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Responsible committee: PEL/121/1 Low voltage switchgear and controlgear

Interested committees:

Title: Draft BS IEC 60947-10 ED1. Low-voltage switchgear and controlgear

Part 10: Semiconductor Circuit-Breakers

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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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UK Vote

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



121A/565/CD

COMMITTEE DRAFT (CD)

PROJECT NUMBER:
IEC 60947-10 ED1

DATE OF CIRCULATION:
2023-06-30

CLOSING DATE FOR COMMENTS:
2023-09-22

SUPERSEDES DOCUMENTS:
121A/489/CD, 121A/517A/CC

IEC SC 121A : LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR	
SECRETARIAT: France	SECRETARY: Mr Michaël LAHEURTE
OF INTEREST TO THE FOLLOWING COMMITTEES: TC 9,TC 22,SC 22G,TC 23,SC 23E,TC 44,TC 64,TC 69	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CD to the secretary.
FUNCTIONS CONCERNED: ☒ EMC ☐ ENVIRONMENT ☐ QUALITY ASSURANCE ☒ SAFETY	

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TITLE:

Low-voltage switchgear and controlgear – Part 10: Semiconductor Circuit-Breakers

NOTE FROM TC/SC OFFICERS:

SC121A Officers support circulation of CD2 for project IEC 60947-10 ED1.

Secretary Note1: NC experts are kindly requested to refer their comments to line number.

Secretary Note2: text highlighted is related to missing cross references as this stage and PT 60947-10 does not expect comments from NCs on this.

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CONTENTS

1	FOREWORD.....	9
2	1 Scope.....	11
3	2 Normative references	11
4	3 Terms, definitions, symbols and reference clauses	13
5	3.1 General.....	13
6	3.2 General terms and definitions	13
7	4 Classification.....	16
8	4.1 According to type	16
9	4.2 According to the method of controlling the operating mechanism	16
10	4.3 According to operation on fault conditions for overload.....	16
11	4.4 According to the method of controlling the operation	16
12	4.5 According to the provision for maintenance:.....	16
13	4.6 According to the provision for software upgrade of embedded software	16
14	4.7 According to the method of installation	16
15	4.8 According to communication method.....	16
16	4.9 Behaviour in case of loss of control circuit supply:	16
17	4.10 According to the source of control circuit supply.....	17
18	4.10.1 Self-powered by the current (functionally independent of line voltage or of an external supply).....	17
19	4.10.2 Dependent on line voltage	17
20	4.10.3 Dependent on an external supply”	17
21	4.11 According to the degree of protection provided by the enclosure (see 8.1.12 of IEC 60947-1:2020)	17
22	4.12 According to the direction of current flow and protection.....	17
23	4.12.1 Circuit-breakers protecting only in one direction of current, and enabling the current only in that direction	17
24	4.12.2 Circuit-breakers protecting only in one direction of current, and enabling the current in both directions	17
25	4.12.3 Circuit-breakers protecting in both directions of current, and enabling the current in both directions	17
26	4.13 According to the existence of a standby state	17
27	4.14 According to the integral cooling method of the breaker	17
28	5 Characteristics of semiconductor circuit-breaker.....	17
29	5.1 Summary of characteristics	17
30	5.2 Type of circuit-breaker	17
31	5.3 Rated and limiting values of the main circuit	18
32	5.3.1 General	18
33	5.3.2 Rated voltages.....	18
34	5.3.3 Currents	18
35	5.3.4 Rated frequency.....	19
36	5.3.5 Rated duty	19
37	5.3.6 Short-circuit characteristics	19
38	5.4 Electrical Control Circuits	20
39	5.5 Auxiliary Circuits	20
40	5.6 Releases	20
41	5.6.1 Release functions	20
42	5.6.2 Characteristics	21

50	5.6.3	Current setting of over-current releases	21
51	5.6.4	Tripping time setting of over-current releases	22
52	6	Product information	22
53	6.1	Nature of the information	22
54	6.2	Marking.....	22
55	6.3	Instructions for installation, operation and maintenance instructions, decommissioning and dismantling.....	22
57	7	Normal service, mounting and transport conditions	22
58	8	Constructional and performance requirements	23
59	8.1	Constructional requirements	23
60	8.1.1	General	23
61	8.1.2	Withdrawable circuit-breakers	23
62	8.1.3	Requirements for isolation function	24
63	8.1.4	Clearances and creepage distances	24
64	8.1.5	Requirements for the safety of the operator	24
65	8.1.6	List of construction breaks.....	24
66	8.1.7	Additional requirements for circuit-breakers provided with a neutral pole	24
67	8.1.8	Digital inputs and outputs for use with programmable logic controllers (PLCs)	24
69	8.1.9	Indication of the standby state position	25
70	8.1.10	Fault on components.....	25
71	8.2	Performance requirements	25
72	8.2.1	Operating conditions	25
73	8.2.2	Temperature-rise	26
74	8.2.3	Dielectric properties	27
75	8.2.4	Ability to make and break under no load, normal load and overload conditions	28
77	8.2.5	Ability to make and break under short-circuit conditions	28
78	8.2.6	Requirements for isolation function	28
79	8.3	Electromagnetic compatibility (EMC).....	28
80	9	Tests	28
81	9.1	Kind of tests.....	28
82	9.1.1	General	28
83	9.1.2	Type tests.....	29
84	9.1.3	Routine tests	29
85	9.1.4	Special tests	29
86	9.2	Compliance with constructional requirements.....	29
87	9.2.1	General	29
88	9.2.2	Breakdown of components	29
89	9.3	Type tests	30
90	9.3.1	General	30
91	9.3.2	Test sequences.....	30
92	9.3.3	General test conditions	31
93	9.3.4	Test sequence I: General performance characteristics	38
94	9.3.5	Test sequence II: Rated service short-circuit breaking capacity	48
95	9.3.6	Test sequence III: Rated ultimate short-circuit breaking capacity	49
96	9.3.7	Components tests	50
97	9.3.8	Rated individual pole ultimate short-circuit breaking capacity at phase- to-neutral AC voltage	50
99	9.3.9	Maximum admissible short-circuit current rate of rise	51

100	9.3.10	Additional verifications for circuit-breakers dependent on line voltage (4.10.2) or on an external voltage (4.10.3)	52
102	9.4	Routine tests	53
103	9.4.1	General	53
104	9.4.2	Mechanical operation tests	53
105	9.4.3	Verification of the calibration of overcurrent releases	53
106	9.4.4	Verification of the operation of undervoltage and shunt releases	54
107	9.4.5	Dielectric tests	54
108	9.4.6	Test for the verification of clearances less than those corresponding to case A of Table 13 of IEC 60947-1:2020.....	55
110	9.5	Special tests – Damp heat, salt mist, vibration and shock.....	55
111	Annex A (normative)	Coordination between a circuit-breaker and another short-circuit protective device associated in the same circuit	77
113	Annex B (normative)	Circuit-breakers incorporating residual current protection	78
114	Annex C (normative)	Individual pole short-circuit test sequence	79
115	C.1	General.....	79
116	C.2	Test of individual pole short-circuit breaking capacity	79
117	C.3	Verification of dielectric withstand and leakage current	79
118	C.4	Verification of overload releases	79
119	Annex D (normative)	Additional requirements for circuit-breakers intended for connection of aluminium conductors	80
121	Annex E (void)		81
122	Annex F (normative)	Additional tests for circuit-breakers with electronic overcurrent protection	82
124	F.1	General.....	82
125	F.2	List of tests	82
126	F.2.1	General	82
127	F.2.2	Electromagnetic compatibility (EMC) tests	82
128	F.2.3	Suitability for multiple frequencies	82
129	F.2.4	Dry heat test	83
130	F.2.5	Damp heat test	83
131	F.2.6	Temperature variation cycles at a specified rate of change	83
132	F.3	General test conditions.....	83
133	F.3.1	General	83
134	F.3.2	Electromagnetic compatibility tests	83
135	F.4	Immunity tests.....	84
136	F.4.1	Harmonic currents.....	84
137	F.4.2	Electrostatic discharges	85
138	F.4.3	Radiated RF electromagnetic fields	85
139	F.4.4	Electrical fast transient/burst (EFT/B)	86
140	F.4.5	Surges	86
141	F.4.6	Conducted disturbances induced by RF fields (common mode)	86
142	F.4.7	Current dips.....	86
143	F.5	Emission tests.....	87
144	F.5.1	Harmonics	87
145	F.5.2	Voltage fluctuations.....	87
146	F.5.3	Conducted RF disturbances (150 kHz to 30 MHz)	87
147	F.5.4	Radiated RF disturbances (30 MHz to 1 GHz).....	87
148	F.6	Suitability for multiple frequencies	88
149	F.6.1	General	88
150	F.6.2	Test conditions	88

151	F.6.3	Test procedure.....	88
152	F.6.4	Test results.....	88
153	F.7	Dry heat test	89
154	F.7.1	Test procedure.....	89
155	F.7.2	Test results.....	89
156	F.7.3	Verification of overload releases.....	89
157	F.8	Damp heat test.....	89
158	F.8.1	Test procedure.....	89
159	F.8.2	Verification of overload releases.....	89
160	F.9	Temperature variation cycles at a specified rate of change.....	90
161	F.9.1	Test conditions	90
162	F.9.2	Test procedure.....	90
163	F.9.3	Test results.....	90
164	F.9.4	Verification of overload releases.....	90
165	Annex G (normative)	Power Loss	105
166	Annex H (normative)	Test sequence for circuit-breakers for IT systems.....	106
167	H.1	General.....	106
168	H.2	Individual pole short-circuit.....	106
169	H.3	Verification of dielectric withstand and leakage current	107
170	H.4	Verification of overload releases.....	107
171	H.5	Marking.....	107
172	Annex I (normative)	Determination of reliability.....	108
173	I.1	General method	108
174	I.2	Reliability.....	108
175	Annex J (normative)	Electromagnetic compatibility (EMC) – Requirements and test methods for circuit-breakers.....	109
177	J.1	General.....	109
178	J.2	Immunity.....	109
179	J.2.1	General	109
180	J.2.2	Electrostatic discharges	113
181	J.2.3	Radiated RF electromagnetic fields	114
182	J.2.4	Electrical fast transients/bursts (EFT/B).....	114
183	J.2.5	Surges.....	114
184	J.2.6	Conducted disturbances induced by RF fields (common mode)	114
185	J.3	Emission.....	115
186	J.3.1	General	115
187	J.3.2	Conducted RF disturbances (150 kHz to 30 MHz).....	116
188	J.3.3	Radiated RF disturbances (30 MHz to 6 000 MHz).....	116
189	Annex K (informative)	Glossary of symbols and graphical representation of characteristics	121
190	Annex L (normative)	Circuit-breakers not fulfilling the requirements for overcurrent protection	123
192	Annex M (normative)	Modular residual current devices (without integral current breaking device)	124
194	Bibliography		125
195			
196			

197	Figure 1 – Test arrangement (connecting cables not shown) for short-circuit tests.....	70
198	Figure 2 – example of diagram for the temperature stabilization (see 9.3.3.7) of three-	
199	pole AC circuit-breakers (when tested in 9.3.4.6 or in 9.3.9) and for single-pole DC	
200	circuit-breakers.....	71
201	Figure 3 – example of diagram for the temperature stabilization (see 9.3.3.7) of two-	
202	pole DC circuit-breakers	72
203	Figure 4 – example of diagram for the temperature stabilization (see 9.3.3.7) of three-	
204	pole AC circuit-breakers (when tested in 9.3.4.6 or in 9.3.9)	73
205	Figure 5 – Test of withstand to surges for AC circuit-breakers.....	74
206	Figure 6 – Test of withstand to surges for DC circuit-breakers	75
207	Figure 7 – Test circuit for the breaking operation of circuit breakers that cannot be	
208	switched to the closed position without line power for the “O” operation	76
209	Figure F.1 – Representation of test current produced by back-to-back thyristors in	
210	accordance with F.4.1	91
211	Figure F.2 – Test circuit for immunity and emission tests in accordance with F.4.1.3,	
212	F.4.2, F.4.3, 0, F.4.7.1, F.5.4 and F.6.3 – Two phase poles in series	92
213	Figure F.3 – Test circuit for immunity and emission tests in accordance with F.4.1.3,	
214	F.4.2, F.4.3, 0, F.4.7.1, F.5.4 and F.6.3 – Three phase poles in series	92
215	Figure F.4 – Test circuit for immunity and emission tests in accordance with F.4.1.3,	
216	F.4.2, F.4.3, 0, F.4.7.1, F.5.4 and F.6.3 – Three-phase connection	93
217	Figure F.5 – Test current for the verification of the influence of the current dips and	
218	interruptions in accordance with F.4.7.1	93
219	Figure F.6 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in	
220	accordance with F.4.4 – Two phase poles in series	94
221	Figure F.7 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in	
222	accordance with F.4.4 – Three phase poles in series	94
223	Figure F.8 – Circuit for electrical fast transients/bursts (EFT/B) immunity test in	
224	accordance with F.4.4 – Three-phase connection	95
225	Figure F.9 – Test circuit for the verification of the influence of surges in the main circuit	
226	(line-to-earth) in accordance with F.4.5 – Two phase poles in series	95
227	Figure F.10 – Test circuit for the verification of the influence of surges in the main	
228	circuit (line-to-earth) in accordance with F.4.5 – Three phase poles in series	96
229	Figure F.11 – Test circuit for the verification of the influence of surges in the main	
230	circuit (line-to-earth) in accordance with F.4.5 – Three-phase connection.....	96
231	Figure F.12 – Test circuit for the verification of the influence of current surges in the	
232	main circuit in accordance with F.4.5 – Two phase poles in series	97
233	Figure F.13 – Test circuit for the verification of the influence of current surges in the	
234	main circuit in accordance with F.4.5 – Three phase poles in series	97
235	Figure F.14 – Test circuit for the verification of the influence of current surges in the	
236	main circuit in accordance with F.4.5 – Three-phase connection	98
237	Figure F.15 – Temperature variation cycles at a specified rate of change in	
238	accordance with F.9.1	98
239	Figure F.16 – General test set-up for immunity tests	99
240	Figure F.17 – Test set-up for the verification of immunity to radiated RF	
241	electromagnetic fields	100
242	Figure F.18 – Test set-up for the verification of immunity to electrical fast	
243	transients/bursts (EFT/B) on power lines	100
244	Figure F.19 – Test set-up for verification of immunity to electrical fast transients/bursts	
245	(EFT/B) on signal lines.....	101
246	Figure F.20 – General test set-up for the verification of immunity to conducted	
247	disturbances induced by RF fields (common mode)	101

248	Figure F.21 – Arrangement of connections for the verification of immunity to conducted	
249	disturbances induced by RF fields – Two phase poles in series configuration	102
250	Figure F.22 – Arrangement of connections for the verification of immunity to conducted	
251	disturbances induced by RF fields – Three phase poles in series configuration	103
252	Figure F.23 – Arrangement of connections for the verification of immunity to	
253	conducted disturbances induced by RF fields – Three-phase configuration.....	104
254	Figure J.1 – EUT mounted in a metallic enclosure	117
255	Figure J.2 – Test set up for the measurement of radiated RF emissions	118
256	Figure J.3 – Test set up for the verification of immunity to electrostatic discharges	119
257	Figure J.4 – Test set up for the verification of immunity to radiated RF electromagnetic	
258	fields	119
259	Figure J.5 – Test set up for the verification of immunity to electrical fast	
260	transients/bursts (EFT/B) on power lines	120
261	Figure J.6 – Test set up for the verification of immunity to electrical fast	
262	transients/bursts (EFT/B) on signal lines	120
263		
264	Table 1 – Ratio n between short-circuit making capacity and short-circuit breaking	
265	capacity and related power factor (for AC circuit-breakers) (see 5.3.6.3)	57
266	Table 2 – (vacant).....	57
267	Table 3 – Preferred values of the rated control supply voltage, if different from that of	
268	the main circuit	57
269	Table 4 – Product information	57
270	Table 5 – Characteristics of the opening operation of inverse time-delay over-current	
271	opening releases at the reference temperature	59
272	Table 6 – Temperature-rise limits for terminals and accessible parts	59
273	Table 7 – Number of operating cycles	59
274	Table 8 – Type tests	60
275	Table 9 – Alphabetical index of tests	60
276	Table 10 – Overall schema of test sequences ^a	61
277	Table 11 – Applicability of test sequences according to the relationship between I_{CS} ,	
278	and I_{CU}	61
279	Table 12 – Principle for the application of the alternative test programs	62
280	Table 13 – Applicability of tests or test sequences to 1, 2 and 4-pole circuit-breakers	
281	according to the alternative program 1 of 9.3.2.4	63
282	Table 14 – Applicability of tests or test sequences to 1, 2 and 3-pole circuit-breakers	
283	according to the alternative program 2 of 9.3.2.4	64
284	Table 15 – Number of samples for test (1 of 2)	66
285	Table 15 (2 of 2)	67
286	Table 16 – Values of power factors and time constants corresponding to test currents	68
287	Table 17 – Test sequences I	68
288	Table 18 – Test circuit characteristics for overload performance	68
289	Table 19 – Test sequence II: Rated service short-circuit breaking capacity	69
290	Table 20 – Test sequence III: Rated ultimate short-circuit breaking capacity	69
291	Table 21 – Test sequence: Rated individual pole ultimate short-circuit breaking	
292	capacity at phase-to-neutral AC voltage	69
293	Table C.1 – Tests of Annex C	79
294	Table F.1 – Test parameters for current dips and interruptions.....	87
295	Table H.2 – Product information	107

296	Table J.1 – EMC – Immunity tests	111
297	Table J.2 – Reference data for immunity test specifications	113
298	Table J.3 – EMC – Emission tests	116
299	Table J.4 – Reference data for emission test specifications	116
300	Table K.1 – symbols and graphical representation of characteristics	121
301		

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –
Part 10: Semiconductor circuit-breakers****FOREWORD**

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IEC 60947-10 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 International Standard is based on the following documents:

FDIS	Report on voting
121A/XX/FDIS	121A/XX/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.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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

- 355 • reconfirmed,
- 356 • withdrawn,
- 357 • replaced by a revised edition, or
- 358 • amended.

359

360 The National Committees are requested to note that for this document the stability date
361 is 20XX....

362 THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED
363 AT THE PUBLICATION STAGE.

364

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 10: Semiconductor circuit-breakers

1 Scope

This part of IEC 60947 series applies to semiconductor circuit-breakers, intended to be installed and operated by instructed or skilled persons, the main terminals of which are intended to be connected to circuits, the rated voltage of which does not exceed 1 000 V a.c. or 1 500 V d.c.

This standard covers the following different types:

- Semiconductor Circuit-Breakers (SCCBs) have semiconductor switching elements and, for isolation function mechanical switching elements connected in series.
- Semiconductor Hybrid Circuit-Breakers (SCHCBs) have semiconductor switching elements and mechanical switching elements in parallel and, in addition, for isolation function, mechanical switching elements connected in series.

In this document where the term “Circuit-Breaker” only is used, it applies to both types.

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

The object of this document is to state:

- a) the characteristics of circuit-breakers;
- b) the conditions with which circuit-breakers shall comply with reference to:
 - 1) operation and behaviour in normal service;
 - 2) operation and behaviour in case of overload and operation and behaviour in case of short-circuit, including co-ordination in service (selectivity and back-up protection);
 - 3) dielectric properties;
 - 4) requirements on electromagnetic compatibility, where applicable.
- c) tests intended for confirming that these conditions have been met and the methods to be adopted for these tests;
- d) information to be marked on or given with the circuit-breakers.

NOTE For cybersecurity requirements, see IEC TS 63208

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

AEC - Q101: *Failure mechanism based stress test qualification for discrete semiconductors in automotive applications*

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

IEC 60068-2-30, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*

IEC 60269-1:2006/AMD1:2009

IEC 60269-1:2006/AMD2:2014

- 407 IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage systems – Part 1:*
408 *Principles, requirements and tests*
- 409 IEC 60947-1:2020, *Low-voltage switchgear and controlgear – Part 1: General rules*
- 410 IEC 60947-2:202X¹, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*
- 411 IEC 61000-3-2, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic*
412 *current emissions (equipment input current ≤ 16 A per phase)*
- 413 IEC 61000-3-3, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage*
414 *changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment*
415 *with rated current ≤ 16 A per phase and not subject to conditional connection*
- 416 IEC 61000-4-2:2008 *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement*
417 *techniques – Electrostatic discharge immunity test*
- 418 IEC 61000-4-3:2020, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and*
419 *measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
420
- 421 IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and*
422 *measurement techniques – Electrical fast transient/burst immunity test*
- 423 IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and*
424 *measurement techniques – Surge immunity test*
425 IEC 61000-4-5:2014/AMD1:2017
- 426 IEC 61000-4-6:2013, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and*
427 *measurement techniques – Immunity to conducted disturbances, induced by radio-frequency*
428 *fields*
- 429 IEC 61000-4-11:2020 *Electromagnetic compatibility (EMC) – Part 4-11: Testing and*
430 *measurement techniques – Voltage dips, short interruptions and voltage variations immunity*
431 *tests*
- 432 IEC 62475:2010, *High-current test techniques – Definitions and requirements for test currents*
433 *and measuring systems*
- 434 CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance*
435 *characteristics – Limits and methods of measurement*
436 CISPR 11:2015/AMD1:2016
- 437 CISPR 32:2015, *Electromagnetic compatibility of multimedia equipment – Emission*
438 *requirements*
- 439 JEDEC JESD22-A104, *Temperature cycling*
- 440 JEDEC JESD22-A105, *Power and temperature cycling*
- 441 JEDEC JESD22-A106, *Thermal shock*
- 442 JEDEC JESD22-A108, *Temperature, bias, and operating life*
- 443 JEDEC JESD22-B103, *Vibration, variable frequency*

¹ IEC 60947-2:202X being at AFDIS stage

444 JEDEC JESD47, *Stress-test-driven qualification of integrated circuit*

445 **3 Terms, definitions, symbols and reference clauses**

446 **3.1 General**

447 For the purposes of this document, the terms and definitions given in IEC 60947-1:2020 and
448 IEC 60947-2:202X², apply unless a term or definition is given below.

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

- 451 • IEC Electropedia: available at <https://www.electropedia.org/>
- 452 • ISO Online browsing platform: available at <https://www.iso.org/obp>

453 NOTE Where these definitions are taken unchanged from the *International Electrotechnical Vocabulary (IEV)*,
454 IEC 60050-441, the reference to this publication is given in brackets.

455 **3.2 General terms and definitions**

456 **3.2.1** 457 **semiconductor circuit-breaker (SCCB)**

458 protective device with semiconductor switching elements and, for isolation function mechanical
459 switching elements connected in series, capable of making, carrying and breaking currents
460 under normal circuit conditions and also making, carrying for a specified time and breaking
461 currents under specified abnormal circuit conditions such as those of short-circuit.

462 [SOURCE: IEC 60050-441:1984, 441-14-20, modified]

463 Note 1 to entry: the term “solid state” is often used as a synonymous of “semiconductor”

464 **3.2.2** 465 **semiconductor hybrid circuit-breaker (SCHCB)**

466 protective device with semiconductor switching elements and, for isolation function mechanical
467 switching elements connected in series and have additionally mechanical switching elements
468 in parallel to the semiconductor switching elements to reduce the power loss capable of making,
469 carrying and breaking currents under normal circuit conditions and also making, carrying for a
470 specified time and breaking currents under specified abnormal circuit conditions such as those
471 of short-circuit.

472 [SOURCE: IEC 60050-441:1984, 441-14-20, modified]

473 **3.2.3** 474 **plug-in semiconductor circuit-breaker**

475 device which, in addition, has a set of exterior contacts which enable the semiconductor circuit
476 breakers to be connected.

477 **3.2.4** 478 **withdrawable semiconductor circuit-breaker**

479 device which has a set of connectors which enable the semiconductor circuit-breakers to be
480 withdrawn from the main circuit, and, when placed in the disconnected position, achieves an
481 isolating distance in accordance with specified requirements

482 **3.2.5** 483 **remote control**

484 allows a semiconductor circuit-breaker to be controlled other than by hand

² IEC 60947-2:202X being at AFDIS stage

3.2.6**break time**

interval of time between the specified instant of initiation of the breaking operation and the instant when the current is equal to or lower than the maximum leakage current in standby state.

Note 1 to entry:

– in the case of breaking due to overcurrent, the instant of initiation of the breaking operation is the instant of initiation of a current large enough to cause the circuit-breaker to operate;

– in the case of breaking due to any form of external command, the instant of initiation of the breaking operation is the instant of application of the command.

Note 2 to entry: at the end of the breaking operation the circuit-breaker is not necessarily in open state.

Note 3 to entry: for semiconductor circuit-breakers (SCCBs), the breaking operation does not necessarily involve any mechanical separation of contacts.

3.2.7**commitment time**

interval of time between the specified instant of initiation of the breaking operation and the time when the operating algorithm has committed to trip.

Note 1 to entry:

– in the case of breaking due to overcurrent, the instant of initiation of the breaking operation is the instant of initiation of a current large enough to cause the circuit-breaker to operate;

– in the case of breaking due to any form of external command, the instant of initiation of the breaking operation is the instant of application of the command.

3.2.8**interrupting time**

interval of time between the specified instant of the initiation of the turn-off of the power semiconductor and the instant when the current is equal to or lower than the maximum maximum leakage current in standby state.

3.2.9**isolation time**

interval of time between the specified instant of the initiation of the breaking operation and the instant when the circuit-breaker is in open state.

3.2.10**isolation contacts**

mechanical contacts ensuring the suitability for isolation of the semiconductor circuit-breaker or the semiconductor hybrid circuit-breaker.

3.2.11**parallel mechanical contacts**

of an SCHCB

Integral mechanical switching elements in parallel to the power semiconductor.

3.2.12**open position****open state**

state in which the isolation contacts are open, and the predetermined dielectric withstand voltage requirements between the line and load terminals of the device are satisfied.

3.2.13**closed position****closed state**

position in which the predetermined continuity of the main circuit of the circuit breaker is secured.

3.2.14**standby position**

position (or state) in which:

- the isolation contacts are in closed position, and
- the power semiconductor is switched off and,
- for SCHCBs, the parallel mechanical contacts are open

Note 1 to entry: Standby position is an intentional state of an SCCB or SCHCB waiting for a closing or opening command and not a transitory phase of a switching operation.

3.2.15**power semiconductor**

semiconductor component used to conduct and interrupt the current in the main circuit in a SCCB, and to interrupt the current in the main circuit in a SCHCB.

3.2.16**leakage current**

of a SCCB or a SCHCB in standby state

electric current through each pole in standby state under a defined voltage and testing conditions.

3.2.17**main circuit**

of a semiconductor circuit-breaker

all the conductive parts or components of the semiconductor circuit-breaker, included in the circuit which is intended to carry, make, or break the current to the load.

3.2.18**minimum operating voltage (U_x)**

minimum operating voltage, where applicable, as declared by the manufacturer for circuit-breakers.

3.2.19**short-circuit current rate of rise**

$$\frac{\Delta i}{\Delta t}$$

rate of rise of the short-circuit current between the instant of the initiation of the short-circuit and the instant t_1

$$\frac{\Delta i}{\Delta t} = \frac{(i_1 - i_0)}{(t_1 - t_0)}$$

where:

- t_0 is the instant of initiation of the short-circuit
- i_0 is the current value at the instant t_0
- t_1 is the time to get the current value equal to i_1
- i_1 is equal to 10 times the rated current or the peak current, whatever is the lowest.

3.2.20**maximum admissible short-circuit current rate of rise**

$$\left(\frac{\Delta i}{\Delta t}\right)_{max}$$

maximum admissible rate of rise of the short-circuit current assigned to the circuit-breaker.

4 Classification

4.1 According to type

- semiconductor circuit-breaker (SCCB), see 3.2.1
- semiconductor hybrid circuit-breaker (SCHCB), see 3.2.2

4.2 According to the method of controlling the operating mechanism

- dependent manual operation;
- independent manual operation;
- dependent power operation;
- independent power operation;
- stored energy operation;
- operation in standby position.

4.3 According to operation on fault conditions for overload

- following an overload fault, going into the open position
- following an overload fault, going into standby

4.4 According to the method of controlling the operation

- with remote operation
- without remote operation.

4.5 According to the provision for maintenance:

- maintainable;
- non-maintainable.

4.6 According to the provision for software upgrade of embedded software

- on site
- remotely
- none

4.7 According to the method of installation

- fixed;
- plug-in.
- withdrawable.

4.8 According to communication method

- no communication;
- with communication (e.g. for parametrization, operating actions, measuring...)

4.9 Behaviour in case of loss of control circuit supply:

- the device restores power to the load when the control circuit supply is restored.
- the device goes in standby with or without delay, in the event of a control circuit supply voltage drop to a value less than U_x and does not restore power to the load automatically.
- the device opens automatically, with or without delay, in the event of a control circuit supply voltage drop to a value less than U_x and does not restore power to the load automatically.

4.10 According to the source of control circuit supply**4.10.1 Self-powered by the current (functionally independent of line voltage or of an external supply)****4.10.2 Dependent on line voltage****4.10.3 Dependent on an external supply"****4.11 According to the degree of protection provided by the enclosure (see 8.1.12 of IEC 60947-1:2020)****4.12 According to the direction of current flow and protection****4.12.1 Circuit-breakers protecting only in one direction of current, and enabling the current only in that direction****4.12.2 Circuit-breakers protecting only in one direction of current, and enabling the current in both directions****4.12.3 Circuit-breakers protecting in both directions of current, and enabling the current in both directions****4.13 According to the existence of a standby state**

– with a standby state

– without standby state

4.14 According to the integral cooling method of the breaker

– with active cooling

– with passive cooling

5 Characteristics of semiconductor circuit-breaker**5.1 Summary of characteristics**

The characteristics of a semiconductor circuit-breaker shall be stated in terms of the following, as applicable:

- type of circuit-breaker (5.2);
- rated and limiting values of the main circuit (5.3);
- selectivity categories (XX);
- control circuits (5.4);
- auxiliary circuits (5.5);
- releases (5.6);

5.2 Type of circuit-breaker

The following shall be stated:

- type of semiconductor circuit-breaker (see 4.1);
- direction of current flow and protection (see 4.12);
- number of poles;
- number of protected poles;
- kind of current (AC or DC) and, in the case of AC, number of phases and rated frequency.

5.3 Rated and limiting values of the main circuit

5.3.1 General

The rated values of a semiconductor circuit-breaker shall be stated in accordance with 5.3.2 to 5.5, but it is not necessary to state I_{th} (5.3.3.1), I_{the} (5.3.3.2), rated frequency (5.3.4) in case of a DC only circuit-breaker, rated duty (5.3.5).

5.3.2 Rated voltages

5.3.2.1 Rated operational voltage (U_e)

Subclause 5.3.1.1 of IEC 60947-1:2020 applies with the following amplification:

– Circuit-breakers covered by clause 5.3.1.1 item a) of IEC 60947-1:2020.

U_e is generally stated as the voltage between phases.

NOTE 1 In Canada and the USA, the rated operational voltage U_e is stated as

a) the voltage between phases and earth, together with the voltage between phases (for example 277 V/480 V) for three-phase four-wire neutral earthed systems;

b) the voltage between phases (for example 480 V) for three-phase three-wire unearthed or impedance earthed systems.

Circuit-breakers for unearthed or impedance earthed systems (IT) require additional tests according to Annex H.

– Circuit-breakers covered by clause 5.3.1.1 item b) of IEC 60947-1:2020.

These circuit-breakers require additional tests according to Annex C.

U_e shall be stated as the voltage between phases preceded by the letter C.

NOTE 2 According to present practice in Canada and the USA, circuit-breakers covered by clause 5.3.1.1 item b) of IEC 60947-1:2020 are identified by the voltage between phases only.

5.3.2.2 Rated insulation voltage (U_i)

Subclause 5.3.1.2 of IEC 60947-1:2020 applies.

5.3.2.3 Rated impulse withstand voltage (U_{imp})

Subclause 5.3.1.3 of IEC 60947-1:2020 applies.

5.3.3 Currents

5.3.3.1 Conventional free-air thermal current (I_{th})

Subclause 5.3.2.1 of IEC 60947-1:2020 applies.

5.3.3.2 Conventional enclosed thermal current (I_{the})

Subclause 5.3.2.2 of IEC 60947-1:2020 applies.

5.3.3.3 Rated current (I_n)

For semiconductor circuit-breakers, the rated uninterrupted current (I_u) (see 5.3.2.4 of IEC 60947-1:2020) is equal to the conventional free-air thermal current (I_{th}).

5.3.4 Rated frequency

Subclause 5.3.3 of IEC 60947-1:2020 applies.

5.3.5 Rated duty

The rated duties considered as normal are:

- the eight-hour duty (see 5.3.4.1 of IEC 60947-1:2020),
- the uninterrupted duty (see 5.3.4.2 of IEC 60947-1:2020).

5.3.6 Short-circuit characteristics

5.3.6.1 Rated short-circuit making capacity (I_{cm})

The rated short-circuit making capacity of a circuit-breaker is the value of short-circuit making capacity assigned to that circuit-breaker by the manufacturer for the rated operational voltage at rated frequency and at a specified power factor for AC, or time constant for DC. It is expressed as the maximum prospective peak current.

For AC, the rated short-circuit making capacity of a circuit-breaker shall be not less than its rated ultimate short-circuit breaking capacity, multiplied by the factor n of Table 1 (see 5.3.6.3).

For DC, the rated short-circuit making capacity of a circuit-breaker shall be not less than its rated ultimate short-circuit breaking capacity.

A rated short-circuit making capacity implies that the circuit-breaker shall be able to make the current corresponding to that rated capacity at the appropriate applied voltage related to the rated operational voltage.

5.3.6.2 Rated short-circuit breaking capacities

5.3.6.2.1 General

The rated short-circuit breaking capacities of a circuit-breaker are the values of short-circuit breaking capacity assigned to that circuit-breaker by the manufacturer for the rated operational voltage, under specified conditions.

NOTE A circuit-breaker in accordance with this standard is able to break phase-to-phase, phase-to-earth and phase-to-neutral short-circuits

A rated short-circuit breaking capacity requires that the circuit-breaker shall be able to break any value of short-circuit current up to and including the value corresponding to the rated capacity at a power-frequency recovery voltage corresponding to the prescribed test voltage values and:

- for AC, at any power factor not less than those required in clause 9.3.3.2.4;
- for DC, with any time constant not greater than those required in clause 9.3.3.2.5.

For power-frequency recovery voltages in excess of the prescribed test voltage values (see 9.3.3.2.6), no short-circuit breaking capacity is guaranteed.

For AC, the circuit-breaker shall be capable of breaking a prospective current corresponding to its rated short-circuit breaking capacity and the related power factor given in Table 16, irrespective of the value of the inherent DC component, on the assumption that the AC component is constant.

The rated short-circuit breaking capacities are stated as:

- rated ultimate short-circuit breaking capacity I_{cu} ;
- rated service short-circuit breaking capacity I_{cs} .

5.3.6.2.2 Rated ultimate short-circuit breaking capacity (I_{cu})

The rated ultimate short-circuit breaking capacity of a circuit-breaker is the value of ultimate short-circuit breaking capacity (see 3.11.1 of IEC 60947-2:202X) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 9.3.6. It is expressed as the value of the prospective breaking current, in kA.

5.3.6.2.3 Rated service short-circuit breaking capacity (I_{cs})

The rated service short-circuit breaking capacity of a circuit-breaker is the value of service short-circuit breaking capacity (see 3.11.3 of IEC 60947-2:202X) assigned to that circuit-breaker by the manufacturer for the corresponding rated operational voltage, under the conditions specified in 9.3.5. 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 Standard relationship between short-circuit making and breaking capacities and related power factor, for AC circuit-breakers

The standard relationship between short-circuit breaking capacity and short-circuit making capacity is given in Table 1.

The rated short-circuit making and breaking capacities are only valid when the circuit-breaker is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

For special requirements, the manufacturer may assign a value of rated short-circuit making capacity higher than that required by Table 1. Tests to verify these rated values shall be the subject of agreement between manufacturer and user.

5.3.6.4 Maximum admissible short-circuit current rate of rise

$$\left(\frac{\Delta i}{\Delta t}\right)_{max}$$

Maximum admissible rate of rise of the short-circuit current (see 3.2.20) assigned to that circuit-breaker by the manufacturer, under the conditions specified in 9.3.9. It is expressed in A/μs.

5.4 Electrical Control Circuits

Subclause 5.5.1 of IEC 60947-1:2020 applies, with the following addition:

If the rated control supply voltage is different from that of the main circuit, it is recommended that its value be chosen from Table 3.

5.5 Auxiliary Circuits

Subclause 5.6 of IEC 60947-1:2020 applies.

5.6 Releases**5.6.1 Release functions**

For the purpose of this document, the following types of release functions are considered:

- 1) Shunt release function
- 2) Over-current release function:
 - a) instantaneous;
 - b) definite time delay;

c) inverse time delay:

- independent of previous load;
- dependent on previous load (for example thermal type release).

d) ground fault

NOTE 1 The term "overload release" is used to identify over-current releases intended for protection against overloads (see "3.6.31 of IEC 60947-1:2020). The term "short-circuit release" is used to identify over-current releases intended for protection against short circuits (see 3.7 of IEC 60947-2:202X).

NOTE 2 The term "adjustable release" used in this standard also includes interchangeable releases.

3) Undervoltage release function (for opening);

4) Closing release function;

5) Remote release function;

6) Other releases function.

5.6.2 Characteristics

The following characteristics shall be considered:

1) shunt release and undervoltage release (for opening), and closing release:

- rated control circuit voltage (U_c);
- kind of current;
- rated frequency, if AC;

2) over-current release:

- rated current (I_n);
- kind of current;
- rated frequency, if AC;
- current setting (or range of settings);
- time setting (or range of settings) if applicable.

The rated current of an over-current release is the value of current (RMS, if AC) corresponding to the maximum current setting which it shall be capable of carrying under the test conditions specified in 9.3.3.5, without the temperature-rise exceeding the values specified in Table 6.

5.6.3 Current setting of over-current releases

For circuit-breakers fitted with adjustable releases (see Note 2 to 5.6.1, item 2), the current settings shall be marked on the release, or displayed on the screen of the release, or displayed on screen of an external device connectable to the release. The information may be either directly in amperes or as a multiple of the current value. Means shall be provided by the manufacturer to read the display or the external device regardless of the status of the circuit-breaker. When applicable, the manufacturer shall specify the characteristics of the external device.

For circuit-breakers fitted with non-adjustable releases, the marking may be on the circuit-breaker. If the operating characteristics of the overload release comply with the requirements of Table 5, it will be sufficient to mark the circuit-breaker with its rated current (I_n).

The current settings may be adjusted through an external (local or remote) device connectable to the release, in which case either local setting indications shall not be exceeded, or a local indication shall show that the settings are controlled remotely. The manufacturer shall provide means to the testing laboratory to ensure settings do not change during type tests.

In the case of indirect releases operated by current transformers, 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 release. In either case, the ratio of the current transformer shall be stated.

Unless otherwise specified the operating current value of overload releases is independent of the ambient air temperature within the limits of $-5\text{ }^{\circ}\text{C}$ to $+40\text{ }^{\circ}\text{C}$.

5.6.4 Tripping time setting of over-current releases

The tripping time shall be stated as follows, depending on the type of over-current release:

1) Definite time-delay over-current releases

The time-delay of such releases is independent of the over-current. The tripping time setting shall be stated as the duration in seconds of the opening time of the circuit-breaker, if the time-delay is not adjustable, or the extreme values of the opening time, if the time-delay is adjustable.

2) Inverse time-delay over-current releases

The time-delay of such releases is dependent on the over-current.

The time/current characteristics shall be given by the manufacturer.

These curves shall be given for each extreme value of the current setting and, if the time setting for a given current setting is adjustable, it is recommended that they be given in addition for each extreme value of the time setting.

It is recommended that the current be plotted as abscissa and the time as ordinate, using logarithmic scales. Furthermore, in order to facilitate the study of co-ordination of different types of over-current protection, it is recommended that the current be plotted as multiples of the setting current and the time in seconds on the standard graph sheets detailed in 5.6.1 of IEC 60269-1:2006.

6 Product information

6.1 Nature of the information

Subclause 6.1 of IEC 60947-1:2020 applies, as far as appropriate for a particular design.

In addition, the manufacturer shall make available, upon request, information concerning typical power loss for the various frame sizes (see 3.1.1 of IEC 60947-2:202X). See Annex G.

6.2 Marking

Each circuit-breaker shall be marked in a durable manner; data to be provided and corresponding locations are indicated in Table 4.

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

Subclause 6.3 of IEC 60947-1:2020 applies with the following addition:

Additional information for the decommissioning and dismantling of the circuit-breaker shall be provided to the user in the case of a foreseeable hazardous condition, for example due to stored energy or hazardous substances.

7 Normal service, mounting and transport conditions

Clause 7 of IEC 60947-1:2020 applies with the following addition:

846 Pollution degree (see 7.1.3.2 of IEC 60947-1:2020).

847 Unless otherwise stated by the manufacturer, a circuit-breaker is intended for installation under
848 environmental conditions of pollution degree 3.

849 **8 Constructional and performance requirements**

850 **8.1 Constructional requirements**

851 **8.1.1 General**

852 Subclause 8.1 of IEC 60947-1:2020 applies with the following modifications:

853 a) Where, in 8.1.2.2 of IEC 60947-1:2020, the test temperature is to be specified, the value
854 required by this document for the parts necessary to retain in position current-carrying parts
855 is 960 °C for the main circuit and 850 °C for the other circuits.

856 NOTE 1 "other circuits" cover control circuits (5.5), auxiliary circuits (5.6) and releases (5.7)

857 b) The requirements of 8.1.2 of IEC 60947-1:2020 do not apply to parts with a mass lower than
858 2 g (insignificant mass, in accordance with 3.14 of IEC 60695-2-11:2014). For products
859 containing more than one small part, the total mass of non-tested parts located within 3 mm
860 of each other shall not exceed 10 g.

861 NOTE 2 this distance of 3 mm is defined in 30.2 of IEC 60335-1:2020

862 When aluminium conductors are to be used, Annex D applies.

863 NOTE 3 Guidance for the development of embedded software is offered in IEC TR 63201

864 It shall be possible to operate the circuit-breaker manually.

865 Semiconductors circuit breaker with remote operation function shall be provided with means for
866 locking the circuit breaker in the open position, and it shall not be possible to close the circuit
867 breaker remotely when the open position is locked.

868 **8.1.2 Withdrawable circuit-breakers**

869 In the disconnected position, the connectors of the main circuit and, where applicable, auxiliary
870 circuits of withdrawable circuit-breakers shall have isolating distances which comply with the
871 requirements specified for the isolating function.

872 The withdrawable mechanism shall be fitted with a reliable indicating device which indicates
873 unambiguously the positions of the connectors.

874 The withdrawable mechanism shall be fitted with interlocks which only permit the connectors to
875 be separated or reclosed when all the isolation contacts of the semiconductor circuit-breaker
876 are open.

877 In addition, the withdrawable mechanism shall be fitted with interlocks which only permit all the
878 isolation contacts to be closed

879 – when connectors are fully closed, or

880 – when the specified isolating distance is achieved between the fixed and moving parts of the
881 connectors (disconnected position).

882 When the circuit-breaker is in the disconnected position, means shall be provided to ensure
883 that the specified isolating distances between connectors cannot be inadvertently reduced.

884 NOTE connectors are called "isolating contacts" in IEC 60947-2

8.1.3 Requirements for isolation function

Subclause 8.1.7 of IEC 60947-1:2020 applies.

For additional requirements concerning performance, see 8.2.6.

8.1.4 Clearances and creepage distances

Minimum values are given in Table 13 of IEC 60947-1:2020 and in Table 15 of IEC 60947-1:2020.

For Uimp values exceeding the values given in Table 13 of IEC 60947-1:2020, clearances shall be obtained from Table F.2 of IEC 60664-1:2020.

8.1.5 Requirements for the safety of the operator

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

Compliance is checked by the provisions of 9.3.3.6.1, item b).

8.1.6 List of construction breaks

Circuit-breakers of a given frame size are considered to have a construction break (see 3.1.2 of IEC 60947-2:202X) if any one of the following features are not the same:

- material, finish and dimensions of internal current-carrying parts, admitting, however, the variations listed in a), b), c), f) and g) below;
- size, material, configuration and method of attachment of the isolation contacts and/or parallel mechanical contacts ;
- any integral manual operating mechanism, its materials and physical characteristics;
- moulding and insulating materials;
- the characteristics (including principle of operation, materials, supplier) of the power semiconductor(s), its overvoltage protection device(s), and their control circuits;
- the basic design of the over-current tripping devices, admitting, however, the variations detailed in a), b) and c) below.

Variations in the following do not constitute a construction break:

- a) dimensions of terminals, provided that creepage and clearance distances are not reduced;
- b) in the case of thermal and magnetic releases those dimensions and materials of the release components, including flexible connections, which determine the current rating;
- c) secondary windings of current transformer operated releases;
- d) external operating means, additional to the integral operating means;
- e) type designation and/or purely aesthetic features (e.g. labels);
- f) difference in embedded software (firmware) in electronic trip units, which has no impact on the required performance, in particular the tripping function;
- g) electronic trip unit hardware, due to omitted components on identical printed circuit board layout (e.g. rotary knobs, display, etc.).

8.1.7 Additional requirements for circuit-breakers provided with a neutral pole

Subclause 8.1.9 of IEC 60947-1:2020 applies with the following addition:

8.1.8 Digital inputs and outputs for use with programmable logic controllers (PLCs)

Annex S of IEC 60947-1:2020 applies. For the purposes of this standard, this requirement does not apply to digital inputs and outputs dedicated to devices other than PLCs.

8.1.9 Indication of the standby state position

Breakers having a standby state (4.13) shall indicate that the breaker is in that state. This indication shall be visible when installed.

8.1.10 Fault on components

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 hazard;
- a risk of degradation resulting in emission of flame, burning particles or molten metal of the fire;
- overheating of power semiconductor if any.

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 electric shock and fire hazard will result from failure of the component. Compliance shall be checked by test of 9.2.2.

Components evaluated for their reliability according to relevant product standards are considered to meet these requirements and do not need any further investigation.

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 Closing

Closing the breaker comprises closing the isolation contacts first, turning on the power semiconductor and, for HSCCB, also the closing of the parallel mechanical contacts.

8.2.1.2 Opening

8.2.1.2.1 General

Semiconductor circuit-breakers shall return to and remain in standby or in open position (see 4.3), when the tripping operation is initiated after the initiation of the closing operation, even if the closing command is maintained.

When the circuit-breaker is required to go to open position, the open position shall be reached within 1 second."

8.2.1.2.2 Opening by undervoltage release function

Subclause 8.2.1.3 of IEC 60947-1:2020 applies.

8.2.1.2.3 Opening by shunt releases function

Subclause 8.2.1.4 of IEC 60947-1:2020 applies.

8.2.1.2.4 Opening by over-current function

a) Opening under short-circuit conditions

The short-circuit release shall cause tripping of the circuit-breaker 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 current release.

After each tripping under short-circuit conditions, the circuit-breaker shall be in the open position.

Where necessary for over-current co-ordination (see XX), the manufacturer shall provide information (usually curves):

- maximum cut-off (let-through) peak current (see 3.7.21 of IEC 60947-1:2020) as a function of prospective current (RMS symmetrical);

Conformity with this information may be checked during the relevant type tests in test sequences II and III (see 9.3.5 and 9.3.6).

NOTE 1 It is possible to provide other forms of data to verify co-ordination characteristics of circuit-breakers, for example, tests on combinations of short-circuit protective devices.

b) Opening under overload conditions

1) Instantaneous or definite time-delay operation

The release shall cause tripping of the circuit-breaker with an accuracy of $\pm 10\%$ of the tripping current value of the current setting for all values of current setting of the overload release.

2) Inverse time-delay operation

Conventional values for inverse time-delay operation are given in Table 5.

At the reference temperature (see 5.6.3) and at 1,05 times the current setting (see 3.6.38 of IEC 60947-1:2020), i.e. with the conventional non-tripping current (see 3.7.30 of IEC 60947-1:2020), the opening release being energized on all phase poles, tripping shall not occur in less than the conventional time (see 3.7.30 of IEC 60947-1:2020) from the cold state, i.e. with the circuit-breaker at the reference temperature.

Moreover, when at the end of the conventional time the value of current is immediately raised to 1,30 times the current setting, i.e. with the conventional tripping current (see 3.7.31 of IEC 60947-1:2020), tripping shall then occur in less than the conventional time later.

NOTE 2 The reference temperature is the ambient air temperature on which the time-current characteristic of the circuit-breaker is based.

If a release is declared by the manufacturer as substantially independent of ambient temperature, the current values of Table 5 shall apply within the temperature band declared by the manufacturer, within a tolerance of 0,3 % /K.

The width of the temperature band shall be at least 10 K on either side of the reference temperature.

8.2.1.2.5 Opening by internal error-state of the breaker

If an internal error occurs in the breaker, the breaker shall go into safe state with open isolation contacts.

8.2.2 Temperature-rise

8.2.2.1 Temperature-rise limits

The temperature-rises of the several parts of a circuit-breaker, measured under the conditions specified in 9.3.3.5, shall not exceed the limiting values stated in Table 6 during the tests made in accordance with 9.3.4.9. The temperature-rises of the terminals shall not exceed the limiting values stated in Table 6 during the tests made in accordance with 9.3.5.5.

8.2.2.2 Ambient air temperature

The temperature-rise limits given in Table 6 are applicable only if the ambient air temperature remains within the limits given in 7.1.1 of IEC 60947-1:2020.

1015 8.2.2.3 Main circuit

1016 The main circuit of a circuit-breaker, including the over-current releases which may be
1017 associated with it, shall be capable of carrying its rated current I_n , under the conditions of
1018 Clause 9, without the temperature-rises exceeding the limits specified in Table 6.

1019 8.2.2.4 Electrical control circuits

1020 The control circuits, including control circuit devices, used for the closing and opening
1021 operations of a circuit-breaker, shall permit the rated duty, as specified in 5.3.5, and also the
1022 temperature-rise tests under the test conditions specified in 9.3.3.5, to be made without the
1023 temperature rises exceeding the limits specified in Table 6.

1024 The requirements of this subclause shall be verified on a new circuit-breaker. Alternatively, at
1025 the discretion of the manufacturer, the verification may be made during the temperature-rise
1026 test of 9.3.4.9.

1027 8.2.2.5 Auxiliary circuits

1028 Auxiliary circuits, including auxiliary devices, shall be capable of carrying their conventional
1029 thermal current without the temperature-rises exceeding the limits specified in Table 6 when
1030 tested in accordance with 9.3.3.5.

1031 8.2.3 Dielectric properties**1032 8.2.3.1 General**

1033 Subclauses 8.2.3.1 a) and 8.2.3.1 b) of IEC 60947-1:2020 apply

1034 Type tests shall be made in accordance with 9.3.4.3.

1035 The verification of dielectric withstand during all test sequences shall be made in accordance
1036 with 9.3.4.8.

1037 Routine tests shall be made in accordance with 9.4.5.

1038 8.2.3.2 Impulse withstand voltage

1039 Subclause 8.2.3.2 of IEC 60947-1:2020 applies.

1040 8.2.3.3 Power-frequency withstand voltage of the main, auxiliary and control circuits

1041 Power-frequency tests are used in the following cases:

- 1042 – dielectric tests as type tests for the verification of solid insulation;
- 1043 – dielectric withstand verification, as a criterion of failure, after switching or short-circuit
1044 type tests;
- 1045 – routine tests.

1046 8.2.3.4 Clearances

1047 Subclause 8.2.3.4 of IEC 60947-1:2020 applies.

1048 8.2.3.5 Creepage distances

1049 Subclause 8.2.3.5 of IEC 60947-1:2020 applies.

1050 8.2.3.6 Solid insulation

1051 Solid insulation shall be verified by either power-frequency tests, in accordance with 9.3.3.4.1
1052 item 3) of IEC 60947-1:2020, or DC tests (test voltages for DC tests are under consideration).

For the purposes of this standard, control and auxiliary circuits incorporating solid-state devices and bridging the solid insulation of the main circuits shall be disconnected for the tests.

8.2.3.7 Spacing between separate circuits

Subclause 8.2.3.7 of IEC 60947-1:2020 applies.

8.2.4 Ability to make and break under no load, normal load and overload conditions

8.2.4.1 Overload performance

This requirement applies to circuit-breakers of rated current up to and including 630 A.

The circuit-breaker shall be capable of carrying out the number of operating cycles with current in the main circuit exceeding its rated current, under the test conditions according to 9.3.4.6.

Each operating cycle consists of a making operation followed by a breaking operation.

8.2.4.2 Operational performance capability

Subclause 8.2.4.2 of IEC 60947-1:2020 applies with the following additions:

The circuit-breaker shall be capable of meeting the requirements of Table 7:

- for the test of operational performance without current in the main circuit under the test conditions specified in 9.3.4.5.3;
- for the test of operational performance with current in the main circuit under the test conditions specified in 9.3.4.5.4.

Each operating cycle consists of, either a closing operation followed by an opening operation, or an opening operation followed by a closing operation (both with or without current).

8.2.5 Ability to make and break under short-circuit conditions

Subclause 8.2.5 of IEC 60947-1:2020 applies with the following amplifications:

The rated short-circuit making capacity shall be in accordance with 5.3.6.1 and 5.3.6.3.

The rated short-circuit breaking capacity shall be in accordance with 5.3.6.2.

NOTE It is the manufacturer's responsibility to ensure that the tripping characteristic of the circuit-breaker is compatible with the capability of the circuit-breaker to withstand the inherent thermal and electrodynamic stresses.

8.2.6 Requirements for isolation function

Subclause 8.2.7 of IEC 60947-1:2020 applies and tests shall be made in accordance with 9.3.4.3, 9.3.4.8, 9.3.4.12, 9.3.5.4 and 9.3.6.4, as applicable.

8.3 Electromagnetic compatibility (EMC)

Requirements and test methods are given in Annex J.

9 Tests

9.1 Kind of tests

9.1.1 General

Subclause 9.1 of IEC 60947-1:2020 applies, with the following additions:

1088 The tests to verify the characteristics of circuit-breakers are:

- 1089 – type tests (see 9.3);
- 1090 – routine tests (see 9.4);
- 1091 – special tests (see 9.5).

1092 **9.1.2 Type tests**

1093 Type tests include the tests listed in Table 8.

1094 Type tests shall be carried out by the manufacturer, in their workshop or at any suitable
1095 laboratory of his choice.

1096 **9.1.3 Routine tests**

1097 Routine tests comprise the tests listed in 9.4.

1098 **9.1.4 Special tests**

1099 Special tests comprise the tests listed in 9.5.

1100 **9.2 Compliance with constructional requirements**

1101 **9.2.1 General**

1102 Subclause 9.2 of IEC 60947-1:2020 applies.

1103 **9.2.2 Breakdown of components**

1104 **9.2.2.1 General**

1105 The breakdown of a component, identified as a result of the circuit analysis of 8.1.10, shall be
1106 tested with the product operating with the load creating the more severe condition and with a
1107 supply having a short-circuit prospective current of at least 10 times the rated current at the
1108 highest rated voltage of the equipment.

1109 The test is not required:

- 1110 – when circuit analysis indicates that no other component or portion of the circuit will be
1111 overloaded as a result of open- or short-circuit failure mode of another component;
- 1112 – for components in circuits supplied by limited energy sources;
- 1113 – on power semiconductor devices when equivalent testing is accomplished during short-
1114 circuit tests;
- 1115 – for components that have previously been positively evaluated considering the failure
1116 modes and the circuit conditions in which the component is used within the device.

1117 **9.2.2.2 Breakdown of components test**

1118 Each identified component shall be subjected to a breakdown of components test in open-
1119 and/or short-circuit failure modes, whichever is most severe.

1120 The breakdown of component test may be done with only those circuits of the device that can
1121 affect the result of the test, being fully energized and in operation.

1122 During the test, there shall be no emission of flame or molten metal, nor ignition of cotton. The
1123 fusible element shall not open.

1124 Components, such as capacitors or diodes, are short- or open-circuited. For device without a
1125 dedicated enclosure, an outer metal enclosure or a wire mesh cage (with surrounded cotton on
1126 the cage) that is 1,5 times the size of the device (or different, according to the requirements).

documentation) 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 9.3.4.1.2, d) of IEC 60947-1:2020 to the supply circuit.

9.3 Type tests

9.3.1 General

In order to avoid repetition of identical tests applicable to the various test sequences, the general test conditions have been grouped together at the beginning of this subclause under three headings:

- test conditions applicable to all sequences (9.3.4 to 9.3.9);
- test conditions applicable to temperature-rise tests (9.3.3.5);
- test conditions applicable to short-circuit tests (9.3.3.6).

Wherever appropriate, these general test conditions refer back to, or are based on, the general rules of IEC 60947-1.

Each test sequence refers back to the general test conditions applicable. This requires the use of cross-references, but enables each test sequence to be presented in a much simplified form.

Throughout this clause the term "test" has been used for every test to be made; "verification" should be interpreted as "test for the verification" and has been used where it is intended to verify the condition of the circuit-breaker following an earlier test in a test sequence whereby it may have been adversely affected.

In order to facilitate locating a particular test condition or test, an alphabetical index is given in Table 9, using the terms most likely to be used (not necessarily the exact terms appearing in the relevant subclause heading).

9.3.2 Test sequences

9.3.2.1 General

Type tests are grouped together in a number of sequences, as shown in Table 10.

For each sequence, tests shall be made in the order listed unless otherwise specified in this document.

9.3.2.2 Tests omitted from sequence I and made separately

With reference to 9.1.1 of IEC 60947-1:2020, the following tests of test sequence I (see 9.3.4) may be omitted from the sequence and made on separate samples:

- tripping limits and characteristics (9.3.4.2); in which case the sample(s) tested in the sequence shall be subjected to the tests of 9.3.4.2.3 only on the phase poles at the maximum setting, at room temperature and without the additional test of item b) to verify the time-current characteristic;
- test of dielectric properties (9.3.4.3);
- test of under-voltage releases of 9.3.4.5.2.3 and 9.3.4.5.3 to verify the requirements of 8.2.1.3 of IEC 60947-1:2020, and tests of under-voltage releases at alternative frequencies (see 9.3.3.1);
- test of shunt releases of 9.3.4.5.2.4 and 9.3.4.5.3 to verify the requirements of 8.2.1.4 of IEC 60947-1:2020, and tests of shunt releases at alternative frequencies (see 9.3.3.1);
- additional tests for operational performance capability without current for withdrawable circuit-breakers (9.3.4.5.5).

9.3.2.3 Applicability of sequences according to the relationship between short-circuit ratings

The applicability of test sequences according to the relationship between I_{CS} , I_{CU} and I_{CW} is given in Table 11.

9.3.2.4 Alternative test programmes for AC circuit-breakers having a different number of poles

These alternative test programs may only be applied to AC ratings and when all the ratings are the same or lower than the variant submitted to the full program of Table 10, and construction breaks are the same for all variants. In the case of 1-pole circuit-breakers the voltage ratings shall be equal to or lower than the line-to neutral voltage of the variant tested to Table 10. A 2-pole circuit-breaker produced by removing the center current path from a 3-pole circuit-breaker tested to program 1 or program 2 of this subclause need not be tested as it is considered to be covered by the tests on the 3-pole variant.

Compliance with the test requirements is met by carrying out one of the alternative programs 1 or 2 below.

- Programme 1: The applicable test sequences according to Table 10 shall be carried out on the three-pole variant. In addition, where applicable, the tests or test sequences listed in Table 13 shall be carried out on the other variants.
- Programme 2: The applicable test sequences according to Table 10 shall be carried out on the four-pole variant. In addition, where applicable, the tests or test sequences listed in Table 14 shall be carried out on the other variants.

The principle for the application of the alternative test programs is illustrated in the Table 12.

9.3.3 General test conditions

9.3.3.1 General requirements

Unless otherwise agreed by the manufacturer, each test sequence shall be made on a sample circuit-breaker (or set of samples) in a clean and new condition.

The number of samples to be tested for each test sequence and the test conditions (for example setting of overload releases, terminal connections), according to the circuit-breaker parameters, are given in Table 15 or, where applicable, for the alternative test programs in Table 13 and Table 14 (see 9.3.2.4).

Where necessary, additional information is given in the relevant subclauses.

Unless otherwise specified, tests are to be performed on a circuit-breaker having the maximum rated current for a given frame size and are deemed to cover all rated currents of that frame size.

In the case of one or more construction breaks (see 3.1.2 of IEC 60947-2:202X and 8.1.9) within the frame size, further samples shall be tested in accordance with Table 13 and/or Table 15 as applicable.

Unless otherwise stated, short-circuit releases shall be set at maximum (time and current) for all tests.

The circuit-breakers to be tested shall, in all their essential details, correspond to the design of the type which they represent.

Unless otherwise stated, the tests shall be made with the same kind of current and, in the case of AC, at the same rated frequency and with the same number of phases as in the intended service. Tests performed at 50 Hz cover 60 Hz applications and vice-versa, except for the

1215 performance of under-voltage and shunt releases (see 8.2.1 of IEC 60947-1:2020 and 8.2.2.7
1216 of IEC 60947-1:2020).

1217 If the mechanism is electrically controlled, it shall be supplied at the minimum voltage as
1218 specified in XX. In addition, electrically controlled mechanisms shall be energized via the
1219 appropriate circuit-breaker control circuits complete with switching devices. It shall be verified
1220 that the circuit-breaker operates correctly on no-load when it is operated under the above
1221 conditions.

1222 In case of circuit-breakers with dependent manual operation (see 3.6.12 of 60947-1:2020), the
1223 circuit-breaker shall be operated with an operating speed, during actuation, of $0,1 \text{ m/s} \pm 25 \%$,
1224 this speed being measured where the operating means of the test apparatus touches the
1225 actuating means of the circuit-breaker under test. For rotary handles the angular velocity shall
1226 correspond substantially to the above conditions, referred to the speed of the operating means
1227 (at its extremities) of the circuit-breaker under test.

1228 The circuit-breaker under test shall be mounted complete on its own support or an equivalent
1229 support.

1230 Unless otherwise stated, the connections of the complete circuit-breaker, and of the separate
1231 release (when applicable, see 9.3.4.2.1), shall be made as for normal service, with conductors
1232 of cross-section corresponding to the rated current (I_n) (see Table 9 and Table 10 and Table
1233 11 of IEC 60947-1:2020) and of length according to 9.3.3.3.4 of IEC 60947-1:2020. In case of
1234 aluminium conductors, their cross sections shall be in accordance with Table D.7 or Table D.8
1235 of IEC 60947-2:202X, as applicable.

1236 The circuit-breaker shall be tested in free air unless it is only intended to be used in a specified
1237 individual enclosure.

1238 If a circuit-breaker is intended to be used in specified individual enclosures, it shall be tested
1239 in the smallest of such enclosures stated by the manufacturer.
1240 For each of the following test a new sample may be used:

- 1241 a) A short-circuit test according to 9.3.6, at $U_e \text{ max}$, and corresponding I_{cu} , with release
1242 settings at maximum (see Footnote ^a of Table 15).
1243 b) A temperature-rise test according to the general conditions of 9.3.3.5 on a circuit-breaker
1244 having a maximum I_{th} , at the conventional enclosed thermal rating I_{the} (see 5.3.3.2). The
1245 temperature-rises shall meet the requirements of 8.2.2 except that the temperature rise of
1246 the terminals shall not exceed 70 K.

1247 Details of these tests, including the dimensions of the enclosure, shall be stated in the test
1248 report.

1249 NOTE An individual enclosure is an enclosure designed and dimensioned to contain one circuit-breaker only.

1250 However, if a circuit-breaker may be used in specified individual enclosures and is tested
1251 throughout in the smallest of such enclosures stated by the manufacturer, the tests in free air
1252 need not be made provided that such enclosure is bare metallic, without insulation. Details,
1253 including the dimensions of the enclosure, shall be stated in the test report.

1254 For the tests in free air, for tests concerning overload performance (9.3.4.6), short-circuit
1255 (9.3.5.2, 9.3.6.3, 9.3.8.2, 9.3.8.5 and 9.3.9.4), a metallic screen shall be placed on all sides of
1256 the circuit-breaker in accordance with the manufacturer's instructions. Details, including
1257 distances of the metallic screen from the circuit-breaker, shall be stated in the test report.

1258 The characteristics of the metallic screen shall be as follows:

- 1259 • structure: woven wire mesh; or
1260 perforated metal; or
1261 expanded metal;

- 1262 • ratio hole area/total area: 0,45 to 0,65;
- 1263 • size of hole: not exceeding 30 mm²;
- 1264 • finish: bare or conductive plating;
- 1265 • resistance: shall be included in the calculation for the prospective fault current in the fusible
- 1266 element circuit (see 9.3.4.1.2, item d) of IEC 60947-1:2020) when measured from the
- 1267 furthest point on the metallic screen likely to be reached by arc emissions.

1268 The tightening torques to be applied to the terminal screws shall be in accordance with the
1269 manufacturer's instructions (see 6.2 and Table 4).

1270 Unless otherwise stated, all tests shall be performed with forward connections.

1271 Maintenance or replacements of parts is not permitted.

1272 If, for convenience of testing, it appears useful to increase the severity of a test (for example to
1273 adopt a higher frequency of operation to reduce the duration of the test), this shall not be done
1274 without the consent of the manufacturer.

1275 For single-phase tests on individual poles of multipole circuit-breakers intended for use on
1276 phase-earthed systems, see Annex C.

1277 For additional tests for circuit-breakers for unearthed or impedance earth systems (IT), see
1278 Annex H.

1279 **9.3.3.2 Test quantities**

1280 **9.3.3.2.1 Values of test quantities**

1281 Subclause 9.3.2.2.1 of IEC 60947-1:2020 applies.

1282 **9.3.3.2.2 Tolerances on test quantities**

1283 Subclause 9.3.2.2.2 of IEC 60947-1:2020 applies.

1284 **9.3.3.2.3 Frequency of the test circuit for AC**

1285 All tests shall be made at the rated frequency of the circuit-breaker. For all short-circuit tests,
1286 if the rated breaking capacity is essentially dependent on the value of the frequency, the
1287 tolerance shall not exceed ± 5 %.

1288 If the manufacturer declares the rated breaking capacity to be substantially unaffected by the
1289 value of the frequency, the tolerance shall not exceed ± 25 %.

1290 **9.3.3.2.4 Power factor Time constant of the test circuit**

1291 Subclause 9.3.4.1.3 of IEC 60947-1:2020 applies with the following modification:

1292 Table 16 of IEC 60947-1:2020 is replaced by Table 16 of this document.

1293 **9.3.3.2.5 Time constant of the test circuit**

1294 Subclause 9.3.4.1.4 of IEC 60947-1:2020 applies with the following modification:

1295 Table 16 of IEC 60947-1:2020 is replaced by Table 16 of this document.

1296 **9.3.3.2.6 Power-frequency recovery voltage**

1297 Subclause 9.3.2.2.3, item a) of IEC 60947-1:2020.

1298 9.3.3.2.7 Ripple of the test current for DC

1299 The test current shall comply with the requirements of 6.3.1 of IEC 62475:2010.

1300 9.3.3.3 Evaluation of test results

1301 The condition of the circuit-breaker after tests shall be checked by the verifications applicable
1302 to each sequence.

1303 A circuit-breaker is deemed to have met the requirements of this standard if it meets the
1304 requirements of each sequence as applicable.

1305 The case shall not be broken but hairline cracks are acceptable.

1306 NOTE Hairline cracks are a consequence of high gas pressure or thermal stresses due to arcing when interrupting
1307 very high fault currents and are of a superficial nature. Consequently, they do not develop through the entire thickness
1308 of the moulded case of the device.

1309 9.3.3.4 Test reports

1310 Subclause 9.3.2.4 of IEC 60947-1:2020 applies.

1311 9.3.3.5 Test conditions for temperature-rise test

1312 The circuit-breaker shall meet the requirements of 8.2.2.

1313 Subclause 9.3.3.3 of IEC 60947-1:2020 applies, except 9.3.3.3.6, with the following addition:

1314 The circuit-breaker shall be mounted in accordance with 9.3.3.1.

1315 During the temperature-rise test of sequence I (see 9.3.4.9) coils of under-voltage releases,
1316 where applicable, shall be supplied at one rated frequency and corresponding voltage, chosen
1317 at random. Additional tests to verify coils at other rated frequencies and voltages shall be made
1318 outside the sequence.

1319 For four-pole AC circuit-breakers, a test shall first be made on the three poles which incorporate
1320 over-current releases. For a circuit-breaker having a value of rated current not exceeding 63 A,
1321 an additional test shall be made by passing the test current through the fourth pole and its
1322 adjacent pole. For higher rated current values, the method of testing shall be the subject of a
1323 separate agreement between manufacturer and user.

1324 DC circuit-breakers shall be connected in accordance with manufacturer's instructions. The
1325 details of the connections shall be stated in the test report.

1326 If a hybrid circuit-breaker is intended to carry $0.05I_n$ or more for more than 10 minutes with
1327 the bypass contact open, it shall also be tested with the bypass contact open carrying the
1328 maximum current until temperatures stabilize or the bypass contacts close.

1329 The maximum current will be the current which will be carried with bypass contacts open.

1330 The manufacturer shall provide the respective diagram

1331 9.3.3.6 Test conditions for short-circuit tests**1332 9.3.3.6.1 General requirements**

1333 Subclause 9.3.4.1.1 of IEC 60947-1:2020 is amplified as follows:

1334 a) The circuit-breaker shall be mounted in accordance with 9.3.3.1.

1335 b) Unless it can be shown that, with the manual operating means in any position, there is no
1336 opening around the manual operating means through which a music wire of 0,26 mm
1337 diameter can be inserted so as to reach the any arc chamber area, the following test
1338 arrangement shall apply:

For opening operations only, a clear, low density polyethylene sheet, 0,05 mm ± 0,01 mm thick, of a size 100 mm × 100 mm, positioned as shown in Figure 1, fixed and reasonably stretched in a frame, is placed at a distance of 10 mm from:

- either the maximum projection of the manual closing means of a circuit-breaker without recess for this closing means;
- or the rim of the recess for the manual closing means of a circuit-breaker with recess for this closing means.

The polyethylene sheet shall have the following physical properties:

- density at 23 °C: 0,92 g/cm³ ± 0,05 g/cm³;
- melting point: 110 °C to 120 °C.

On the side remote from the circuit-breaker there shall be an appropriate backing to obviate tearing of the polyethylene sheet due to the pressure wave which may occur during the short-circuit test (see Figure 1).

For tests other than those in an individual enclosure, a shield which may be of insulating material or of metal is placed between the metallic screen and the polyethylene sheet (see Figure 1).

NOTE This test arrangement applies to O operations only, since it is difficult to arrange for CO operations and it is accepted that O operations are no less severe than CO operations (see 9.3.3.6.4).

- c) The circuit-breaker shall be operated during tests to simulate service conditions as closely as possible.

CBs with power operation shall be operated at 85 % of the rated value of their control supply voltage.

- d) If a circuit-breaker is fitted with adjustable over-current releases, the setting of these releases shall be as specified for each test sequence.

For circuit-breakers without over-current releases but fitted with a shunt release, this release shall be energized by the application of a voltage equal to 70 % of the rated control supply voltage of the release (see 8.2.1.2.3), at a time not earlier than that of the initiation of the short-circuit nor later than 10 ms after the initiation of the short-circuit.

- e) For all these tests, the line side of the test circuit shall be connected to the corresponding terminals of the circuit-breaker as marked by the manufacturer. In the absence of such markings, the test connections shall be as specified in Table 15.

9.3.3.6.2 Test circuit

Subclause 9.3.4.1.2 of IEC 60947-1:2020.

9.3.3.6.3 Calibration of the test circuit

Subclause 9.3.4.1.5 of IEC 60947-1:2020 applies.

9.3.3.6.4 Test procedure

9.3.3.6.4.1 General

Subclause 9.3.4.1.6 of IEC 60947-1:2020 applies, with the following addition.

Before each short-circuit operation, a temperature stabilization of the circuit-breaker in accordance 9.3.3.7 with shall be carried out.

9.3.3.6.4.2 Tests on one-, two- and three-pole circuit-breakers

After calibration of the test circuit in accordance with 9.3.3.6.3 the temporary connections are replaced by the circuit-breaker under test and its connecting cables if applicable.

Tests for the performance under short-circuit conditions shall be made according to the sequences in Table 10 (see 9.3.2).

1384 For circuit-breakers having a rated current up to and including 630 A, a cable of maximum
1385 length 75 cm, having a cross-section corresponding to the conventional thermal current (see
1386 9.3.3.3.4, Tables 9 and Table 10 of IEC 60947-1:2020) shall be included as follows:

- 1387 – approximately 50 cm on the supply side;
- 1388 – approximately 25 cm on the load side.

1389 For ratings ≤ 20 A, the manufacturer may specify a larger cross-section, in which case this
1390 cross-section shall be used for all relevant short-circuit tests, and stated in the test report. In
1391 addition, a verification of inverse-time delay releases according to 9.3.4.2.3 b) shall be made
1392 with this cross-section.

1393 The sequence of operations shall be that which is applicable to each test sequence, as specified
1394 in 9.3.5.2 and 9.3.6.3.

1395 Alternative test programs for circuit-breakers having three-pole and four-pole variants are given
1396 in 9.3.2.4.

1397 **9.3.3.6.4.3 Tests on four-pole circuit-breakers**

1398 Additional sequences of operations on one or more new samples, in accordance with Table 15,
1399 shall be carried out on the fourth pole and its adjacent pole, according to test sequences III.

1400 Alternatively, at the request of the manufacturer, these tests may be combined with the tests of
1401 9.3.3.6.4.2 and made on the same samples, in which case the test in each relevant test
1402 sequence shall comprise:

- 1403 – the test on three adjacent poles,
- 1404 – the test on the fourth pole and the adjacent pole.

1405 The tests on the fourth pole and the adjacent pole are made at an applied voltage of $U_e/\sqrt{3}$, in
1406 the circuit shown in Figure 12 of IEC 60947-1:2020 with the connections C1 and C2 removed.
1407 The test current shall be agreed between manufacturer and user but shall be not less than 60 %
1408 of I_{cu} or I_{cw} , as applicable.

1409 Alternative test programs for circuit-breakers having three-pole and four-pole variants are given
1410 in 9.3.2.4. When program 1 is chosen, this subclause applies to the four-pole samples listed in
1411 Table 12.

1412 **9.3.3.6.4.4 Test operations**

1413 The following symbols are used for defining the sequence of operations:

1414 O represents a breaking operation,

1415 If a circuit breaker is unable to be switched to the closed position without line power for the “O”
1416 operation, a load switching means shall be installed between the circuit breaker and short-
1417 circuit point for the “O” operation. It has to be ensured that the tested circuit-breaker is in closed
1418 position. The load switching means shall be in the open position and closed to initiate the short-
1419 circuit current. The switching means and associated connections shall be included in the
1420 calibration of the test circuit (see Figure 7).

1421 CO represents a making operation followed, after the appropriate opening time, by a
1422 breaking operation.

1423 If the closing operations on a short-circuit are prohibited by circuit surveillance components in
1424 the circuit-breaker, then the CO operation is replaced by an O operation.

1425 t represents the time interval between two successive short-circuit operations which shall
1426 be as short as possible, allowing for the resetting time of the circuit-breaker, but not less than
1427 3 min. The actual value of t shall be stated in the test report.

1428 The maximum resetting time shall be 15 min or such longer time as may be stated by the
1429 manufacturer, but not exceeding 1 h, during which time the circuit-breaker shall not be

1430 displaced. Attempts to reclose the circuit-breaker during the resetting time shall be spaced by
1431 at least 1 min.

1432 The maximum value of I^2t (see 3.7.18 of IEC 60947-1:2020) during these tests may be recorded
1433 in the test report (see 8.2.1.2.4, item a)).

1434 **9.3.3.6.5 Behaviour of the circuit-breaker during short-circuit making and breaking** 1435 **tests**

1436 Subclause 9.3.4.1.7 of IEC 60947-1:2020 applies.

1437 **9.3.3.6.6 Interpretation of records**

1438 Subclause 9.3.4.1.8 of IEC 60947-1:2020 applies.

1439 **9.3.3.6.7 Verification after short-circuit tests**

1440 After the opening operations of the short-circuit making and breaking capacity tests of 9.3.5.2,
1441 9.3.6.3, 9.3.9.4, as applicable, the following conditions shall be met:

- 1442 – there shall be no damage to the insulation on conductors used to wire the device;
- 1443 – the polyethylene sheet, where applicable, shall show no holes visible with normal or
1444 corrected vision without additional magnification. Minuscule holes of less than 0,26 mm
1445 diameter can be ignored;
- 1446 – the case shall not be broken but hairline cracks are acceptable;
- 1447 – the circuit-breaker shall be in the open position.

1448 NOTE Hairline cracks are a consequence of high gas pressure or thermal stresses due to arcing when interrupting
1449 very high fault currents and are of superficial nature. Consequently, they do not develop through the entire thickness
1450 of the moulded case of the device.

1451 Additionally, after the short-circuit tests, the circuit-breaker shall comply with the verifications
1452 specified for each test sequence, as applicable.

1453 **9.3.3.7 Temperature stabilization at the rated current before type tests**

1454 **9.3.3.7.1 Temperature stabilization**

1455 The temperature stabilization shall be carried out in accordance with one of the three following
1456 methods:

- 1457 a) at the maximum ambient temperature allowed by the manufacturer without any current
1458 derating, the current value being equal to the current rating of the circuit-breaker;
- 1459 b) at the room temperature, the current value being adjusted to get the reference temperature
1460 determined in 9.3.3.7.2;
- 1461 c) for SCHCBs, without current, at an ambient temperature equal to the reference temperature
1462 determined in 9.3.3.7.2;

1463 The test shall be made indoors in an environment substantially free from air currents, except
1464 those generated by the test object.

1465 The circuit-breaker shall be pre-heated until stabilization of the reference temperature, defined
1466 as:

- 1467 – at the main terminals of the circuit-breaker in the case of method a)
- 1468 – in 9.3.3.7.2, in case of methods b) and c)

1469 The type test (9.3.4.6 or 9.3.9, as applicable) shall be carried out with a reference point
1470 temperature not less than the stabilization temperature minus 2 K.

1471 NOTE An example of methods a) and b) in accordance with Figure 2, Figure 3 and Figure 4 is provided below.