. Les pouvoirs assignés de fermeture et de coupure ne sont valables que lorsque le contacteur ou le démarreur fonctionne suivant les exigences de 8.2.1.1 et 8.2.1.2.

5.3.5.4 Pouvoir assigné de coupure

Les exigences concernant les différentes catégories d'emploi (voir 5.4) sont données en 8.2.4.1. Les pouvoirs assignés de fermeture et de coupure ne sont valables que lorsque le contacteur ou le démarreur fonctionne suivant les exigences de 8.2.1.1 et 8.2.1.2.

5.3.5.5 Fonctionnement conventionnel en service

Ce fonctionnement est spécifié en 8.2.4.2 comme étant une série de manœuvres d'établissement et de coupure.

5.3.5.6 Caractéristiques de démarrage et d'arrêt des démarreurs (voir la Figure C.6)

5.3.5.6.1 Généralités

Les conditions représentatives de service des démarreurs sont:

- a) un sens de rotation avec coupure du moteur lancé en conditions normales de service (catégories d'emploi AC-2, AC-3 et AC-3e);
- b) deux sens de rotation, mais la marche dans le deuxième sens n'est réalisée qu'après la mise hors tension du démarreur et l'arrêt complet du moteur (catégories d'emploi AC-2, AC-3 et AC-3e);
- c) un sens de rotation ou deux sens de rotation comme au point b), mais avec la possibilité de marche par à-coups peu fréquente. Pour cette condition de service, des démarreurs directs sont souvent utilisés (catégorie d'emploi AC-3 et AC-3e);
- d) un sens de rotation avec de fréquentes marches par à-coups. Pour ce service, des démarreurs directs sont souvent utilisés (catégorie d'emploi AC-4);

- e) un ou deux sens de rotation, mais avec la possibilité d'inversions de marche peu fréquentes pour arrêter le moteur, l'inversion de marche étant accompagnée d'un freinage par résistance rotorique lorsque celle-ci existe (démarreur-inverseur avec freinage). Un démarreur rotorique à résistances est souvent utilisé pour cette condition de service (catégorie d'emploi AC-2);
- f) deux sens de rotation, mais avec la possibilité d'inversion des connexions d'alimentation du moteur pendant qu'il tourne dans le premier sens (marche par à-coups), afin d'assurer sa rotation dans l'autre sens, avec mise hors tension du moteur lancé en conditions normales de service. Pour cette condition de service, un démarreur-inverseur direct moteur en marche est souvent utilisé (catégorie d'emploi AC-4).

Sauf indication contraire, les démarreurs sont conçus en fonction des caractéristiques de démarrage des moteurs compatibles avec les pouvoirs de fermeture du Tableau 7. Ces pouvoirs de fermeture couvrent à la fois les courants de démarrage transitoires et en régime établi de la grande majorité des moteurs normaux. Cependant, les courants de démarrage pour quelques gros moteurs peuvent atteindre des valeurs de crête correspondant à des facteurs de puissance beaucoup plus bas que ceux spécifiés pour le circuit d'essai du Tableau 7. Dans de tels cas, il convient de réduire le courant d'emploi du contacteur ou du démarreur pour qu'il atteigne une valeur plus basse que sa valeur assignée et telle que le pouvoir de fermeture du contacteur ou du démarreur ne soit pas dépassé.

5.3.5.6.2 Caractéristiques de démarrage des démarreurs rotoriques à résistances

Une distinction doit être faite entre les courants et tensions dans les circuits du stator et du rotor des moteurs à bagues. Cependant, les modifications des valeurs du courant dans les circuits du stator et du rotor, causées par les différentes étapes du démarrage, sont presque proportionnelles dans les conditions normales de fonctionnement.

Les définitions qui suivent traitent surtout des caractéristiques du circuit du rotor:

U_{er} est la tension assignée rotorique d'emploi;

I_{er} est le courant assigné rotorique d'emploi;

Z_r est l'impédance caractéristique du rotor d'un moteur à induction à bagues à courant alternatif;

où

$$Z_r = \frac{U_{er}}{\sqrt{3} \times I_{er}} ;$$

I_1 est le courant dans le circuit du rotor immédiatement avant qu'une section des résistances soit court-circuitée;

I_2 est le courant dans le circuit du rotor immédiatement après qu'une section des résistances soit court-circuitée;

$I_m = 1/2 (I_1 + I_2)$;

T_e est le couple assigné de fonctionnement du moteur;

t_s est la durée de démarrage;

k est la sévérité du démarrage = $\frac{I_m}{I_{er}}$.

Il est reconnu que, pour de nombreuses applications, les exigences de démarrage des démarreurs rotoriques à résistances sont très spécifiques et peuvent se traduire non seulement par des nombres différents d'étapes de démarrage et différentes valeurs de I_1 et I_2 , mais aussi par des valeurs de I_1 et I_2 qui peuvent être différentes pour les sections de résistances elles-mêmes. Aucune tentative d'établissement des paramètres normaux n'a été réalisée, mais il convient de tenir compte des facteurs suivants:

- deux à six étapes de démarrage conviennent à la plupart des applications en fonction du couple de charge, de l'inertie et de la sévérité de démarrage exigés;
- il convient que les sections de résistances aient, de préférence, des caractéristiques thermiques assignées tenant compte de la durée de démarrage de l'entraînement, qui dépend du couple et de l'inertie de la charge.

5.3.5.6.3 Conditions normales de fermeture et de coupure correspondant aux caractéristiques de démarrage des démarreurs rotoriques à résistances

Ces conditions sont données dans le Tableau 7 et sont relatives au démarrage à fort couple (en ce qui concerne la désignation des appareils mécaniques de connexion, voir la Figure C.4).

Les conditions de fermeture et de coupure données dans le Tableau 7 pour la catégorie d'emploi AC-2 sont considérées comme des conditions normales.

Le circuit du démarreur doit être conçu de façon à ouvrir tous les appareils de connexion des résistances du rotor avant ou à peu près en même temps que l'ouverture de l'appareil de connexion du stator. Sinon, l'appareil de connexion du stator doit satisfaire aux exigences des catégories d'emploi AC-3 et AC-3e.

5.3.5.6.4 Caractéristiques de démarrage des démarreurs par autotransformateur à deux étapes

Sauf indication contraire, la conception des démarreurs par autotransformateur (et plus particulièrement des autotransformateurs) repose sur l'hypothèse d'une durée de démarrage pour toutes les classes de service (voir 5.3.4) qui ne doit pas dépasser 15 s. Par hypothèse, le nombre de cycles de démarrage par heure s'effectue à des intervalles de temps égaux entre les démarrages. Toutefois, dans le cas de deux cycles de manœuvres effectués très rapidement l'un après l'autre, le démarreur et l'autotransformateur doivent être en mesure de revenir à la température de l'air ambiant avant d'effectuer un autre démarrage.

Si une durée de démarrage supérieure à 15 s est exigée, cela doit faire l'objet d'un accord entre le fabricant et l'utilisateur.

5.3.6 Caractéristiques de court-circuit

5.3.6.1 Pouvoir de coupure ultime en court-circuit assigné d'un ACPM (I_{cu})

Le pouvoir de coupure ultime en court-circuit assigné d'un ACPM est la valeur du pouvoir de coupure ultime en court-circuit que le fabricant assigne à cet ACPM pour la tension assignée d'emploi correspondante, dans les conditions spécifiées à l'Article P.3. Il s'agit de la valeur du courant coupé présumé, en kA (valeur efficace du composant en courant alternatif dans le cas du courant alternatif).

5.3.6.2 Pouvoir de coupure de service en court-circuit assigné d'un ACPM (I_{cs})

Le pouvoir de coupure de service en court-circuit assigné d'un ACPM est la valeur du pouvoir de coupure de service en court-circuit que le fabricant assigne à cet ACPM pour la tension assignée d'emploi correspondante U_e , dans les conditions spécifiées à l'Article P.2. Il s'agit d'une valeur du courant coupé présumé, en kA ou en % de I_{cu} (par exemple $I_{cs} = 25 \% I_{cu}$).

I_{cs} doit être au moins égal à 25 % de I_{cu} .

5.3.6.3 Courant assigné de court-circuit conditionnel

Le 4.3.6.4 de l'IEC 60947-1:2007/AMD2:2014 s'applique.

5.3.7 Impédance de pôle d'un contacteur (Z)

L'impédance de pôle peut être spécifiée par le fabricant. Elle est déterminée en mesurant la chute de tension résultant du passage du courant à travers le pôle.

5.4 Catégorie d'emploi

5.4.1 Généralités

Le 4.4 de l'IEC 60947-1:2007 s'applique avec les ajouts suivants:

Pour les contacteurs et les démarreurs, les catégories d'emploi énumérées dans le Tableau 1 sont considérées comme normales. Tout autre type d'emploi doit faire l'objet d'un accord entre le fabricant et l'utilisateur, mais les renseignements donnés dans le catalogue ou l'offre du fabricant peuvent constituer un tel accord.

Chaque catégorie d'emploi est caractérisée par les valeurs des courants, des tensions, des facteurs de puissance ou des constantes de temps et des autres données du Tableau 7 et du Tableau 10, ainsi que par les conditions d'essai spécifiées dans le présent document.

Pour les contacteurs ou les démarreurs définis par leur catégorie d'emploi, il est donc inutile de spécifier séparément les pouvoirs assignés de fermeture et de coupure puisque ces valeurs dépendent directement de la catégorie d'emploi (voir le Tableau 7).

Pour toutes les catégories d'emploi, la tension est la tension assignée d'emploi dans le cas d'un contacteur ou d'un démarreur autre qu'un démarreur rotorique à résistances, et la tension assignée statorique d'emploi dans le cas d'un démarreur rotorique à résistances.

Tous les démarreurs directs appartiennent à au moins l'une des catégories d'emploi suivantes: AC-3, AC-3e, AC-4, AC-7b, AC-8a et AC-8b.

Tous les démarreurs étoile-triangle et tous les démarreurs par autotransformateur à deux étapes appartiennent à la catégorie d'emploi AC-3 ou AC-3e.

Les démarreurs rotoriques à résistances appartiennent à la catégorie d'emploi AC-2.

5.4.2 Attribution des catégories d'emploi en fonction des résultats d'essais

- a) Un contacteur ou un démarreur qui a été soumis à l'essai pour une catégorie d'emploi ou à toute autre combinaison de paramètres (tels que tension et courant d'emploi maximaux, etc.) peut se voir attribuer d'autres catégories d'emploi sans essai complémentaire à condition que les grandeurs d'essai (courants, tensions, facteurs de puissance ou constantes de temps, nombre de cycles de manœuvres, durée à l'état passant et non passant) figurant dans le Tableau 7 et dans le Tableau 10 et que le circuit d'essai pour les catégories d'emploi attribuées ne soient pas plus sévères que ceux auxquels le contacteur ou le démarreur a été soumis à l'essai, et que l'échauffement ait été vérifié à un courant au moins égal à la valeur maximale du courant assigné d'emploi en service continu.

Par exemple, un contacteur soumis à l'essai pour la catégorie d'emploi AC-4 peut se voir attribuer la catégorie d'emploi AC-3 à condition que I_e pour AC-3 ne soit pas supérieur à $1,2 I_e$ pour AC-4 à la même tension assignée d'emploi.

- b) Les contacteurs de catégorie DC-3 et DC-5 sont censés être en mesure d'ouvrir et de fermer des charges autres que celles ayant été soumises à l'essai, à condition que:

- la tension et le courant ne dépassent par les valeurs spécifiées pour U_e et I_e ;
- l'énergie J emmagasinée dans la charge réelle soit inférieure ou égale à l'énergie J_c emmagasinée dans la charge avec laquelle ils ont été soumis à l'essai.

Les valeurs de l'énergie emmagasinée dans le circuit d'essai sont les suivantes:

Catégorie d'emploi	Énergie emmagasinée J_c
DC-3	$0,005\,25 \times U_e \times I_e$
DC-5	$0,031\,5 \times U_e \times I_e$

Les valeurs des constantes 0,005 25 et 0,031 5 sont déduites de la formule:

$$J_c = 1/2 LI^2$$

dans laquelle la constante de temps a été remplacée par:

$2,5 \times 10^{-3}$ s (DC-3) et:

15×10^{-3} s (DC-5)

et où $U = 1,05 U_e$, $I = 4 I_e$ et L est l'inductance du circuit d'essai (voir le Tableau 7 du présent document).

IECNORM.COM : Click to view the full PDF of IEC 60947-4-1:2018 RLV

Tableau 1 – Catégories d'emploi

Nature du courant	Catégories d'emploi	Indication supplémentaire de catégorie	Charge type
Courant alternatif	AC-1	Usage général	Charges non inductives ou faiblement inductives
	AC-2		Moteurs à bagues ou combinaison de charges résistives et inductives, incluant de faibles surcharges
	AC-3		Moteurs à cage d'écureuil ^d : démarrage, coupure des moteurs lancés, inversion ^a
	AC-3e ^e		Moteurs à cage d'écureuil avec courant rotor bloqué plus élevé ^e : démarrage, coupure des moteurs lancés, inversion ^a
	AC-4		Moteurs à cage d'écureuil ^d : démarrage, inversion de marche, marche par à-coups
	AC-5a	Ballast Lampe à incandescence	Lampes à décharge
	AC-5b		Lampes à incandescence en courant alternatif
	AC-6a		Transformateurs
	AC-6b		Batteries de condensateurs
	AC-7a ^c		Charges faiblement inductives pour appareils domestiques et applications analogues
	AC-7b ^c		Moteurs pour applications domestiques
	AC-8a		Commande de moteurs de compresseurs hermétiques de réfrigération ^b avec réarmement manuel des déclencheurs de surcharge
	AC-8b		Commande de moteurs de compresseurs hermétiques de réfrigération ^b avec réarmement automatique des déclencheurs de surcharge
Courant continu	DC-1	Lampe à incandescence	Charges non inductives ou faiblement inductives
	DC-3		Moteurs à excitation en dérivation: démarrage, inversion de marche, marche par à-coups, coupure dynamique de moteurs en courant continu
	DC-5		Moteurs série: démarrage, inversion de marche, marche par à-coups, coupure dynamique de moteurs en courant continu
	DC-6		Lampes à incandescence en courant continu

^a La catégorie AC-3 peut être utilisée pour des marches par à-coups ou des inversions de marche de manœuvres occasionnelles de durée limitée, telles que le montage d'une machine. Il convient que le nombre de ces manœuvres pendant ces durées limitées ne dépasse pas cinq manœuvres par minute ni plus de dix pour une durée de 10 min.

^b Un moteur de compresseur hermétique de réfrigération est un appareil combiné comprenant un compresseur et un moteur, tous deux enfermés dans le même boîtier sans arbre ou joints d'arbre extérieurs, le moteur fonctionnant dans le réfrigérant.

^c Pour AC-7a et AC-7b, voir l'IEC 61095.

^d Moteur asynchrone de conception N et H conformément à l'IEC 60034-12:2016.

^e Moteur asynchrone de conception NE et HE, conformément à l'IEC 60034-12:2016, présentant une puissance et un courant rotor bloqué étendus/supérieurs à ceux de la conception N et H respectivement, afin d'atteindre une classe de rendement supérieure conformément à l'IEC 60034-30-1.

5.5 Circuits de commande

Le 4.5 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 s'applique avec les ajouts suivants.

La liste des caractéristiques donnée en 4.5.1 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 doit être complétée par:

- l'énergie limitée (si la source est conforme à 8.1.14);
- l'alimentation TBTS (TBTP) (conformément à l'Annexe N de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014);
- la consommation d'énergie de l'électro-aimant d'un contacteur, nécessaire pour déterminer les caractéristiques de l'alimentation du circuit de commande, qui est donnée par:
 - la puissance de maintien,
 - la puissance d'appel.

NOTE Aux États-Unis et au Canada, les circuits de commande se caractérisent par des sources de Classe 2 telles que définies dans le NFPA 70, National Electrical Code et le CSA C22.1, Canadian Electrical Code (CE Code) en lieu et place ou en complément des sources TBTS (TBTP).

5.6 Circuits auxiliaires

Le 4.6 de l'IEC 60947-1:2007 s'applique.

Les entrées et/ou sorties numériques contenues dans les contacteurs et les démarreurs de moteurs et conçues pour être compatibles avec les API doivent satisfaire aux exigences de l'Annexe S de l'IEC 60947-1:2007.

5.7 Caractéristiques du relais et du déclencheur des relais de surcharge et de l'appareil de connexion de protection des moteurs (ACPM)

NOTE Dans le reste du présent document, l'expression «relais de surcharge» est utilisée pour désigner, suivant le cas, aussi bien un relais de surcharge qu'un déclencheur de surcharge.

5.7.1 Énumération des caractéristiques

Les caractéristiques des relais et des déclencheurs doivent être indiquées dans les termes suivants, s'il y a lieu:

- types du relais ou du déclencheur (voir 5.7.2);
- valeurs caractéristiques (voir 5.7.3);
- désignation et courant de réglage des relais de surcharge (voir 5.7.4);
- caractéristiques temps-courant des relais de surcharge (voir 5.7.5);
- influence de la température de l'air ambiant (voir 5.7.6);
- fonctions étendues comme indiqué dans l'Annexe H;
- indicateurs de surveillance de charge comme indiqué dans l'Annexe O.

5.7.2 Types du relais ou du déclencheur

- a) Déclencheur à bobine en dérivation (déclencheur shunt).
- b) Relais ou déclencheur d'ouverture à minimum de tension et à minimum de courant.
- c) Relais de surcharge à fonctionnement temporisé dont le retard est:
 - 1) notablement indépendant de la charge préalable;
 - 2) dépendant de la charge préalable;
 - 3) dépendant de la charge préalable et du relais ou déclencheur de surcharge sensible à une perte de phase.
- d) Relais ou déclencheur de surcharge à fonctionnement instantané;
- e) Relais ou déclencheurs instantanés de court-circuit.

NOTE Un ACPM comporte une combinaison de relais ou de déclencheurs de c) et e) ci-dessus.

- f) Relais ou déclencheur de calage.

- g) Autres relais ou déclencheurs (relais de commande associé à des dispositifs de protection thermique du moteur, par exemple).

5.7.3 Valeurs caractéristiques

- a) Déclencheur à bobine en dérivation, relais ou déclencheur d'ouverture à minimum de tension (minimum de courant), à maximum de tension (maximum de courant à fonctionnement instantané), à déséquilibre de courant ou de tension et à inversion de phase:
- tension (ou courant) assigné(e);
 - fréquence assignée;
 - tension (courant) d'emploi;
 - temps de fonctionnement (s'il y a lieu);
 - temps d'inhibition (s'il y a lieu).
- b) Relais et déclencheur de surcharge (intégrant la fonction de surcharge d'un ACPM):
- désignation et courant de réglage (voir 5.7.4);
 - fréquence assignée, si nécessaire (dans le cas d'un relais de surcharge commandé par un transformateur de courant, par exemple);
 - caractéristiques temps-courant (ou domaine de caractéristiques), s'il y a lieu;
 - classe de déclenchement selon la classification du Tableau 2 ou valeur de la durée maximale de déclenchement, exprimée en secondes, dans les conditions spécifiées en 8.2.1.5.1, Tableau 3, colonne D, lorsque cette durée dépasse 40 s;
 - nature du relais: thermique, magnétique, électronique ou électronique sans mémoire thermique (les relais électroniques ne satisfaisant pas aux essais de vérification de mémoire thermique selon 8.2.1.5.1.2 doivent être marqués ~~Thm~~);
 - nature du réarmement: si manuel/automatique, le réglage doit être indiqué;
 - temps de déclenchement des relais de surcharge de classe 10A lorsque celui-ci est supérieur à 2 min à -5 °C ou à une température inférieure (voir 8.2.1.5.1.1, point c)).
- c) Déclencheur avec relais de détection de courant résiduel:
- courant assigné;
 - courant d'emploi;
 - temps de fonctionnement ou caractéristiques temps-courant conformément au Tableau T.1 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010;
 - temps d'inhibition (s'il y a lieu);
 - désignation du type (voir l'Annexe T de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010).
- d) Déclencheur de court-circuit d'un ACPM:
- courants assignés d'emploi (I_e) ou puissances assignées d'emploi;
 - fréquence assignée;
 - courant de réglage (ou plage de réglages), s'il y a lieu.

Tableau 2 – Classes de déclenchement des relais de surcharge

Classe de déclenchement	Temps de déclenchement T_p dans les conditions spécifiées en 8.2.1.5.1, Tableau 3, colonne D ^a	Temps de déclenchement T_p dans les conditions spécifiées en 8.2.1.5.1, Tableau 3, colonne D pour les tolérances plus étroites (bande de tolérance E) ^a
	s	s
2	–	$T_p \leq 2$
3	–	$2 < T_p \leq 3$
5	$0,5 < T_p \leq 5$	$3 < T_p \leq 5$
10A	$2 < T_p \leq 10$	–
10	$4 < T_p \leq 10$	$5 < T_p \leq 10$
20	$6 < T_p \leq 20$	$10 < T_p \leq 20$
30	$9 < T_p \leq 30$	$20 < T_p \leq 30$
40	–	$30 < T_p \leq 40$

NOTE 1 Selon la nature du relais, les conditions de déclenchement sont données en 8.2.1.5.

NOTE 2 Dans le cas d'un démarreur rotorique à résistances, le relais de surcharge est placé d'habitude dans le circuit du stator. Par conséquent, il ne peut pas protéger efficacement le circuit du rotor et plus particulièrement les résistances (en général plus exposées que le rotor lui-même ou les appareils de connexion en cas de démarrage défectueux). La protection du circuit du rotor fait l'objet d'un accord particulier entre le fabricant et l'utilisateur (voir notamment 8.2.1.1.3).

NOTE 3 Dans le cas d'un démarreur par autotransformateur à deux étapes, l'autotransformateur de démarrage est normalement conçu pour n'être utilisé que pendant la période de démarrage. Par conséquent, il ne peut pas être efficacement protégé par le relais de surcharge en cas de démarrage défectueux. La protection de l'autotransformateur fait l'objet d'un accord particulier entre le fabricant et l'utilisateur (voir 8.2.1.1.4).

NOTE 4 Les valeurs limites les plus faibles de T_p sont choisies pour tenir compte des caractéristiques de l'élément chauffant et des tolérances de fabrication.

^a Le fabricant doit ajouter la lettre E aux classes de déclenchement pour indiquer la conformité à la bande E.

5.7.4 Désignation et courants de réglage des relais de surcharge

Les relais de surcharge sont désignés par leur courant de réglage (ou les limites supérieure et inférieure de la plage de courants de réglage, si celle-ci est réglable) et leur classe de déclenchement.

Le courant de réglage (ou la plage de courants de réglage) doit être marqué sur les relais.

Cependant, si le courant de réglage dépend des conditions d'utilisation ou d'autres facteurs qui ne peuvent facilement être marqués sur le relais, le relais ou toute partie remplaçable de celui-ci (les éléments chauffants, les bobines de commande ou les transformateurs de courant, par exemple) doit porter un numéro ou un repère d'identification permettant d'obtenir les renseignements correspondants auprès du fabricant ou dans son catalogue ou, de préférence, à partir d'indications fournies avec le démarreur.

Pour les relais de surcharge commandés par un transformateur de courant, le marquage peut se rapporter soit au courant primaire du transformateur de courant qui les alimente, soit au courant de réglage des relais de surcharge. Dans l'un et l'autre cas, le rapport de transformation du transformateur de courant doit être indiqué.

5.7.5 Caractéristiques temps-courant des relais de surcharge

Les caractéristiques temps-courant typiques doivent être données sous forme de courbes fournies par le fabricant. Ces courbes doivent indiquer dans quelle mesure le temps de déclenchement à partir de l'état froid (voir 5.7.6) varie en fonction du courant jusqu'à une

valeur d'au moins huit fois le courant de pleine charge du moteur avec lequel le relais est destiné à être utilisé. Le fabricant doit être en mesure d'indiquer par des moyens appropriés les tolérances relatives à ces courbes ainsi que les sections des conducteurs utilisées pour établir ces courbes (voir 9.3.3.2.2, point c)).

NOTE Le courant est porté en abscisses et le temps en ordonnées, en utilisant des échelles logarithmiques. Le courant est porté en multiples du courant de réglage I_r et le temps en secondes en utilisant les échelles normalisées décrites en 5.6.1 et à la Figure 1 de l'IEC 60269-1:2006, et à la Figure 104, à la Figure 504 et à la Figure 505 de l'IEC 60269-2:2013.

5.7.6 Influence de la température de l'air ambiant

Les caractéristiques temps-courant (voir 5.7.5) correspondent à une valeur déterminée de la température de l'air ambiant et elles se rapportent à une absence de charge préalable du relais de surcharge (c'est-à-dire à un état initial froid). Cette valeur de température de l'air ambiant doit être clairement indiquée sur les courbes de temporisation, les valeurs préférentielles étant +20 °C ou +40 °C.

Les relais de surcharge doivent être en mesure de fonctionner dans la plage de températures de l'air ambiant comprises entre –5 °C et +40 °C. Le fabricant doit être en mesure de spécifier l'effet des variations de la température de l'air ambiant sur les caractéristiques des relais de surcharge.

5.8 Coordination avec les dispositifs de protection contre les courts-circuits

La coordination des contacteurs et des démarreurs est caractérisée par le type, les caractéristiques assignées et les caractéristiques des dispositifs de protection contre les courts-circuits (DPCC) qui assurent une protection du contacteur et du démarreur contre les courants de court-circuit. Les exigences sont données en 8.2.5.1 et 8.2.5.2 du présent document et en 4.8 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010.

Les exigences relatives aux démarreurs assignés AC-3e avec une coordination de type 2 sont données en 8.2.5.3.

Si un ACPM est utilisé comme démarreur à main sans association avec un contacteur, il n'est pas nécessaire de le soumettre à l'essai conformément au présent paragraphe.

5.9 Vide

5.10 Types et caractéristiques des appareils de commande automatique de commutation et des appareils de commande automatique d'accélération

5.10.1 Types

- Dispositifs à action différée, par exemple contacteurs auxiliaires temporisés (conformes à l'IEC 60947-5-1), applicables aux appareils pour circuits de commande ou relais de tout-ou-rien temporisés (conformes à l'IEC 61810-1).
- Dispositifs à minimum de courant (relais à minimum de courant).
- Autres dispositifs pour la commande automatique d'accélération:
 - dispositifs voltmétriques;
 - dispositifs wattmétriques;
 - dispositifs tachymétriques.

5.10.2 Caractéristiques

- Les caractéristiques des dispositifs à action différée sont:
 - le retard assigné ou sa plage, si elle est réglable;
 - pour les dispositifs à action différée comportant une bobine, la tension assignée, si elle diffère de la tension d'alimentation du démarreur.

- b) Les caractéristiques des dispositifs à minimum de courant sont:
- le courant assigné (courant thermique et/ou courant assigné de courte durée admissible, suivant l'indication du fabricant);
 - le courant de réglage ou sa plage, si elle est réglable.
- c) Les caractéristiques des autres dispositifs doivent faire l'objet d'un accord entre le fabricant et l'utilisateur.

5.11 Types et caractéristiques des autotransformateurs des démarreurs par autotransformateur à deux étapes

Compte tenu des caractéristiques de démarrage (voir 5.3.5.6.3), les autotransformateurs de démarrage doivent être caractérisés par:

- la tension assignée de l'autotransformateur;
- le nombre de prises disponibles pour régler le couple et le courant de démarrage;
- la tension de démarrage, c'est-à-dire la tension aux bornes des prises, en pourcentage de la tension assignée de l'autotransformateur;
- le courant qu'ils peuvent supporter pendant une durée spécifiée;
- le service assigné (voir 5.3.4);
- le mode de refroidissement { par air;
par huile.

Les autotransformateurs peuvent être:

- soit incorporés au démarreur, auquel cas l'échauffement qui en résulte doit être pris en considération lors de la détermination des caractéristiques assignées du démarreur;
- soit livrés séparément, auquel cas la nature et les dimensions des conducteurs de liaison doivent être spécifiées dans le cadre d'un accord entre le fabricant du transformateur et le fabricant du démarreur.

5.12 Types et caractéristiques des résistances de démarrage des démarreurs rotoriques à résistances

Compte tenu des caractéristiques de démarrage (voir 5.3.5.6.2), les résistances de démarrage doivent être caractérisées par:

- la tension assignée rotorique d'isolement (U_{ir});
- leur valeur ohmique;
- le courant thermique moyen, défini par la valeur du courant constant qu'elles peuvent supporter pendant un temps spécifié;
- le service assigné (voir 5.3.4);
- le mode de refroidissement { convection;
air forcé;
immersion dans l'huile.

Elles peuvent être:

- soit incorporées au démarreur, auquel cas l'échauffement qui en résulte doit être limité pour ne pas endommager les autres organes du démarreur;
- soit livrées séparément, auquel cas la nature et les dimensions des conducteurs de liaison doivent être spécifiées dans le cadre d'un accord entre le fabricant des résistances et le fabricant du démarreur.

6 Informations sur le matériel

6.1 Nature des informations

6.1.1 Identification

- a) nom du fabricant ou sa marque de fabrique;
- b) désignation du type ou numéro de série;
- c) numéro du présent document si le fabricant déclare s'y conformer.

6.1.2 Caractéristiques, valeurs assignées fondamentales et utilisation

Caractéristiques:

- d) tensions assignées d'emploi (voir 5.3.1.1);
- e) polarité des bornes, le cas échéant;
- f) catégorie d'emploi et courants assignés d'emploi (ou puissances assignées), aux tensions assignées d'emploi du matériel (voir 5.3.2.5 et 5.4);
- g) soit la valeur de la fréquence assignée 50 Hz/60 Hz soit le symbole $\overline{\overline{\overline{\quad}}}$ (IEC 60417-5031), soit d'autres fréquences assignées (16 2/3 Hz, 400 Hz, par exemple);
- h) service assigné avec indication de la classe de service intermittent, s'il y a lieu (voir 5.3.4) et la durée à l'état non passant comme spécifié dans la note de bas de tableau d) du Tableau 10, si nécessaire;
- i) impédance de pôle de l'appareil de connexion (Z);
- j) déclaration de matière conformément à l'Annexe W de l'IEC 60947-1:2007/AMD2:2014;

Valeurs associées:

- k) pouvoirs assignés de fermeture et de coupure. Ces indications peuvent être remplacées, s'il y a lieu, par l'indication de la catégorie d'emploi du Tableau 7 et du Tableau M.2.

Sécurité et installation:

- l) tension assignée d'isolement (voir 5.3.1.2);
- m) tension assignée de tenue aux chocs (voir 5.3.1.3);
- n1) code IP conformément à l'Annexe C de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010;
- n2) degré de pollution (voir l'Article 7);
- o) caractéristiques assignées en court-circuit :
 - pour les contacteurs ou démarreurs: courant assigné de court-circuit conditionnel (voir 5.3.6) et type de coordination (voir 8.2.5.1) ainsi que type, courant assigné et caractéristiques du DPCC associé;
 - pour les combinés de démarrage, combinés d'appareils de connexion, démarreurs protégés ou appareils de connexion protégés: courant assigné de court-circuit conditionnel (voir 5.3.6) et type de coordination (voir 8.2.5.1);
 - pour les ACPM: pouvoir de coupure ultime en court-circuit assigné (I_{cu}) et pouvoir de coupure de service en court-circuit assigné (I_{cs}) (voir 8.2.4.7).
- p1) altitude maximale admissible du site d'installation, si elle est supérieure à 2 000 m.
- p2) raccordement de conducteur sur borne:
 - longueur de l'isolant à retirer avant l'insertion du conducteur dans la borne;
 - nombre maximal de conducteurs pouvant être serrés.

Pour les bornes non universelles sans vis:

- «S» ou «sol» pour les bornes déclarées pour conducteurs rigides-massifs;
- «r» pour les bornes déclarées pour conducteurs rigides (massifs et câblés);
- «f» pour les bornes déclarées pour conducteurs souples.

q) référence des accessoires de câblage dédiés qui peuvent être utilisés pour câbler le démarreur ou le combiné de contacteurs;

Circuits de commande:

Les informations suivantes relatives aux circuits de commande doivent figurer soit sur la bobine, soit sur le matériel:

r) tension assignée des circuits de commande (U_c), nature du courant et fréquence assignée;

NOTE 1 D'autres informations peuvent être trouvées dans la documentation du produit (la puissance de maintien ou d'appel, par exemple).

s) si nécessaire, nature du courant, fréquence assignée et tension d'alimentation assignée du circuit de commande;

Dans le cas de bobines d'électro-aimants commandées électroniquement, d'autres informations peuvent également être nécessaires, par exemple la configuration du circuit de commande (voir 5.5 du présent document et l'Annexe U de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014).

Dispositifs d'alimentation en air comprimé pour les démarreurs ou les contacteurs commandés par air comprimé:

t) pression assignée d'alimentation en air comprimé et limites de variation de cette pression, si elles sont différentes de celles spécifiées en 8.2.1.2.

Circuits auxiliaires:

u) caractéristiques assignées des circuits auxiliaires (voir 5.6).

Relais et déclencheurs à maximum de courant:

v1) caractéristiques selon 5.7.2, 5.7.5 et 5.7.6;

v2) caractéristiques selon 5.7.3 et 5.7.4.

Informations supplémentaires pour certains types de contacteurs et de démarreurs:

Démarreurs rotoriques à résistances:

w) schéma des circuits;

x) sévérité du démarrage (voir 5.3.5.6.1);

y) durée de démarrage (voir 5.3.5.6.1).

Démarreurs par autotransformateur:

z) la ou les tensions assignées de démarrage, c'est-à-dire la ou les tensions aux bornes des prises.

NOTE 2 Cette valeur peut être exprimée en pourcentage de la tension assignée d'emploi du démarreur.

CEM:

aa) environnement A ou B: voir 7.3.1 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010;

ab) exigences spéciales, le cas échéant (conducteurs blindés ou torsadés, par exemple).

NOTE 3 Les conducteurs non blindés ou non torsadés sont considérés comme étant des conditions normales d'installation.

6.2 Marquage

Le 5.2 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 s'applique aux contacteurs, aux démarreurs et aux relais de surcharge avec les ajouts suivants.

Les indications des points d) à ab) de 6.1.2 doivent figurer sur la plaque signalétique ou sur le matériel, ou sur la documentation publiée par le fabricant.

Les indications des points c) de 6.1.1, e), n (si le degré de protection est différent de IP00) et v2) de 6.1.2 doivent être marquées sur le matériel; les caractéristiques temps-courant (ou plage de caractéristiques) peuvent être indiquées dans la documentation publiée par le fabricant.

NOTE Aux États-Unis et au Canada, sur de nombreux matériels, l'indication supplémentaire de catégorie indiquée dans le Tableau 1 est marquée sur le produit.

De plus, l'ACPM doit être marqué à un endroit visible et lisible lors de son installation, pour:

- l'aptitude au sectionnement, si applicable, avec le symbole  (IEC 60617-500287 «Disjoncteur» combiné à IEC 60417-6169-1 «Sectionneur; isolateur»);
- indication des positions d'ouverture et de fermeture, avec  (IEC 60417-5008 «ARRÊT» (alimentation)) et  (IEC 60417-5007 «MARCHE» (alimentation)) respectivement, si les symboles sont utilisés (voir 7.1.6.1 de l'IEC 60947-1:2007);

Les données suivantes doivent être marquées à l'extérieur de l'ACPM de façon à pouvoir être visibles et lisibles lors de l'installation de l'ACPM:

- plage des courants assignés instantanés de réglage de court-circuit (I_i), pour les déclencheurs réglables.

Pour les accessoires dédiés utilisés pour le câblage du démarreur ou du combiné de contacteurs, les données de 6.1.1 c), 6.1.2 l) et le courant I_{th} , le cas échéant, doivent être indiqués dans la documentation publiée par le fabricant.

6.3 Instructions d'installation, de fonctionnement, de maintenance, de mise hors service et de démontage

Le 5.3 de l'IEC 60947-1:2007 et de l'IEC 60947-1:2007/AMD2:2014 s'applique avec les ajouts suivants.

Les instructions doivent également couvrir les accessoires de câblage dédiés.

Des informations supplémentaires relatives à la mise hors service et au démontage de l'appareil doivent être maintenues à disposition de l'utilisateur en cas de conditions dangereuses prévisibles de l'appareil (en raison de l'énergie emmagasinée, de l'instabilité ou de la chute d'objets, par exemple).

Dans le cas des démarreurs protégés, le fabricant doit également fournir les instructions nécessaires pour le montage et le câblage.

Le fabricant d'un démarreur incorporant un relais de surcharge à réarmement automatique capable d'être connecté pour permettre un redémarrage automatique doit fournir, avec le démarreur, les informations nécessaires pour alerter l'utilisateur de la possibilité de redémarrage automatique.

Si la construction exige la mise sous tension par une source d'énergie externe qui n'est pas une source d'énergie limitée (telle que définie en 8.1.14), le fabricant doit fournir les informations appropriées relatives à la protection des accès contre les courts-circuits et contre les surintensités.

Pour chaque danger potentiel applicable, le fabricant doit fournir des signaux de sécurité, des symboles graphiques ou des notes de sécurité du danger à l'aide, par exemple, de l'IEC 60417-5036. Des mots indicateurs doivent être définis conformément à l'ISO 3864-2.

NOTE L'ISO/IEC 82079-1 donne des recommandations pour le développement des instructions de sécurité.

6.4 Informations relatives à l'environnement

Le 5.4 de l'IEC 60947-1:2007/AMD2:2014 s'applique.

NOTE La future publication IEC TS 63058 indiquera la méthode d'évaluation de l'impact des appareillages sur l'environnement.

7 Conditions normales de service, de montage et de transport

L'Article 6 de l'IEC 60947-1:2007 s'applique avec les ajouts suivants:

Sauf indication contraire du fabricant, un contacteur ou un démarreur est destiné à être utilisé dans les conditions d'environnement du degré de pollution 3, définies en 6.1.3.2 de l'IEC 60947-1:2007. Toutefois, d'autres degrés de pollution peuvent s'appliquer en fonction du micro-environnement.

Le montage sur rail doit être spécifié conformément à l'IEC 60715:2017, le cas échéant.

Les conditions normales de vibrations sont définies dans la note de bas de page ^b du Tableau Q.1 de l'IEC 60947-1:2007/AMD2:2014.

Les altitudes supérieures à 2 000 m font l'objet d'un accord entre le fabricant et l'utilisateur.

8 Exigences relatives à la construction et au fonctionnement

8.1 Exigences relatives à la construction

8.1.1 Généralités

Le 7.1.1 de l'IEC 60947-1:2007 s'applique avec les ajouts suivants:

Des mesures doivent être fournies pour réduire la probabilité de blessure ou, en cas d'incendie, de dommages matériels, dans les conditions d'installation, de maintenance, de fonctionnement normal, de fonctionnement anormal et en cas de mauvais usages raisonnablement prévisibles. Les exigences du présent document précisent en général ces mesures.

La protection contre les dangers provoqués par les circuits électroniques doit être maintenue dans les conditions normales et les conditions de premier défaut, comme le spécifie le présent document.

La méthode d'appréciation du risque de la fonction de protection électromécanique contre les surcharges utilisée dans des applications de sécurité est donnée à l'Annexe L.

Les composants utilisés pour la construction du matériel, conformes à la norme de produit IEC correspondante, n'exigent pas d'évaluation distincte. Les composants ou assemblages de

composants, pour lesquels il n'existe aucune norme de produit correspondante, doivent être soumis à l'essai selon les exigences du présent document.

Si le produit est destiné à être utilisé avec un matériel auxiliaire particulier et des accessoires de câblage dédiés, l'évaluation de la sécurité et les essais doivent inclure ce matériel auxiliaire et les accessoires, sauf s'il peut être démontré qu'il n'a aucun impact sur la sécurité du matériel.

La partie accessible de l'appareil, et plus particulièrement les organes de manœuvre, ne doivent présenter aucune arête vive ni aucun angle pouvant blesser l'opérateur.

Il convient de bien prendre en compte l'Annexe O de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014, particulièrement pour remplacer les substances dangereuses ou réduire leur utilisation ou, si cela s'avère impossible, pour fournir des mesures visant à empêcher leur émission ou leur contact.

8.1.2 Matériaux

8.1.2.1 Exigences générales pour les matériaux

Le 7.1.2.1 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 s'applique avec les ajouts suivants.

NOTE Les aspects liés aux dangers d'incendie sont détaillés dans l'IEC TR 63054.

La conformité des pièces de matériau isolant situées dans les circuits électriques alimentés par des sources d'énergie limitée (voir 8.1.14) aux exigences du présent paragraphe n'est pas exigée.

8.1.2.2 Essai au fil incandescent

Le 7.1.2.2 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 s'applique avec l'ajout suivant.

Lorsque les essais sur le matériel ou sur des parties issues du matériel sont réalisés, les pièces de matériau isolant nécessaires au maintien en position des parties conductrices doivent satisfaire à l'essai au fil incandescent de 8.2.1.1.1 de l'IEC 60947-1:2007 à une température d'essai de 850 °C.

8.1.2.3 Essai selon la catégorie d'inflammabilité

Le 7.1.2.3 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 s'applique.

8.1.3 Parties conductrices et leurs connexions

Le 7.1.3 de l'IEC 60947-1:2007 s'applique.

8.1.4 Distances d'isolement et lignes de fuite

Le 7.1.4 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 s'applique avec les ajouts suivants.

La conformité des distances d'isolement et lignes de fuite à l'intérieur des circuits électriques alimentés par des sources d'énergie limitée telles que définies en 8.1.14 aux exigences du présent paragraphe n'est pas exigée.

Les distances d'isolement et lignes de fuite sur les cartes à câblage imprimé (PWB), y compris les composants montés sur cartes, pour l'isolation fonctionnelle, principale,

supplémentaire et renforcée, conçues selon 8.1.14, sont réputées satisfaire aux exigences et une investigation approfondie ne s'avère donc pas nécessaire.

Si les circuits TBTS et TBTP sont accessibles, ils doivent être séparés des autres parties actives dangereuses conformément aux exigences de l'Annexe N relative à l'impédance de protection, en plus de l'Annexe N de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014.

NOTE Si certains circuits sont uniquement accessibles dans les conditions de maintenance ou analogues, ils peuvent, en fonction du niveau de risque (sévérité du préjudice et probabilité d'occurrence) être considérés comme étant des conditions normales de service (voir 6.1) et n'utiliser que l'isolation principale. Les parties accessibles peuvent être identifiées à l'aide de calibres d'essai selon l'IEC 61032.

8.1.5 Organe de commande

8.1.5.1 Isolement

Le 7.1.5.1 de l'IEC 60947-1:2007 s'applique.

8.1.5.2 Sens du mouvement

Le 7.1.5.2 de l'IEC 60947-1:2007 s'applique.

8.1.5.3 Montage

Les organes de commande montés sur des panneaux démontables ou des portes doivent être conçus pour être dans la position convenable par rapport au mécanisme associé lors du remplacement du panneau ou de la fermeture de la porte.

8.1.5.4 Protection

Aucun chemin ni aucune ouverture ne doit permettre à des particules incandescentes de quitter la zone des organes de manœuvre manuels.

8.1.6 Indication de la position des contacts

8.1.6.1 Dispositifs indicateurs

Le 7.1.6.1 de l'IEC 60947-1:2007 est applicable aux démarreurs à commande manuelle.

8.1.6.2 Indication par l'organe de commande

Le 7.1.6.2 de l'IEC 60947-1:2007 s'applique.

8.1.7 Exigences supplémentaires pour les matériels aptes au sectionnement

Le 7.1.7 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 s'applique avec les ajouts suivants:

Si la position déclenchée de l'ACPM n'est pas la position d'ouverture indiquée, il convient que cela soit clairement visible. La vérification de la position du contact principal d'un démarreur à main et d'un ACPM apte au sectionnement doit être soumise à l'essai selon 9.3.3.2.3.

Les ACPM et les démarreurs moteurs à main aptes au sectionnement doivent être équipés de moyens de verrouillage en position ouverte.

8.1.8 Bornes

8.1.8.1 Généralités

Le 7.1.8 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 s'applique avec les ajouts suivants.

8.1.8.2 Identification et marquage des bornes

Le 7.1.8.4 de l'IEC 60947-1:2007 s'applique avec les exigences supplémentaires de l'Annexe A.

8.1.9 Exigences supplémentaires pour les matériels équipés d'un pôle neutre

Le 7.1.9 de l'IEC 60947-1:2007 s'applique.

8.1.10 Dispositions pour assurer la mise à la terre de protection

Le 7.1.10 de l'IEC 60947-1:2007 s'applique.

8.1.11 Enveloppes pour le matériel

8.1.11.1 Conception

Le 7.1.11.1 de l'IEC 60947-1:2007 s'applique avec les ajouts suivants.

Les résistances de démarrage montées à l'intérieur d'une enveloppe doivent être disposées ou protégées de telle manière que la chaleur dégagée ne cause aucun dommage aux autres appareils et matériaux situés dans l'enveloppe.

Dans le cas particulier des combinés de démarrage, le couvercle ou la porte doit être verrouillé de façon à ne pas pouvoir être ouvert sans que l'appareil de connexion à commande manuelle soit en position d'ouverture.

Cependant, l'ouverture de la porte ou du couvercle à l'aide d'un outil peut être prévue, l'appareil de connexion à commande manuelle étant en position MARCHE.

8.1.11.2 Isolement

Le 7.1.11.2 de l'IEC 60947-1:2007 s'applique.

8.1.12 Degrés de protection du matériel sous enveloppe

Le 7.1.12 de l'IEC 60947-1:2007 s'applique.

8.1.13 Traction, torsion et flexion avec des conduits métalliques

Le 7.1.13 de l'IEC 60947-1:2007 s'applique.

8.1.14 Source d'énergie limitée

8.1.14.1 Généralités

Une source d'énergie limitée peut être mise en œuvre comme circuit secondaire dérivé des circuits connectés à la partie active dangereuse avec les moyens de séparation suivants:

- a) séparation galvanique;
- b) impédance de limitation de courant.

NOTE Les sources de Classe 2 définies par le NFPA 70, National Electrical Code et le CSA C22.1, Canadian Electrical Code (CE Code), présentent les mêmes caractéristiques de sortie électrique que les sources d'énergie limitée à séparation galvanique.

8.1.14.2 Source d'énergie limitée à séparation galvanique

Une source d'énergie limitée à séparation galvanique intègre un composant d'isolation (un transformateur entre le circuit primaire et la sortie d'énergie limitée, par exemple). Elle doit satisfaire à l'une des exigences suivantes:

- la sortie est par nature limitée, conformément au Tableau 19; ou
- une impédance linéaire ou non linéaire limite la sortie, conformément au Tableau 19. Si un dispositif à coefficient de température positif (CTP, par exemple) est utilisé, il doit satisfaire aux essais applicables de l'IEC 60730-1; ou
- un réseau de régulation limite la sortie conformément au Tableau 19, avec et sans premier défaut dans ledit réseau; ou
- un dispositif de protection contre les surintensités est utilisé et la sortie est limitée conformément au Tableau 20.

Si un dispositif de protection contre les surintensités est utilisé, il doit s'agir d'un fusible ou d'un dispositif électromécanique non réglable.

La conformité pour déterminer la puissance admise maximale est vérifiée par l'essai de 9.2.4.

Dans le cas de l'alimentation électrique externe sans dispositif de protection contre les surintensités, les valeurs indiquées dans le Tableau 19 ne doivent pas être dépassées. Dans le cas de l'alimentation électrique externe avec dispositifs de protection contre les surintensités, les valeurs indiquées dans le Tableau 20 ne doivent pas être dépassées.

Tableau 19 – Limites pour les sources d'énergie limitée sans dispositif de protection contre les surintensités

Tension de sortie ^a		Courant de sortie ^{b, d}	Puissance maximale ^c
U_{oc}			
V courant alternatif	V courant continu	I_{sc} A	S VA
≤ 30 valeur efficace	≤ 30 V	≤ 8	100
-	$30 < U_{oc} \leq 60^e$	$\leq \frac{150}{U_{oc}}$	100

NOTE Ce tableau sera reproduit dans la révision future de l'IEC 60947-1, donc il est numéroté différemment des autres tableaux de ce document.

^a U_{oc} : tension de sortie mesurée avec tous les circuits de charge déconnectés. Il s'agit de tensions alternatives sensiblement sinusoïdales et de tensions continues sans ondulation. Pour les tensions alternatives et continues non sinusoïdales dont l'ondulation est supérieure à 10 % de la crête, la tension de crête ne doit pas dépasser 42,4 V.

^b I_{sc} : courant de sortie maximal avec une charge non capacitive, y compris un court-circuit.

^c S (VA): puissance apparente de sortie maximale en VA avec une charge non capacitive telle que déterminée en 9.2.4.

^d Le mesurage de I_{sc} est réalisé 5 s après l'application de la charge si la protection est assurée par un circuit électronique ou un dispositif à coefficient de température positif (CTP, par exemple), et 60 s dans les autres cas.

^e Aux États-Unis, la limite est 60 V courant continu ou commutation en courant continu hors de la plage 10 Hz à 200 Hz, 24,8 V courant continu commutation à 10 Hz à 200 Hz.

Tableau 20 – Limites pour les sources d'énergie limitée avec dispositif de protection contre les surintensités

Tension de sortie ^a		Courant de sortie ^{b, d} I_{sc} A	Puissance maximale ^{c, d} S VA	Courant assigné du dispositif de protection contre les surintensités ^e A
V courant alternatif	V courant continu			
≤ 20	≤ 20	$\leq \frac{1000}{U_{oc}}$	250	≤ 5,0
20 < U_{oc} ≤ 30	20 < U_{oc} ≤ 30 ^f			$\leq \frac{100}{U_{oc}}$
-	30 < U_{oc} ≤ 60 ^f			$\leq \frac{100}{U_{oc}}$
NOTE 1 La raison justifiant les mesurages en contournant les dispositifs de protection contre les surintensités est qu'il s'agit de déterminer la quantité d'énergie disponible pour provoquer une éventuelle surchauffe pendant la durée de fonctionnement des dispositifs de protection contre les surintensités. NOTE 2 Ce tableau sera reproduit dans la révision future de l'IEC 60947-1, donc il est numéroté différemment des autres tableaux de ce document.				
^a U_{oc}: tension de sortie mesurée avec tous les circuits de charge déconnectés. Il s'agit de tensions alternatives sensiblement sinusoïdales et de tensions continues sans ondulation. Pour les tensions alternatives et continues non sinusoïdales dont l'ondulation est supérieure à 10 % de la crête, la tension de crête ne doit pas dépasser 42,4 V. ^b I_{sc}: courant de sortie maximal avec une charge non capacitive, y compris un court-circuit, mesuré 60 s après l'application de la charge. ^c S (VA): puissance de sortie maximale en VA avec une charge non capacitive mesurée 60 s après l'application de la charge telle que déterminée en 9.2.4. ^d L'impédance de limitation de courant reste dans le circuit pendant le mesurage, mais les dispositifs de protection contre les surintensités sont contournés. ^e Les courants assignés des dispositifs de protection contre les surintensités qui coupent le circuit dans les 120 s qui suivent avec un courant égal à 210 % du courant assigné indiqué dans le tableau. ^f Aux États-Unis, la limite est 60 V courant continu ou commutation en courant continu hors de la plage 10 Hz à 200 Hz, 24,8 V courant continu commutation à 10 Hz à 200 Hz.				

8.1.14.3 Source d'énergie limitée avec impédance de limitation de courant

Une source d'énergie limitée avec impédance de limitation de courant présente les caractéristiques suivantes:

- la tension de sortie est limitée, conformément au Tableau 21; et
- une impédance linéaire ou non linéaire limite la sortie, conformément au Tableau 21, et ce en cas de premier défaut ou non.

Une source d'énergie limitée avec impédance de limitation de courant peut être dérivée du réseau ou d'un circuit à séparation galvanique (le secondaire d'un transformateur, par exemple).

**Tableau 21 – Limites pour la source d'énergie limitée
avec impédance de limitation de courant**

Tension de sortie ^a		Courant de sortie ^{b, d}	Puissance maximale ^c
U_{oc}			
V courant alternatif	V courant continu	I_{sc} A	S VA
≤ 30 V valeur efficace	≤ 30 V	0,5	15

NOTE Ce tableau sera reproduit dans la révision future de l'IEC 60947-1, donc il est numéroté différemment des autres tableaux de ce document.

^a U_{oc} : tension de sortie mesurée avec tous les circuits de charge déconnectés. Il s'agit de tensions alternatives sensiblement sinusoïdales et de tensions continues sans ondulation. Pour les tensions alternatives et continues non sinusoïdales dont l'ondulation est supérieure à 10 % de la crête, la tension de crête ne doit pas dépasser 42,4 V.

^b I_{sc} : courant de sortie maximal mesuré à la sortie de la source d'énergie limitée.

^c S (VA): puissance apparente de sortie maximale en VA telle que déterminée en 9.2.4.

^d Le mesurage de I_{sc} est réalisé 5 s après l'application du court-circuit.

8.1.15 Circuit d'énergie de charge emmagasinée

Les parties contenant une charge emmagasinée (condensateurs) et qui sont amovibles pour l'entretien (le remplacement d'une bobine, par exemple), son installation ou sa déconnexion ne doivent présenter aucun risque de danger électrique après sa déconnexion.

Les condensateurs connectés à des parties actives dangereuses accessibles doivent être déchargés à un niveau d'énergie inférieur à 0,5 mJ dans les 5 s qui suivent la coupure d'alimentation. Sinon, une note de mise en garde aisément visible doit être placée sur le produit, indiquant le temps de décharge jusqu'aux valeurs limites ou une méthode préférentielle de déchargement du condensateur avant de toucher les parties de connexion.

8.1.16 Conditions de défaut et conditions anormales

Le produit doit être conçu pour éviter les modes ou séquences de fonctionnement qui peuvent être à l'origine d'une condition de défaut ou d'une défaillance du composant et donnant lieu à un danger, sauf si d'autres mesures permettant d'éviter le danger sont fournies par l'installation et sont décrites dans les informations sur l'installation fournies avec le produit. Les exigences du présent article s'appliquent également aux conditions anormales de fonctionnement, selon le cas.

Le circuit doit faire l'objet d'analyses ou d'essais pour déterminer si la défaillance d'un composant particulier (y compris les systèmes d'isolation) était susceptible ou pas de provoquer un danger.

Ces analyses doivent inclure les situations dans lesquelles une défaillance du composant ou de l'isolation (principale et supplémentaire):

- aurait un impact sur le risque de choc électrique;
- créerait un risque de dégradation conduisant à l'émission de flammes, de particules brûlantes ou de métal en fusion.

Les analyses ou essais doivent inclure les effets des conditions de court-circuit et de circuit ouvert du composant. Les essais sont nécessaires, sauf si les analyses peuvent permettre de conclure que, dans des conditions de court-circuit et de circuit ouvert, aucun danger lié aux chocs ou au feu ne serait le résultat de la défaillance du composant. La conformité doit être vérifiée par l'essai de 9.2.5.

Les composants évalués pour leur fiabilité conformément aux normes de produits applicables sont considérés comme satisfaisant à ces exigences et peuvent ne pas faire l'objet d'examens approfondis, si les essais se déroulent dans les conditions satisfaisant à celles pour lesquelles le produit a été conçu.

8.1.17 Protection des accès contre les courts-circuits et les surcharges

Lorsque la source d'alimentation d'un accès par les bornes de signaux ou de puissance externe à l'appareil ne satisfait pas aux exigences relatives aux sources d'énergie limitée de 8.1.14, le produit ne doit présenter aucun danger dans les conditions de court-circuit ou de surcharge. Des instructions relatives à l'installation d'une protection externe contre les surintensités doivent être fournies conformément à 6.3.

La conformité doit être vérifiée par examen et, le cas échéant, par simulation des conditions de premier défaut.

8.2 Exigences relatives au fonctionnement

8.2.1 Conditions de fonctionnement

8.2.1.1 Généralités

8.2.1.1.1 Conditions générales

Le 7.2.1.1 de l'IEC 60947-1:2007 s'applique avec les ajouts suivants.

Les exigences relatives au dispositif de protection contre les courts-circuits d'un combiné de démarrage ou d'un démarreur protégé sont données dans l'IEC 60947-2 pour les disjoncteurs, dans l'IEC 60947-3 pour les combinés-fusibles et dans le présent document pour les ACPM.

Les exigences relatives aux caractéristiques normales de charge et de surcharge conformes à 5.3.5 sont données en 8.2.4.1, 8.2.4.2 et 8.2.4.4.

Les exigences s'appliquent au produit et aux accessoires de câblage dédiés.

S'il n'y a pas de différence entre U_s et U_c , l'essai doit alors être effectué avec U_c .

8.2.1.1.2 Conditions générales A

Les démarreurs doivent être construits de façon à:

- a) être à déclenchement libre;
- b) pouvoir ouvrir leurs contacts par les moyens prévus lorsqu'ils sont en fonctionnement et à tout instant durant la séquence de démarrage;
- c) ne pas fonctionner à des séquences autres que leur séquence correcte de démarrage.

8.2.1.1.3 Conditions générales B

Les démarreurs utilisant des contacteurs ne doivent pas être déclenchés par les chocs causés par la manœuvre des contacteurs lorsqu'ils sont soumis à l'essai conformément à 9.3.3.1, après que le démarreur a été parcouru par son courant assigné de pleine charge à la température ambiante de référence (c'est-à-dire +20 °C) et qu'il a atteint son équilibre thermique, au réglage minimal et au réglage maximal du relais de surcharge, si celui-ci est réglable.

8.2.1.1.4 Conditions générales C

Pour les démarreurs à résistances, le relais de surcharge doit être relié au circuit du stator. Des dispositions spéciales peuvent être réalisées pour protéger les contacteurs et les résistances du circuit du rotor contre un échauffement excessif, sur demande de l'utilisateur.

8.2.1.1.5 Conditions générales D

Si les démarreurs sont utilisés dans des conditions telles qu'un échauffement excessif des résistances de démarrage ou des transformateurs présente un danger particulier, il est recommandé de prévoir un dispositif approprié pour mettre le démarreur hors tension automatiquement avant qu'il atteigne une température dangereuse.

8.2.1.1.6 Conditions générales E

Les contacts mobiles des matériels multipolaires destinés à assurer simultanément la fermeture et la coupure doivent être accouplés de manière telle que tous les pôles soient fermés ou coupés pratiquement en même temps, que la manœuvre soit manuelle ou automatique.

8.2.1.2 Limites de fonctionnement des contacteurs et des démarreurs à manœuvre à source d'énergie extérieure

Le 7.2.1.2 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 s'applique avec les ajouts suivants:

Pour les contacteurs à accrochage, les appareils doivent relâcher leurs contacts et s'ouvrir complètement lorsqu'une tension de décrochage comprise entre 85 % et 110 % de la tension de décrochage assignée est appliquée.

8.2.1.3 Limites de fonctionnement des relais et déclencheurs à minimum de tension

Le 7.2.1.3 de l'IEC 60947-1:2007 s'applique avec l'ajout suivant: les essais sont spécifiés en 9.3.3.2.2 du présent document.

8.2.1.4 Limites de fonctionnement des déclencheurs à bobine en dérivation (déclencheur shunt)

Le 7.2.1.4 de l'IEC 60947-1, IEC 60947-1:2007/AMD2:2014 s'applique avec l'ajout suivant: les essais sont spécifiés en 9.3.3.2.2 du présent document.

8.2.1.5 Limites de fonctionnement des relais et déclencheurs à détection de courant

8.2.1.5.1 Limites de fonctionnement des relais de surcharge à fonctionnement différé quand tous leurs pôles sont alimentés

8.2.1.5.1.1 Exigences générales de déclenchement des relais de surcharge

NOTE 1 La protection thermique des moteurs en présence d'harmoniques dans la tension d'alimentation est à l'étude.

Les relais doivent satisfaire aux exigences du Tableau 3, lorsqu'ils sont soumis à l'essai comme suit:

- a) le relais de surcharge ou le démarreur étant dans son enveloppe, s'il en est normalement équipé, le déclenchement ne doit pas se produire en moins de 2 h à A fois le courant de réglage, à partir de l'état froid, à la température de référence de l'air ambiant précisée dans le Tableau 3. Cependant, lorsque les bornes du relais de surcharge ont atteint l'équilibre thermique, au courant d'essai, en moins de 2 h, la durée de l'essai peut être le temps nécessaire pour atteindre cet équilibre thermique;

- b) lorsque le courant est ensuite augmenté à *B* fois la valeur du courant de réglage, le déclenchement doit se produire en moins de 2 h;
- c) pour les relais de surcharge de classes 2, 3, 5 et 10A chargés à *C* fois leur courant de réglage, le déclenchement doit se produire en moins de 2 min à partir de l'équilibre thermique, au courant de réglage, conformément à 9.3.3 de l'IEC 60034-1:2017. Pour les relais de surcharge de classe 10A, pour une température de l'air ambiant de -5°C ou moins, le fabricant peut déclarer un temps de déclenchement plus long mais ne dépassant pas 4 min;

NOTE 2 Le 9.3.3 de l'IEC 60034-1:2017 indique: «Les moteurs polyphasés dont la puissance (utile) assignée est inférieure ou égale à 315 kW et dont la tension assignée est inférieure ou égale à 1 kV doivent être capables de supporter un courant égal à 1,5 fois le courant assigné pendant au moins 2 min».

- d) pour les relais de surcharge de classes 10, 20, 30 et 40 alimentés à *C* fois leur courant de réglage, le déclenchement doit se produire moins de 4 min, 8 min, 12 min ou 16 min respectivement, à partir de l'équilibre thermique, au courant de réglage;
- e) à *D* fois le courant de réglage, le déclenchement doit se produire dans les limites fixées dans le Tableau 2, pour la classe de déclenchement et la bande de tolérance appropriées, à partir de l'état froid.

Dans le cas de relais de surcharge ayant une plage de courants de réglage, les limites de fonctionnement doivent s'appliquer aussi bien lorsque le relais est parcouru par le courant correspondant au réglage maximal que lorsqu'il est parcouru par le courant correspondant au réglage minimal.

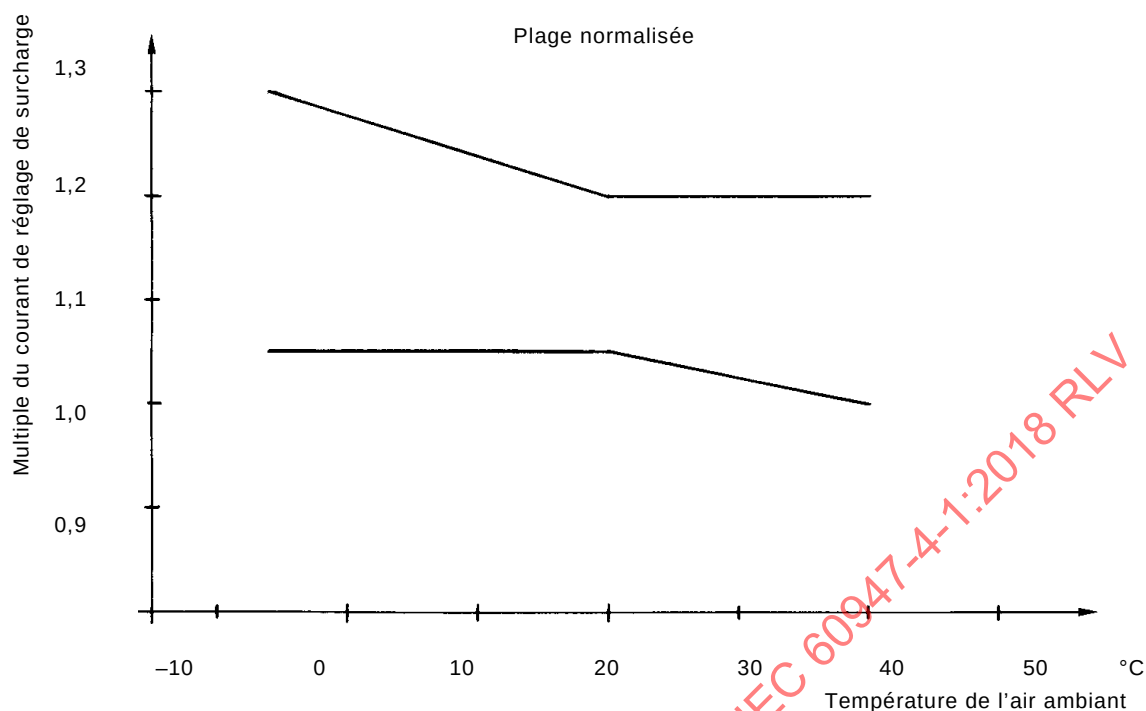
Pour les relais de surcharge non compensés, la caractéristique multiple courant/température ambiante ne doit pas dépasser 1,2 %/K.

NOTE 3 1,2 %/K est la caractéristique de déclassement des conducteurs isolés au PVC.

Un relais de surcharge est considéré comme compensé s'il satisfait aux exigences applicables du Tableau 3 à $+20^{\circ}\text{C}$ et s'il se trouve dans les limites du Tableau 3 à d'autres températures (voir la Figure 1).

Tableau 3 – Limites de fonctionnement des relais de surcharge à fonctionnement différé alimentés sur tous leurs pôles

Type du relais de surcharge	Multiples de la valeur du courant de réglage				Valeurs de température de l'air ambiant
	A	B	C	D	
Type thermique non compensé pour les variations de température de l'air ambiant	1,0	1,2 ^b	1,5	7,2	$+40^{\circ}\text{C}$
Type thermique compensé pour les variations de température de l'air ambiant	c	c	–	–	inférieure à -5°C ^d
	1,05	1,3	1,5	–	-5°C
	1,05	1,2 ^b	1,5	7,2	$+20^{\circ}\text{C}$
	1,0	1,2 ^b	1,5	–	$+40^{\circ}\text{C}$
	c	c	–	–	supérieure à $+40^{\circ}\text{C}$ ^d
Type électronique ^a	1,05	1,2 ^b	1,5	7,2	0°C , $+20^{\circ}\text{C}$ et $+40^{\circ}\text{C}$
^a Cet essai doit être réalisé uniquement à 20°C pour les multiples A, B et D du courant de réglage. ^b Si cela est spécifié par le fabricant, le courant de déclenchement peut ne pas être égal à 120 %, mais il ne doit pas dépasser 125 %. Dans ce cas, la valeur du courant d'essai doit être égale à la valeur du courant de déclenchement. Dans ce cas, la valeur du courant de déclenchement doit être marquée sur l'appareil. ^c Il convient que le fabricant déclare les multiples de courant de réglage. ^d Voir 9.3.3.2.2 pour les essais en dehors de la plage -5°C $+40^{\circ}\text{C}$.					



IEC

Figure 1 – Limites des multiples de la valeur du courant de réglage des relais de surcharge à fonctionnement différé compensés pour la température de l'air ambiant

8.2.1.5.1.2 Essai de vérification de la mémoire thermique

À moins que le fabricant ait spécifié que l'appareil ne comporte pas de mémoire thermique, les relais électroniques de surcharge doivent satisfaire aux exigences suivantes (voir la Figure 2):

- appliquer un courant égal à I_e jusqu'à ce que l'appareil ait atteint l'équilibre thermique;
- interrompre le courant pendant une durée de $2 \times T_p$ (voir le Tableau 2) avec une tolérance relative de $\pm 10 \%$ (où T_p est le temps mesuré au courant D selon le Tableau 3);
- appliquer un courant égal à $7,2 \times I_e$;
- le relais doit déclencher dans les 50 % du temps T_p .

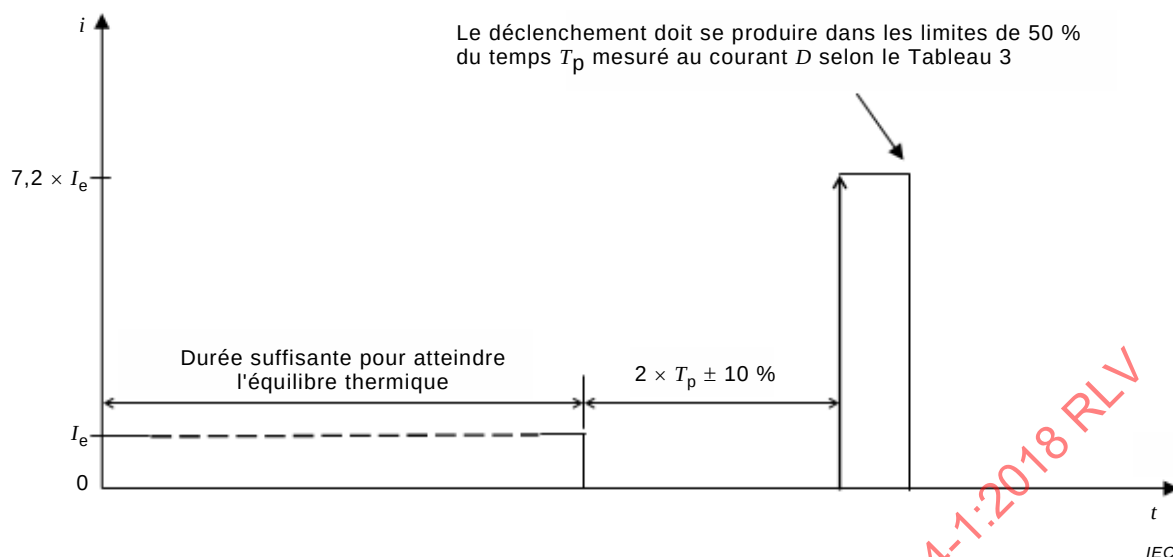


Figure 2 – Essai de mémoire thermique

8.2.1.5.2 Limites de fonctionnement des relais de surcharge tripolaires à fonctionnement différé alimentés sur deux pôles

En se reportant au Tableau 4:

Le relais de surcharge ou le démarreur doit être soumis à l'essai dans son enveloppe s'il en est normalement équipé. Le relais étant alimenté sur trois pôles, à A fois le courant de réglage, le déclenchement ne doit pas se produire en moins de 2 h à partir de l'état froid, à la valeur de la température de l'air ambiant précisée dans le Tableau 4.

En outre, lorsque la valeur du courant circulant dans deux pôles (ceux qui sont parcourus par le courant le plus élevé, dans le cas d'un relais ou déclencheur de surcharge sensible à une perte de phase) est portée à B fois la valeur du courant de réglage et que le troisième pôle est mis hors tension, le déclenchement doit se produire en moins de 2 h.

Ces valeurs doivent s'appliquer à toutes les combinaisons de pôles.

Dans le cas des relais de surcharge ayant un courant de réglage ajustable, les caractéristiques doivent s'appliquer aussi bien lorsque le relais est parcouru par le courant correspondant au réglage maximal que lorsqu'il est parcouru par le courant correspondant au réglage minimal.

Tableau 4 – Limites de fonctionnement des relais de surcharge tripolaires à fonctionnement différé alimentés sur deux pôles seulement

Type du relais de surcharge	Multiples de la valeur du courant de réglage		Température de référence de l'air ambiant
	A	B	
Thermique, compensé pour les variations de température de l'air ambiant ou électronique Insensible à une perte de phase	3 pôles 1,0	2 pôles 1,32 1 pôle 0	+20 °C
Thermique, non compensé pour les variations de température de l'air ambiant Insensible à une perte de phase	3 pôles 1,0	2 pôles 1,25 1 pôle 0	+40 °C
Thermique, compensé pour les variations de température de l'air ambiant ou électronique Sensible à une perte de phase	2 pôles 1,0 1 pôle 0,9	2 pôles 1,15 1 pôle 0	+20 °C

8.2.1.5.3 Limites de fonctionnement des relais de surcharge magnétiques instantanés

Pour toutes les valeurs du courant de réglage, les relais de surcharge magnétiques instantanés doivent déclencher avec une exactitude égale à $\pm 10\%$ de la valeur publiée du courant correspondant au courant de réglage.

NOTE Les relais de surcharge magnétiques à fonctionnement instantané qui font l'objet du présent document ne sont pas prévus pour assurer la protection contre les courts-circuits.

8.2.1.5.4 Limites de fonctionnement des relais et déclencheurs à minimum de courant pour la commutation automatique

8.2.1.5.4.1 Limites de fonctionnement des relais à minimum de courant

Lorsqu'il est associé à un appareil de connexion, un relais ou un déclencheur à minimum de courant doit provoquer l'ouverture de celui-ci dans un intervalle de temps compris entre 80 % et 120 % de la valeur de réglage du temps lorsque le courant est inférieur à 0,9 fois le réglage du minimum de courant dans tous les pôles pendant le fonctionnement. Lorsque le temps de fonctionnement est inférieur à 1 s, une tolérance différente peut être donnée par le fabricant, mais la valeur supérieure ne doit pas dépasser 1,2 s.

NOTE La tolérance dépend de la technologie de détection.

8.2.1.5.4.2 Limites de fonctionnement de commutation automatique par relais à minimum de courant

Le présent paragraphe s'applique:

- aux démarreurs étoile-triangle, d'étoile en triangle, et
- aux démarreurs par autotransformateur, de la position de démarrage à la position MARCHE.

Le courant de retombée minimal d'un relais à minimum de courant ne doit pas être supérieur à 1,5 fois le courant de réglage réel du relais de surcharge qui est actif dans la position de démarrage ou la position en étoile. Le relais à minimum de courant doit être capable de supporter n'importe quelle valeur de courant, depuis le courant de réglage minimal jusqu'au courant de calage dans la position de démarrage ou la position en étoile, pendant le temps de déclenchement déterminé par le relais de surcharge à son courant de réglage maximal.

8.2.1.5.5 Limites de fonctionnement des relais de calage

Un relais de calage doit, lorsqu'il est associé à un appareil de connexion, provoquer l'ouverture de celui-ci dans un intervalle de temps compris entre 80 % et 120 % de la valeur de réglage du temps (temps d'inhibition de calage) ou dans l'exactitude spécifiée par le fabricant, lorsque:

- a) relais de détection de courant: le courant est 20 % supérieur à la valeur de réglage du courant de calage;

EXEMPLE Courant de réglage du relais de calage: 100 A; temps de réglage: 6 s; exactitude: ± 10 %, le relais doit déclencher entre 5,4 s et 6,6 s lorsque le courant est supérieur ou égal à $100 \text{ A} \times 1,2 = 120 \text{ A}$.

- b) relais de détection de rotation: un signal d'entrée indique l'absence de rotation du moteur.

8.2.1.5.6 Limites de fonctionnement des relais et déclencheurs de blocage

Un relais ou un déclencheur de blocage doit, lorsqu'il est associé à un appareil de connexion, provoquer l'ouverture de celui-ci dans un intervalle de temps compris entre 80 % et 120 % de la valeur de réglage du temps (temps d'inhibition de blocage) ou dans l'exactitude spécifiée par le fabricant, lorsque le courant est supérieur à 1,2 fois la valeur du courant de réglage du relais de blocage, pendant le fonctionnement après l'achèvement du démarrage.

8.2.1.5.7 Limites de fonctionnement du déclencheur de court-circuit d'un ACPM

Le fonctionnement du déclencheur de court-circuit d'un ACPM doit provoquer son déclenchement avec une exactitude de ± 20 % de la valeur du courant de déclenchement du courant de réglage pour toutes les valeurs du courant de réglage du déclencheur de court-circuit, s'il est réglable.

8.2.2 Échauffement

8.2.2.1 Généralités

Les exigences de 7.2.2 de l'IEC 60947-1:2007 sont applicables aux contacteurs et aux démarreurs à l'état neuf et propre.

NOTE 1 La résistance de contact due à l'oxydation peut avoir un impact sur l'essai d'échauffement à des tensions inférieures à 100 V. Si l'essai est réalisé à une tension inférieure à 100 V, les contacts de ces appareils peuvent être nettoyés soit par une méthode non abrasive soit en réalisant 10 cycles de manœuvres dans les conditions du Tableau 13 pour toutes les catégories d'emploi applicables, quelle que soit la tension.

Les échauffements des différents organes du contacteur ou du démarreur, mesurés au cours d'un essai effectué dans les conditions spécifiées en 9.3.3, ne doivent pas dépasser les valeurs limites précisées dans le Tableau 5 du présent document et en 7.2.2.1 et 7.2.2.2 de l'IEC 60947-1:2007.

Dans le cas d'une bobine d'électro-aimant commandée électroniquement, le mesurage de température de la bobine par variation de résistance peut être impraticable, auquel cas, d'autres méthodes sont autorisées (thermocouples ou toute autre méthode appropriée, par exemple).

Tableau 5 – Limites d'échauffement pour les bobines isolées dans l'air et dans l'huile

Classe du matériau isolant (selon l'IEC 60085:2007)	Limite d'échauffement (mesurages effectués par variation de résistance)	
	K	
	Bobines dans l'air	Bobines dans l'huile
A	85	60
E	100	60
B	110	60
F	135	–
H	160	–

Étant donné que, dans le cas d'un démarreur par autotransformateur, l'autotransformateur n'est parcouru par du courant que de façon intermittente, un échauffement maximal dépassant de 15 K les valeurs figurant dans le Tableau 5 est permis pour les enroulements du transformateur lorsque le démarreur est actionné selon les exigences de 5.3.4 et 5.3.5.6.4.

NOTE 2 Les limites d'échauffement indiquées dans le Tableau 5 du présent document et en 7.2.2.2 de l'IEC 60947-1:2007 ne sont applicables que si la température de l'air ambiant reste comprise entre -5°C et $+40^{\circ}\text{C}$.

8.2.2.2 Bornes

Le 7.2.2.1 de l'IEC 60947-1:2007 s'applique.

8.2.2.3 Parties accessibles

Le 7.2.2.2 de l'IEC 60947-1:2007 s'applique.

8.2.2.4 Température de l'air ambiant

Le 7.2.2.3 de l'IEC 60947-1:2007 s'applique.

8.2.2.5 Circuit principal

Le circuit principal d'un contacteur ou d'un démarreur parcouru par du courant en position MARCHE, y compris les déclencheurs à maximum de courant pouvant lui être associés, doit être en mesure de supporter, sans dépasser les limites d'échauffement spécifiées en 7.2.2.1 de l'IEC 60947-1:2007, lorsqu'il est soumis à l'essai conformément à 9.3.3.3.4:

- pour un contacteur ou un démarreur prévu pour un service continu: son courant thermique conventionnel (voir 5.3.2.1 et/ou 5.3.2.2);
- pour un contacteur ou un démarreur prévu pour un service ininterrompu, un service intermittent ou un service temporaire: son courant assigné d'emploi applicable (voir 5.3.2.5).

8.2.2.6 Circuits de commande

Le 7.2.2.5 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 s'applique.

8.2.2.7 Enroulements des bobines et des électro-aimants

8.2.2.7.1 Enroulements pour service ininterrompu et service de huit heures

Le circuit principal étant parcouru par un courant égal à la valeur maximale du courant selon 8.2.2.5, les enroulements des bobines, y compris celles des électrovalves des contacteurs ou des démarreurs électropneumatiques, doivent supporter, en régime continu et à la fréquence assignée, s'il y a lieu, la tension assignée maximale d'alimentation du circuit

de commande, sans que les échauffements dépassent les limites spécifiées dans le Tableau 5 du présent document et en 7.2.2.6 de l'IEC 60947-1:2007.

NOTE Selon la technologie (pour certaines bobines d'électro-aimants commandées électroniquement, par exemple), la tension d'alimentation de commande ne peut pas être appliquée directement sur les enroulements de la bobine raccordée comme en service normal.

8.2.2.7.2 Enroulements pour service intermittent

Le circuit principal n'étant parcouru par aucun courant, les enroulements des bobines doivent supporter, à la fréquence assignée, s'il y a lieu, leur tension d'alimentation maximale assignée du circuit de commande comme indiqué dans le Tableau 6, suivant leur classe de service intermittent, sans que les échauffements dépassent les limites spécifiées dans le Tableau 5 du présent document et en 7.2.2.2 de l'IEC 60947-1:2007.

NOTE Selon la technologie (pour certaines bobines d'électro-aimants commandées électroniquement, par exemple), la tension d'alimentation de commande ne peut pas être appliquée directement sur les enroulements de la bobine raccordée comme en service normal.

Tableau 6 – Données pour les cycles d'essai de service intermittent

Classe de service intermittent		Un cycle de manœuvres de fermeture-ouverture toutes les	Durée de maintien de l'alimentation de la bobine de commande
Contacteurs	Démarreurs		
1	1	3 600 s	Il convient que le temps de passage du courant corresponde au facteur de marche spécifié par le fabricant
3	3	1 200 s	
12	12	300 s	
30	30	120 s	
120		30 s	
300		12 s	
1 200		3 s	

8.2.2.7.3 Enroulements assignés spéciaux (pour service temporaire ou périodique)

Les enroulements assignés spéciaux doivent être soumis à l'essai dans les conditions de fonctionnement correspondant au service le plus sévère auquel ils peuvent être destinés et leurs caractéristiques assignées doivent être précisées par le fabricant.

NOTE Les enroulements assignés spéciaux peuvent être des bobines de démarreurs qui ne sont sous tension que durant la période de démarrage, des bobines de déclenchement de contacteurs à accrochage et certaines bobines d'électrovalves destinées au verrouillage de contacteurs ou de démarreurs pneumatiques.

8.2.2.8 Circuits auxiliaires

Le 7.2.2.7 de l'IEC 60947-1:2007 s'applique.

8.2.2.9 Autres parties

Le 7.2.2.8 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014 est applicable, en remplaçant les mots «plastiques et matériaux isolants» par «parties isolantes».

8.2.3 Propriétés diélectriques

8.2.3.1 Généralités

Le 7.2.3 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 s'applique avec les ajouts suivants:

8.2.3.2 Composants de limitation de tension entre circuits

Les exigences générales concernant les appareils incluant des composants de limitation de tension insérés entre les circuits qui ne sont pas connectés à la masse ou à la terre et à soumettre à l'essai diélectrique sont décrites comme suit.

Ces composants de limitation de tension appelés varistances utilisés pour protéger les éléments électroniques des ondes de choc dans l'appareil doivent satisfaire à l'IEC 61051-2. Dans le présent article, le but n'est pas de diminuer les distances d'isolement. Pour l'essai de type de l'appareil, les composants de limitation de tension peuvent être déconnectés.

L'IEC 61051-2 s'applique comme suit:

a) Catégories climatiques préférentielles de la varistance:

- température inférieure maximale: $-10\text{ }^{\circ}\text{C}$;
- température supérieure minimale: $+85\text{ }^{\circ}\text{C}$.

Le fabricant de l'appareil doit vérifier que la varistance est appropriée à l'utilisation à la température ambiante étendue le cas échéant.

b) La tension assignée minimale de la varistance doit être égale à 1,2 fois la tension de crête maximale lorsque la varistance est connectée.

c) Lorsqu'elles sont connectées au réseau électrique, les varistances doivent résister à l'essai de surtension conformément à 9.4.2.5.

NOTE 1 Avec la vérification des varistances ci-dessus, il est admis par hypothèse qu'un fusible de protection de la varistance n'est pas nécessaire.

NOTE 2 La possibilité donnée en 8.3.3.4.1 point 1) de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010, IEC 60947-1:2007/AMD2:2014 de déconnecter les circuits entre pôles ne peut pas être appropriée dans l'essai individuel de série, car les produits sont finis et il n'est pas approprié de les rouvrir et de les manipuler. L'objectif principal de cet essai est d'identifier le bon fonctionnement du composant de limitation de tension.

8.2.4 Exigences de fonctionnement dans des conditions normales de charge et de surcharge

8.2.4.1 Pouvoirs de fermeture et de coupure

Les contacteurs ou les démarreurs doivent être en mesure d'établir et de couper les courants sans défaillance dans les conditions précisées dans le Tableau 7 pour les catégories d'emploi exigées et le nombre de manœuvres indiqué (voir 9.3.3.5).

Les valeurs de durée à l'état passant et de durée à l'état non passant données dans le Tableau 7 et dans le Tableau 8 ne doivent pas être dépassées.

Ces pouvoirs correspondent aux caractéristiques de charge normale données en 5.3.5.3 et 5.3.5.4.

L'ACPM doit être soumis à l'essai dans les conditions indiquées dans le Tableau 7 avec les exceptions suivantes:

- Si le déclencheur de surcharge se déclenche pendant l'essai, la durée à l'état non passant peut être rallongée jusqu'au point auquel aucun déclenchement ne se produit.
- Si le déclencheur de court-circuit se déclenche pendant l'essai, le déclencheur instantané de court-circuit doit être inhibé. Si la caractéristique assignée du courant instantané de court-circuit est inférieure au courant d'essai, ce dernier peut être réduit à la valeur du courant assigné instantané de réglage de court-circuit (I_i) plus 20 % si le fabricant ne précise pas de tolérance inférieure. Dans le cas d'une unité de déclenchement instantané réglable, le déclenchement doit être établi au réglage maximal.

- a $\cos \phi = 0,45$ pour $I_e \leq 100$ A; $0,35$ pour $I_e > 100$ A
- b La durée peut être inférieure à $0,05$ s, à condition que les contacts soient en mesure d'être convenablement positionnés avant réouverture. Pour des raisons liées à la faisabilité de l'essai, et dans le cadre d'un accord avec le fabricant, une durée à l'état passant plus longue peut être définie.
- c Essais à effectuer avec une charge constituée par des lampes à incandescence.
- d Si la polarité n'est pas marquée sur l'appareil, 25 cycles de manœuvres à une polarité et 25 cycles de manœuvres à la polarité inverse.
- e La charge doit être constituée de combinaisons de condensateurs disponibles dans le commerce permettant d'obtenir un courant réactif en régime établi I_e calculé selon 9.3.3.3.4. D'autres valeurs capacitives assignées peuvent être déterminées par des essais de commutation de condensateurs ou attribuées en se fondant sur la pratique et l'expérience courantes. En tant que guide, des références peuvent être faites à la formule donnée dans le Tableau 9, qui ne tient pas compte des effets thermiques dus aux courants harmoniques. La capacité de courant disponible aux bornes d'essai doit être supérieure ou égale au courant présumé «r». Elle peut être déterminée par une évaluation analytique.
- f Durée à l'état non passant donnée dans le Tableau 8 qui peut être réduite en accord avec le fabricant.
- g Pour U / U_e , une tolérance de ± 20 % est acceptée.
- h Les valeurs indiquées concernent les contacteurs de stator. Pour les contacteurs de rotor, l'essai doit être effectué avec un courant égal à quatre fois le courant assigné rotorique d'emploi et un facteur de puissance de $0,95$.
- i Les conditions d'établissement pour les catégories d'emploi AC-3, AC-3e et AC-4 doivent également être vérifiées. Cette vérification peut être effectuée au cours de l'essai d'établissement et de coupure, sous réserve de l'accord du fabricant. Dans ce cas, les multiples du courant établi doivent être ceux qui sont indiqués pour I / I_e et ceux du courant coupé doivent être ceux qui sont indiqués pour I_c / I_e . 25 cycles de manœuvres doivent être exécutés avec une tension d'alimentation de commande égale à 110 % de la tension d'alimentation assignée du circuit de commande U_s et 25 cycles de manœuvres à 85 % de U_s .
- j Le fabricant doit vérifier les caractéristiques assignées AC-6a par un essai avec un transformateur ou peut les déduire à partir des valeurs d'essai pour AC-3 selon le Tableau 9.
- k Un rapport inférieur de I_c / I_e (courant rotor bloqué sur courant à pleine charge) peut être utilisé si cela est spécifié par le fabricant.
- l La durée à l'état passant doit être suffisamment longue pour atteindre le courant stabilisé.
- m Durée à l'état non passant selon le Tableau 8. La valeur d'une résistance de décharge doit être déterminée afin d'atteindre moins de 50 V à la fin de la durée à l'état non passant.
- n En variante, le facteur I / I_e peut être choisi à la discrétion du fabricant entre 12 et 13 . Dans ce cas, le facteur de puissance est donné par les formules suivantes:
- $I_e \leq 100$ A: $\cos \phi = 0,1 \times I / I_e - 0,85$
- $I_e > 100$ A: $\cos \phi = 0,1 \times I / I_e - 0,95$
- o $\cos \phi = 0,35$ pour $I_e \leq 100$ A; $\cos \phi = 0,25$ pour $I_e > 100$ A

Tableau 8 – Relation entre le courant d'essai et la durée à l'état non passant pour la vérification des pouvoirs assignés de fermeture et de coupure

Courant d'essai <i>I</i> A	Durée à l'état non passant s
$I \leq 100$	10
$100 < I \leq 200$	20
$200 < I \leq 300$	30
$300 < I \leq 400$	40
$400 < I \leq 600$	60
$600 < I \leq 800$	80
$800 < I \leq 1\,000$	100
$1\,000 < I \leq 1\,300$	140
$1\,300 < I \leq 1\,600$	180
$1\,600 < I \leq 2\,500$	240
$2\,500 < I$	accord entre l'utilisateur et le fabricant

La valeur de durée à l'état non passant peut être réduite avec l'accord du fabricant.

Tableau 9 – Détermination du courant d'emploi pour les catégories d'emploi AC-6a et AC-6b à partir des caractéristiques assignées pour AC-3

Courant assigné d'emploi	Détermination à partir du courant établi pour la catégorie d'emploi AC-3
I_e (AC-6a) pour la connexion des transformateurs dont les valeurs de crête du courant d'appel ne dépassent pas 30 fois la valeur de crête du courant assigné	$0,45 I_e$ (AC-3)
I_e (AC-6b) pour la connexion de batteries de condensateurs uniques dans des circuits ayant un courant présumé de court-circuit i_k à l'emplacement de la batterie de condensateurs	$i_k \frac{x^2}{(x-1)^2}$ avec $x = 13,3 \times \frac{I_e \text{ (AC-3)}}{i_k}$ et pour $i_k > 205 I_e \text{ (AC-3)}$
L'expression du courant d'emploi I_e (AC-6b) provient de la formule donnant la valeur de crête maximale du courant d'appel: $I_{pmax} = \frac{U_e \times \sqrt{2}}{\sqrt{3}} \times \frac{1 + \sqrt{\frac{X_c}{X_L}}}{X_L - X_c}$ où U_e est la tension assignée d'emploi; X_L est l'impédance en court-circuit du circuit; X_c est la réactance de la batterie de condensateurs. Cette formule est valable à condition que la capacité côté alimentation du contacteur ou du démarreur puisse être négligée et que le condensateur n'ait pas de charge initiale.	

8.2.4.2 Fonctionnement conventionnel en service

Le 7.2.4.2 de l'IEC 60947-1:2007 s'applique avec les ajouts suivants.

Les contacteurs ou les démarreurs doivent être en mesure d'établir et de couper, sans défaillance, les courants dans les conditions conventionnelles définies dans le Tableau 10 pour les catégories d'emploi exigées et le nombre de cycles de manœuvres indiqué en 9.3.3.6. L'ACPM doit être soumis à l'essai dans les mêmes conditions que celles indiquées dans le Tableau 10 avec les exceptions suivantes:

Si le déclencheur de surcharge se déclenche pendant l'essai, la durée à l'état non passant peut être rallongée jusqu'au point auquel aucun déclenchement ne se produit.

Tableau 10 – Fonctionnement conventionnel en service – Conditions de fermeture et de coupure en fonction de la catégorie d'emploi

Catégorie d'emploi	Conditions d'essai de fermeture et de coupure					
	I_c / I_e	U_r / U_e	$\cos \phi$	Durée à l'état passant	Durée à l'état non passant	Nombre de cycles de manœuvres
				s	s	
AC-1	1,0	1,05	0,80	0,05 ^b	^c	6 000 ⁱ
AC-2	2,0	1,05	0,65	0,05 ^b	^c	6 000 ⁱ
AC-3, AC-3e	2,0	1,05	^a	0,05 ^b	^c	6 000 ⁱ
AC-4	6,0	1,05	^a	0,05 ^b	^c	6 000 ⁱ
AC-5a	2,0	1,05	0,45	0,05 ^b	^c	6 000 ⁱ
AC-5b	1,0 ^e	1,05	^e	0,05 ^b	60	6 000 ⁱ
AC-6a	g	g	g	g	g	g
AC-6b	1 ^k	1,05		l	m	6 000
AC-8a	1,0	1,05	0,80	0,05 ^b	^c	30 000
AC-8b ^{h, j}	6,0	1,05	^a	1	9	5 900
				10	90 ^d	100
Catégorie d'emploi	I_c / I_e	U_r / U_e	L / R ms	Durée à l'état passant	Durée à l'état non passant	Nombre de cycles de manœuvres
				s	s	
DC-1	1,0	1,05	1,0	0,05 ^b	^c	6 000 ^f
DC-3	2,5	1,05	2,0	0,05 ^b	^c	6 000 ^f
DC-5	2,5	1,05	7,5	0,05 ^b	^c	6 000 ^f
DC-6	1,0 ^e	1,05	^e	0,05 ^b	60	6 000 ^f

I_c = courant établi ou coupé. Sauf pour les catégories AC-5b, AC-6 ou DC-6, le courant établi est exprimé en courant continu ou en courant alternatif, comme la valeur efficace des composantes symétriques, étant entendu qu'en courant alternatif, la valeur réelle de crête au cours de la manœuvre d'établissement peut avoir une valeur plus élevée que la valeur de crête de la composante symétrique.

I_e = courant assigné d'emploi

U_r = tension de rétablissement à fréquence industrielle ou en courant continu

U_e = tension assignée d'emploi

$\cos \phi$ = facteur de puissance du circuit d'essai

L / R = constante de temps du circuit d'essai

- ^a $\cos \phi = 0,45$ pour $I_e \leq 100$ A; $0,35$ pour $I_e > 100$ A.
- ^b La durée peut être inférieure à 0,05 s, à condition que les contacts soient en mesure d'être convenablement positionnés avant réouverture. Pour des raisons liées à la faisabilité de l'essai, et dans le cadre d'un accord avec le fabricant, une durée à l'état passant plus longue peut être définie.
- ^c Ces durées à l'état non passant ne doivent pas être supérieures aux valeurs du Tableau 8.
- ^d Le fabricant peut choisir n'importe quelle valeur pour la durée à l'état non passant jusqu'à 200 s.
- ^e Essais à effectuer avec une charge constituée par des lampes à incandescence.
- ^f Si la polarité n'est pas marquée sur l'appareil, 3 000 cycles de manœuvres à une polarité et 3 000 cycles de manœuvres à la polarité inverse.
- ^g Le fabricant doit vérifier les caractéristiques assignées AC-6a par un essai avec un transformateur ou peut les déduire à partir des valeurs d'essai pour AC-3 selon le Tableau 9.
- ^h Les essais pour la catégorie AC-8b doivent être complétés par des essais pour la catégorie AC-8a. Ces essais peuvent être réalisés sur des échantillons différents.
- ⁱ Pour les appareils de connexion à commande manuelle, le nombre de cycles de manœuvres doit être 1 000 en charge, suivis de 5 000 à vide.
- ^j Un rapport inférieur de I_c / I_e (courant rotor bloqué sur courant à pleine charge) peut être utilisé si cela est spécifié par le fabricant.
- ^k La charge doit être constituée de combinaisons de condensateurs disponibles dans le commerce permettant d'obtenir un courant réactif en régime établi I_e calculé selon 9.3.3.3.4. D'autres valeurs capacitives assignées peuvent être déterminées par des essais de commutation de condensateurs ou attribuées en se fondant sur la pratique et l'expérience courantes. En tant que guide, des références peuvent être faites à la formule donnée dans le Tableau 9, qui ne tient pas compte des effets thermiques dus aux courants harmoniques. La capacité de courant disponible aux bornes d'essai doit être supérieure ou égale au courant présumé «r». Elle peut être déterminée par une évaluation analytique.
- ^l La durée à l'état passant doit être suffisamment longue pour atteindre le courant stabilisé.
- ^m Durée à l'état non passant selon le Tableau 8. La valeur d'une résistance de décharge doit être déterminée afin d'atteindre moins de 50 V à la fin de la durée à l'état non passant.

8.2.4.3 Durabilité

8.2.4.3.1 Durabilité mécanique

Le 7.2.4.3.1 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 s'applique avec l'ajout suivant:

La durabilité mécanique d'un contacteur ou d'un démarreur est vérifiée par un essai spécial effectué à la discrétion du fabricant. Les recommandations pour effectuer cet essai figurent à l'Annexe B.

8.2.4.3.2 Durabilité électrique

Le 7.2.4.3.2 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 s'applique avec l'ajout suivant:

La durabilité électrique d'un contacteur ou d'un démarreur est vérifiée par un essai spécial effectué à la discrétion du fabricant. Les recommandations pour effectuer cet essai figurent à l'Annexe B.

8.2.4.4 Capacité de tenue des contacteurs aux courants de surcharge

Les contacteurs des catégories d'emploi AC-3, AC-3e ou AC-4 doivent supporter les courants de surcharge figurant dans le Tableau 11, tel que spécifié en 9.3.5.

Tableau 11 – Exigences de tenue aux courants de surcharge

Courant assigné d'emploi	Courant d'essai ^c	Durée de l'essai ^a
≤ 630 A	$8 \times I_e \text{ max/AC-3}$ $8 \times I_e \text{ max/AC-3e}$	10 s
> 630 A	$6 \times I_e \text{ max/AC-3}^b$ $6 \times I_e \text{ max/AC-3e}$	10 s
^a Pour les démarreurs appartenant au moins à la classe 20 de protection contre les surcharges, le choix du contacteur fait l'objet d'un accord entre le fabricant et l'utilisateur. ^b Avec une valeur minimale de 5 040 A. ^c Cet essai s'applique également aux cas de services pour lesquels la valeur du courant est inférieure et la durée de l'essai est supérieure, à condition que la valeur d'essai de I^2t ne soit pas dépassée.		

NOTE Pour les besoins de la coordination, et plus particulièrement pour AC-3e, un facteur plus élevé de I_e peut être utilisé (voir l'Article B.4).

8.2.4.5 Consommation de puissance de la bobine

La consommation de puissance de l'électro-aimant d'un contacteur caractérise l'alimentation électrique de sa bobine nécessaire aux manœuvres de maintien et d'appel.

Si la consommation de puissance de l'électro-aimant est donnée, elle doit être soumise à l'essai selon 9.3.3.2.1.2.

8.2.4.6 Impédance des pôles

Si l'impédance des pôles est donnée, elle doit faire l'objet d'un essai selon 9.3.3.2.1.3.

8.2.4.7 Aptitude d'un ACPM à établir et couper le courant dans des conditions de court-circuit

Le 7.2.5 de l'IEC 60947-1:2007 s'applique avec les ajouts suivants:

L'aptitude de l'ACPM à établir, transporter et couper les courants de court-circuit est établie dans les termes suivants:

- Pouvoir de coupure ultime en court-circuit assigné I_{cu} (voir 5.3.6.1);
- Pouvoir de coupure de service en court-circuit assigné I_{cs} (voir 5.3.6.2).

Les essais de court-circuit doivent être conformes à l'Annexe P.

NOTE Un ACPM seul ne peut pas être coordonné avec lui-même. Par conséquent, il n'exige pas de courant assigné de court-circuit conditionnel ni d'être soumis au courant d'essai «r».

8.2.5 Coordination avec les dispositifs de protection contre les courts-circuits

8.2.5.1 Fonctionnement en condition de court-circuit (courant assigné de court-circuit conditionnel)

Le courant assigné de court-circuit conditionnel des contacteurs et des démarreurs protégés par un ou plusieurs dispositif(s) de protection contre les courts-circuits (DPCC ou ACPM), des combinés de démarrage, des combinés d'appareils de connexion, des démarreurs protégés et des appareils de connexion protégés doit être vérifié par des essais de court-circuit (voir 9.3.4). Si le combiné de démarrage, le combiné d'appareils de connexion, le démarreur protégé et l'appareil de connexion protégé satisfont aux exigences de 8.2.4.7, ils sont considérés comme un ACPM. Dans ce cas, aucun essai de coordination n'est exigé, sauf s'il est combiné à un appareil de connexion supplémentaire.

Ces essais sont obligatoires:

- a) à la valeur appropriée du courant présumé indiquée dans le Tableau 14 ou le Tableau 13 (courant d'essai «*r*»), et
- b) au courant assigné de court-circuit conditionnel I_q , s'il est supérieur au courant d'essai «*r*».

Les caractéristiques assignées du DPCC doivent convenir à toutes les valeurs données du courant assigné d'emploi, de la tension assignée d'emploi et à la catégorie d'emploi correspondante.

Deux types de coordinations sont admis, le type «1» ou «2». Les conditions d'essai pour ces deux types sont données en 9.3.4.2.1 et 9.3.4.2.2.

La coordination de type «1» implique l'exigence suivante: en condition de court-circuit, le contacteur ou le démarreur ne doit en aucun cas mettre en danger les personnes ou les installations et ne peut pas être en mesure de fonctionner ensuite sans réparation ou remplacement de pièces.

La coordination de type «2» implique l'exigence suivante: en condition de court-circuit, le contacteur ou le démarreur ne doit en aucun cas mettre en danger les personnes ou les installations et doit être en mesure de fonctionner ensuite. Le risque de soudure des contacts est admis, auquel cas, le fabricant doit indiquer les mesures à prendre en ce qui concerne la maintenance du matériel.

NOTE L'emploi d'un DPCC non conforme aux recommandations du fabricant peut annuler la coordination.

Ces essais ne s'appliquent qu'aux caractéristiques assignées des moteurs à courant alternatif.

8.2.5.2 Coordination au courant d'intersection entre démarreur et DPCC associé

La coordination au courant d'intersection entre démarreur et DPCC est un essai spécial. La manière de la vérifier est décrite à l'Article B.4.

8.2.5.3 Essai de coordination entre un démarreur assigné AC-3e et le DPCC associé

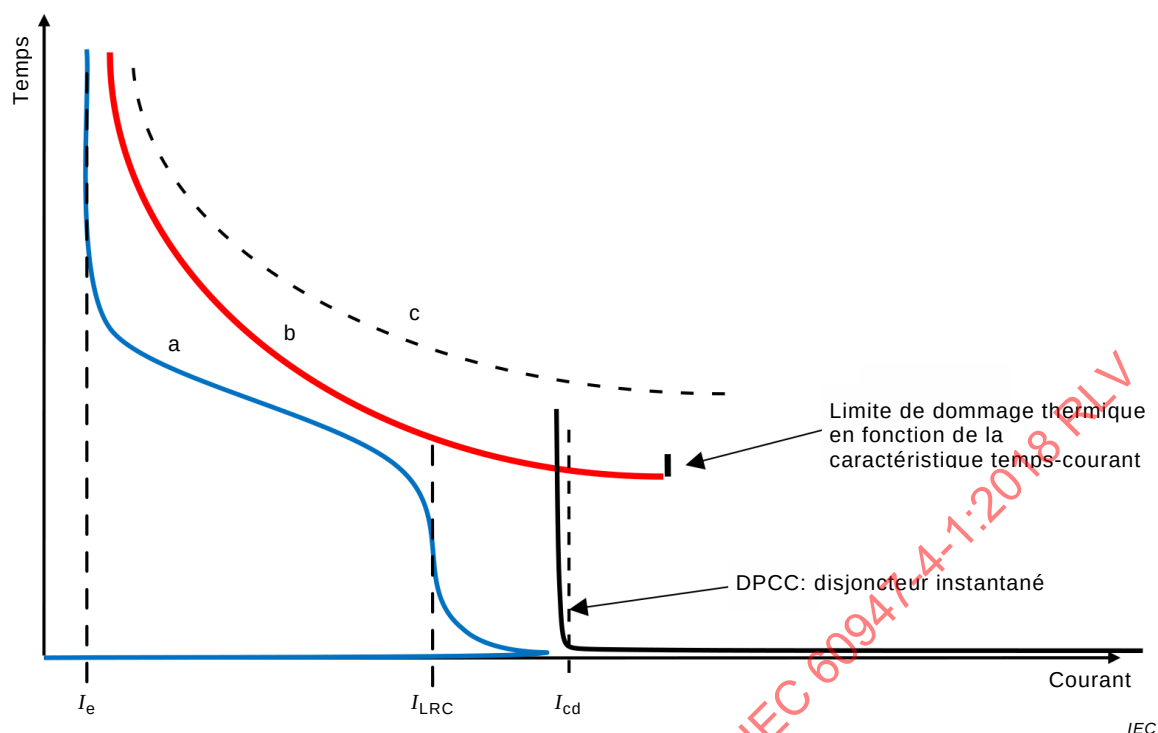
8.2.5.3.1 Généralités

Pour les démarreurs assignés AC-3e avec coordination de type 2, l'essai de coordination de 8.2.5.3.2 doit être réalisé.

Cet essai vise à vérifier la coordination du démarreur assigné AC-3e et le DPCC associé (disjoncteur instantané), dans lequel la protection contre les surcharges du démarreur déclenche le contacteur en cas de court-circuit des courants de défaut inférieurs au courant de déclenchement du DPCC (disjoncteur instantané). L'essai est réalisé à un courant de défaut simulé I_{cd} juste au-dessus du courant de déclenchement du DPCC.

Le courant I_{cd} est déterminé par le fabricant en fonction des caractéristiques du DPCC associé données au point p) de 6.1.2, afin d'assurer la coordination décrite à la Figure 3 avec un facteur de puissance donné dans le tableau 16 de l'IEC 60947-1:2007. Cet essai n'est pas nécessaire si le courant de défaut déterminé I_{cd} est inférieur ou égal au courant établi et de coupure soumis à l'essai pour AC-3e.

NOTE Un moteur asynchrone de conception NE ou HE peut présenter un courant d'appel plus élevé, ce qui implique un réglage supérieur du courant de déclenchement du DPCC. Par conséquent, le pouvoir de coupure du contacteur est vérifié à une valeur supérieure au pouvoir de fermeture et de coupure du Tableau 7.



Légende

- a courant de démarrage type du moteur
- b caractéristique temps-courant moyenne du relais de surcharge à partir de l'état froid
- c capacité de tenue temps-courant du contacteur selon 9.3.5

Figure 3 – Exemples de caractéristiques de coordination d'un démarreur

8.2.5.3.2 Procédure d'essai de coordination AC-3e

Les conditions d'essai de 8.3.3.5 de l'IEC 60947-1:2007 s'appliquent avec les ajouts suivants.

- Procédure d'essai: le contacteur ou le démarreur doit couper le courant d'essai (I_{cd}) pour le nombre de cycles de manœuvres donné dans le Tableau 15. Cela est fait sans le DPCC dans le circuit.

Tableau 15 – Procédure d'essai pour I_{cd}

	U_r/U_e	$\cos \phi$	Durée à l'état passant ^b s	Durée à l'état non passant s	Nombre de manœuvres
I_{cd}	1,05	a	0,05	c	3
NOTE Pour la prochaine édition, ce tableau, ainsi que le présent paragraphe, sera reproduit à la fin de 9.3.4 et est donc numéroté différemment des autres tableaux du présent document.					
a Facteur de puissance à déterminer selon le Tableau 16 de l'IEC 60947-1:2007.					
b La durée peut être inférieure à 0,05 s, à condition que les contacts puissent être convenablement positionnés avant réouverture.					
c Voir le Tableau 8.					

- Comportement des contacteurs et démarreurs pendant et après l'essai I_{cd} :
 - a) au cours de l'essai, il ne doit se produire ni arc permanent, ni amorçage entre pôles, ni fusion de l'élément fusible inséré dans le circuit de terre (voir 9.3.3.5.2), ni soudure des contacts.

b) après l'essai:

- 1) les contacts doivent fonctionner correctement lorsque le contacteur ou le démarreur est manœuvré par le mode de commande approprié;
- 2) les propriétés diélectriques des contacteurs et des démarreurs doivent être vérifiées par un essai diélectrique sur le contacteur ou le démarreur avec une tension d'essai essentiellement sinusoïdale égale à deux fois la tension assignée d'emploi U_e utilisée pour l'essai I_{cd} , avec un minimum de 1 000 V. La tension d'essai doit être appliquée conformément à 8.3.3.4.1 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD2:2014, point 4.

8.2.5.4 Coordination entre un ACPM et un autre dispositif de protection contre les courts-circuits

Pour la coordination entre un ACPM et un autre dispositif de protection contre les courts-circuits, voir l'Annexe Q.

8.3 Compatibilité électromagnétique (CEM)

8.3.1 Généralités

Le 7.3.1 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 s'applique avec l'ajout suivant.

Les essais au champ magnétique à la fréquence industrielle ne sont pas exigés, étant donné que les appareils sont naturellement soumis à ce type de champs. L'immunité est démontrée par la réussite des essais d'aptitude au fonctionnement en service (voir 9.3.3.5 et 9.3.3.6).

Ce matériel est par nature sensible aux creux de tension et aux interruptions de courte durée sur l'alimentation de la commande. Il doit réagir dans les limites de 8.2.1.2, ce qui est vérifié par les essais de limites de fonctionnement donnés en 9.3.3.2.

Les niveaux d'essai d'immunité du présent document, reposant sur les exigences de l'IEC 60947-1, correspondent à l'environnement industriel sévère défini dans l'IEC 61000-6-2. Des niveaux d'essai d'immunité plus élevés peuvent s'avérer nécessaires pour les postes haute tension extérieurs (voir l'IEC 61000-6-5).

8.3.2 Immunité

8.3.2.1 Matériel ne comprenant pas de circuits électroniques

Le 7.3.2.1 de l'IEC 60947-1:2007 s'applique.

8.3.2.2 Matériel comprenant des circuits électroniques

Le 7.3.2.2 de l'IEC 60947-1:2007, IEC 60947-1:2007/AMD1:2010 s'applique avec l'ajout suivant.

Les résultats d'essai sont spécifiés en utilisant les critères de performances donnés dans le Tableau 16.