

Low-voltage switchgear and controlgear

Part 4-2: Contactors and motor-starters — Semiconductor
motor controllers, starters and soft-starters

National foreword

This British Standard is the UK implementation of EN IEC 60947-4-2:2023+A1:2024. It is identical to IEC 60947-4-2:2020, incorporating amendment 1:2024. It supersedes BS EN IEC 60947-4-2:2023, which will be withdrawn on 31 December 2027.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to IEC text carry the number of the IEC amendment. For example, text altered by IEC amendment 1 is indicated by A1 A1.

The UK participation in its preparation was entrusted to Technical Committee PEL/121, Switchgear and Controlgear and their assemblies for low voltage.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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English Version

Low-voltage switchgear and controlgear - Part 4-2: Contactors
and motor-starters - Semiconductor motor controllers, starters
and soft-starters
(IEC 60947-4-2:2020)

Appareillage à basse tension - Partie 4-2: Contacteurs et
démarreurs de moteurs - Gradateurs, démarreurs et
démarreurs progressifs à semiconducteurs de moteurs
(IEC 60947-4-2:2020)

Niederspannungsschaltgeräte - Teil 4-2: Schütze und
Motorstarter - Halbleiter-Motor-Steuergeräte, Starter und
Sanftstarter
(IEC 60947-4-2:2020)

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European foreword

The text of document 121A/353/FDIS, future edition 4 of IEC 60947-4-2, prepared by SC 121A "Low-voltage switchgear and controlgear" of IEC/TC 121 "Switchgear and controlgear and their assemblies for low voltage" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 60947-4-2:2023.

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- latest date by which the national standards conflicting with the (dow) 2026-01-11 document have to be withdrawn

This document supersedes EN 60947-4-2:2012 and all of its amendments and corrigenda (if any).

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The text of the International Standard IEC 60947-4-2:2020 was approved by CENELEC as a European Standard without any modification.

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IEC 60034-30-1	NOTE Approved as EN 60034-30-1
IEC 60068-2-2:2007	NOTE Approved as EN 60068-2-2:2007 (not modified)
IEC 60079 (series)	NOTE Approved as EN IEC 60079-7 (series)
IEC 60085:2007	NOTE Approved as EN 60085:2008 (not modified)
IEC 60269-1:2006	NOTE Approved as EN 60269-1:2007 (not modified)
IEC 60364-1	NOTE Approved as HD 60364-1
IEC 60664 (series)	NOTE Approved as EN 60664 (series)
IEC 60947-2	NOTE Approved as EN 60947-2
IEC 60947-3	NOTE Approved as EN IEC 60947-3
IEC 60947-4-1	NOTE Approved as EN IEC 60947-4-1
IEC 60947-4-3	NOTE Approved as EN 60947-4-3

IEC 60990:2016	NOTE Approved as EN 60990:2016 (not modified)
IEC 61000-4 (series)	NOTE Approved as EN 61000-4 (series)
IEC 61032	NOTE Approved as EN 61032
IEC 61800 (series)	NOTE Approved as EN 61800 (series)
IEC 62443 (series)	NOTE Approved as EN IEC 62443 (series)
IEC 62477-1:2012	NOTE Approved as EN 62477-1:2012 (not modified) +A11:2014
IEC 62683-1	NOTE Approved as EN 62683-1
IEC/TR 63201	NOTE Approved as CLC IEC/TR 63201

European foreword to Amendment 1

The text of document 121A/615/FDIS, future edition 4 of IEC 60947-4-2/AMD1, prepared by SC 121A "Low-voltage switchgear and controlgear" of IEC/TC 121 "Switchgear and controlgear and their assemblies for low voltage" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 60947-4-2:2023/A1:2024.

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Endorsement notice

The text of the International Standard IEC 60947-4-2:2020/AMD1:2024 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC/TR 63216 NOTE Approved as CLC IEC/TR 63216

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60034-1	2017	Rotating electrical machines - Part 1: Rating and performance	-	-
IEC 60445	2021	Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals, conductor terminations and conductors	EN IEC 60445	2021
IEC 60715	-	Dimensions of low-voltage switchgear and controlgear - Standardized mounting on rails for mechanical support of switchgear, controlgear and accessories	EN 60715	-
IEC 60730-1	-	Automatic electrical controls - Part 1: General requirements	-	-
IEC 60947-1	2020	Low-voltage switchgear and controlgear - Part 1: General rules	EN IEC 60947-1	2021
IEC 61000-3-2	-	Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current $16 \leq A$ per phase)	EN IEC 61000-3-2	-
IEC 61000-3-3	-	Electromagnetic compatibility (EMC) - Part 3-3: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection	EN 61000-3-3	-
IEC 61000-3-11	-	Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems - Equipment with rated current ≤ 75 A and subject to conditional connection	EN IEC 61000-3-11 -	

IEC 61000-3-12	-	Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤ 75 A per phase	EN 61000-3-12	-
IEC 61140	2016	Protection against electric shock - Common aspects for installation and equipment	EN 61140	2016
CISPR 11	2015	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement	EN 55011	2016
+ A1	2016		+ A1	2017
-	-		+ A11	2020
ISO 2859-1	1999	Sampling procedures for inspection by attributes - Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection	-	-
IEC 63404	2024	Switchgear and controlgear and their assemblies for low voltage - Integration of radiocommunication device above 380 MHz into an equipment	-	-
IEC/TS 63058	-	Switchgear and controlgear and their assemblies for low voltage - Environmental aspects	-	-

CONTENTS

FOREWORD.....	7
INTRODUCTION.....	9
1 Scope.....	10
2 Normative references	11
3 Terms, definitions, symbols and abbreviated terms.....	12
3.1 Terms and definitions.....	12
3.1.1 Terms and definitions concerning the types of semiconductor motor controllers and starters	12
3.1.2 Terms and definitions concerning semiconductor motor controllers and starters	13
3.1.3 Terms and definitions concerning safety aspects	17
3.1.4 Alphabetical index of terms	18
3.2 Symbols and abbreviated terms	20
4 Classification	20
5 Characteristics of semiconductor motor controllers and starters	20
5.1 Summary of characteristics	20
5.2 Type of equipment	21
5.2.1 Kind of equipment	21
5.2.2 Number of poles	21
5.2.3 Kind of current	21
5.2.4 Interrupting medium (air, vacuum, etc.).....	21
5.2.5 Operating conditions of the equipment	21
5.3 Rated and limiting values for main circuits	22
5.3.1 Rated voltages.....	22
5.3.2 Currents.....	24
5.3.3 Rated frequency	25
5.3.4 Duty cycle values and sequences	25
5.3.5 Normal load and overload characteristics.....	25
5.3.6 Rated conditional short-circuit current.....	26
5.3.7 Semiconductor motor controller power losses	27
5.4 Utilization category	27
5.4.1 General.....	27
5.4.2 Assignment of ratings based on the results of tests	28
5.5 Control circuits.....	29
5.6 Auxiliary circuits.....	29
5.7 Characteristics of relays and releases (overload relays).....	29
5.7.1 Summary of characteristics	29
5.7.2 Types of relay or release	29
5.7.3 Characteristic values	29
5.7.4 Designation and current settings of overload relays	31
5.7.5 Time-current characteristics of overload relays	31
5.7.6 Influence of ambient air temperature.....	31
5.8 Coordination with short-circuit protective devices (SCPD)	31
6 Product information	32
6.1 Nature of information	32
6.2 Marking.....	33

6.3	Instructions for installation, operation, maintenance, decommissioning and dismantling	33
6.4	Environmental information	34
7	Normal service, mounting and transport conditions	34
7.1	Normal service conditions	34
7.1.1	Ambient air temperature	34
7.1.2	Altitude	35
7.1.3	Atmospheric conditions	35
7.1.4	Shock and vibrations	35
7.2	Conditions during transport and storage	35
7.3	Mounting	35
7.4	Electrical system disturbances and influences	35
8	Constructional and performance requirements	35
8.1	Constructional requirements	35
8.1.1	General	35
8.1.2	Materials	36
8.1.3	Current-carrying parts and their connections	36
8.1.4	Clearances and creepage distances	36
8.1.5	Actuator	37
8.1.6	Indication of the contact position	37
8.1.7	Additional requirements for equipment suitable for isolation	37
8.1.8	Terminals	37
8.1.9	Additional requirements for equipment provided with a neutral pole	37
8.1.10	Provisions for protective earthing	37
8.1.11	Enclosures for equipment	37
8.1.12	Degrees of protection of enclosed equipment	37
8.1.13	Conduit pull-out, torque and bending with metallic conduits	37
8.1.14	Limited energy source	38
8.1.15	Stored charge energy circuit	40
8.1.16	Fault and abnormal conditions	40
8.1.17	Short-circuit and overload protection of ports	41
8.2	Performance requirements	41
8.2.1	Operating conditions	41
8.2.2	Temperature-rise	46
8.2.3	Dielectric properties	47
8.2.4	Normal load and overload performance requirements	48
8.2.5	Coordination with short-circuit protective devices	53
8.3	EMC requirements	53
8.3.1	General	53
8.3.2	Immunity	54
8.3.3	Emission	55
9	Tests	55
9.1	Kinds of tests	55
9.1.1	General	55
9.1.2	Type tests	56
9.1.3	Routine tests	56
9.1.4	Sampling tests	56
9.1.5	Special tests	57
9.2	Compliance with constructional requirements	57

9.2.1	General.....	57
9.2.2	Electrical performance of screwless-type clamping units	58
9.2.3	Ageing test for screwless-type clamping units	58
9.2.4	Limited energy source test.....	58
9.2.5	Breakdown of components	58
9.2.6	Wire flexing test.....	59
9.2.7	Abnormal operating tests	59
9.3	Compliance with performance requirements	61
9.3.1	Test sequences	61
9.3.2	General test conditions	62
9.3.3	Performance under no load, normal load, and overload conditions	62
9.3.4	Performance under short-circuit conditions	72
9.4	EMC tests	75
9.4.1	General.....	75
9.4.2	EMC immunity tests	76
9.4.3	EMC emission tests	77
9.5	Routine and sampling tests	78
9.5.1	General.....	78
9.5.2	Operation and operating limits	78
9.5.3	Dielectric tests	79
Annex A (normative)	Marking and identification of terminals	80
A.1	General.....	80
A.2	Marking and identification of terminals of semiconductor controllers and starters	80
A.2.1	Marking and identification of terminals of main circuits.....	80
A.2.2	Marking and identification of terminals of control circuits.....	80
A.3	Marking and identification of terminals of overload relays	80
Annex B (xxx)		81
Annex C (normative)	Coordination at the crossover current between the starter and associated SCPD	82
C.1	General and definitions	82
C.1.1	General.....	82
C.1.2	Terms and definitions	82
C.2	Condition for the test for the verification of coordination at the crossover current by a direct method	82
C.3	Test currents and test circuits	82
C.4	Test procedure and results to be obtained	83
C.4.1	Test procedure	83
C.4.2	Results to be obtained	83
C.5	Verification of coordination at the crossover current by an indirect method for type "2" coordination.....	83
C.5.1	General.....	83
C.5.2	Test for I_{cd}	83
C.5.3	Time-current characteristic withstand capability of controllers/starters	84
Annex D (xxx)		86
Annex E (xxx)		87
Annex F (informative)	Operating capability.....	88
Annex G (informative)	Rated operational currents and rated operational powers of switching devices for electrical motors	89

G.1	General.....	92
G.2	Rated operational powers and rated operational currents.....	92
Annex H (xxx)		96
Annex I (normative)	Modified test circuit for short-circuit testing of semiconductor motor controllers and starters	97
Annex J (xxx)		99
Annex K (xxx)		100
Annex L (normative)	Examples of overvoltage category reduction	101
L.1	General.....	101
L.2	Insulation to the surroundings	101
L.2.1	Circuits connected directly to the supply mains	101
L.2.2	Insulation between circuits.....	102
Annex M (xxx)		106
Annex N (normative)	Additional requirements and tests for equipment with protective separation.....	107
N.1	General.....	107
N.2	Definitions.....	107
N.3	Requirements	107
N.3.1	Test method for implementing protective impedance	107
N.3.2	Touch current measurement	108
Bibliography		110
Figure 1	Semiconductor motor control devices	13
Figure 2	Connecting methods	24
Figure 3	Thermal memory test	44
Figure 4	Multiple of current setting limits for ambient air temperature compensated time-delay overload relays	71
Figure C.1	Examples of time-current withstand characteristic.....	85
Figure F.1	Thermal stability test profile	89
Figure F.2	Overload capability test profile	90
Figure F.3	Blocking and commutating capability test profile	91
Figure I.1	Modified circuit for short-circuit testing of semiconductor devices.....	97
Figure I.2	Time line for the short-circuit test of 9.3.4.1.6	98
Figure L.1	Basic insulation evaluation for circuits connected directly to the origin of the installation mains supply	101
Figure L.2	Basic insulation evaluation for circuits connected directly to the mains supply	102
Figure L.3	Basic insulation evaluation for equipment not permanently connected to the mains supply.....	102
Figure L.4	Basic insulation evaluation for insulation between circuits connected directly to the origin of the installation mains supply and that are declared galvanically separated	103
Figure L.5	Basic insulation evaluation for insulation between circuits connected directly to the mains supply and that are declared galvanically separated	103
Figure L.6	Basic insulation evaluation for insulation between circuits not permanently connected directly to the mains supply and that are declared galvanically separated	104

Figure L.7 – Basic insulation evaluation for insulation between circuits connected directly to the origin of the installation mains supply and that are declared galvanically separated where internal SPDs are used	104
Figure L.8 – Basic insulation evaluation for insulation between circuits connected directly to the mains supply and that are declared galvanically separated where internal SPDs are used	105
Figure L.9 – Basic insulation evaluation for insulation between circuits connected directly to the mains supply and that are declared galvanically separated	105
Figure N.1 – Protection by means of protective impedance	108
Figure N.2 – Measuring instrument	109
Table 1 – Utilization categories	28
Table 2 – Relative levels of severity	28
Table 3 – Trip classes of overload relays	30
Table 19 – Limits for limited energy sources without an over-current protective device	39
Table 20 – Limits for limited energy sources with an over-current protective device	39
Table 21 – Limits for limited energy source with current limiting impedance	40
Table 4 – Limits of operation of time-delay overload relays when energized on all poles	43
Table 5 – Limits of operation of three-pole time-delay overload relays when energized on two poles only	45
Table 6 – Temperature-rise limits for insulated coils in air and in oil	47
Table 7 – Minimum overload current withstand time (T_X) in relation to overload current ratio (X) and corresponding to overload relay trip class (see Table 3)	49
Table 8 – Minimum requirements for thermal stability test conditions	49
Table 9 – Prospective locked rotor current by utilization categories	50
Table 10 – Minimum requirements for overload capability test conditions	50
Table 11 – Making and breaking capacity test; making and breaking conditions according to utilization categories for the mechanical switching device	52
Table 12 – Conventional operational performance making and breaking conditions according to utilization categories for the mechanical switching device	52
Table 13 – Specific performance criteria when EM disturbances are present	54
Table 14 – Thermal stability test specifications	66
Table 15 – Initial case temperature requirements	66
Table 16 – Minimum requirements and conditions for performance testing with an induction motor load	68
Table 17 – Terminal disturbance voltage limits for conducted radio-frequency emission (AC mains power port)	77
Table 18 – Radiated emissions test limits	78
Table A.1 – Main circuit terminal markings	80
Table C.1 – Test conditions	84
Table G.1 – Rated operational powers and rated operational currents of motors	93
Table L.1 – Drawing keys	101

INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 4-2: Contactors and motor-starters – Semiconductor motor controllers, starters and soft-starters

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60947-4-2 has been prepared by subcommittee 121A: Low-voltage switchgear and controlgear, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low voltage.

This fourth edition cancels and replaces the third edition published in 2011. This edition constitutes a technical revision.

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

- scope exclusions;
- editorial correction of notes and hanging paragraphs;
- reference to IEC 62683-1;

- safety aspects related to:
 - general aspects;
 - limited energy circuits;
 - electronic circuits;
- mention of dedicated wiring accessories;
- power consumption measurement;
- alignment to IEC 60947-1:2020.

The provisions of the general rules dealt with IEC 60947-1 are applicable to this part of IEC 60947 series where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to IEC 60947-1:2020.

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

FDIS	Report on voting
121A/353/FDIS	121A/360/RVD

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

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

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

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

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

INTRODUCTION

This document covers low-voltage semiconductor motor controllers, starters and soft-starters that have many capabilities and features beyond the simple starting and stopping of an induction motor, such as controlled starting and stopping, manoeuvring and controlled running.

The generic term “controller” is used in this document wherever reference is made to elements of power semiconductor switching devices.

The generic term “starter” is used in this document wherever reference is made to the elements of power semiconductor switching devices together with suitable overload protective devices.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 4-2: Contactors and motor-starters – Semiconductor motor controllers, starters and soft-starters

1 Scope

This part of IEC 60947 applies to semiconductor motor controllers, starters and soft-starters which can include a series mechanical switching device, intended to be connected to circuits the rated voltage of which does not exceed 1 000 V AC.

This document characterizes semiconductor motor controllers and starters with and without bypass means.

This document does not apply to:

- semiconductor motor controllers and starters used for continuous operation of AC motors at motor speeds other than the normal speed;
- electromechanical contactors and external overload relays (see IEC 60947-4-1);
- short-circuit protective device associated with semiconductor motor controllers and starters (see IEC 60947-4-1 (MPSD), IEC 60947-2 and IEC 60947-3);
- semiconductor equipment, including semiconductor contactors (3.4.13 of IEC 60947-1:2020) controlling non-motor loads (see IEC 60947-4-3);
- semiconductor motor controllers and starters used for rotor circuits;
- adjustable speed electrical power drive systems (see IEC 61800 series);
- use of the product within explosive atmospheres (see IEC 60079 series);
- software and firmware requirements;

NOTE 1 Guidance on embedded software is given in IEC TR 63201.

- cyber security aspects (see IEC TS 63208).

Contactors, overload relays and control circuit devices used in semiconductor motor controllers and starters are considered compliant with the requirements of their relevant product standard. Where mechanical switching devices are used, they are considered meeting the requirements of their own IEC product standard, and the additional requirements of this document.

The object of this document is to state as follows:

- the characteristics of semiconductor motor controllers, starters and soft-starters and associated equipment;
- the conditions with which semiconductor motor controllers, starters and soft-starters comply with reference to
 - a) their operation and behaviour in normal and abnormal operating conditions including overcurrent operating conditions;
 - b) their dielectric properties;
 - c) the degrees of protection provided by their enclosures where applicable;
 - d) their construction including safety measures against electric shock, fire hazard and mechanical hazard;
- the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests;

- the information to be given with the equipment, or in the manufacturer's literature.

NOTE 2 For the purpose of this document, the term "controller" is used instead of "semiconductor motor controller".

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

 IEC 60445:2021, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors* 

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

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

IEC 60947-1:2020, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 61000-3-2, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)*

IEC 61000-3-3, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection*

IEC 61000-3-11, *Electromagnetic compatibility (EMC) – Part 3-11: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems – Equipment with rated current ≤ 75 A and subject to conditional connection*

IEC 61000-3-12, *Electromagnetic compatibility (EMC) – Part 3-12: Limits – Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current > 16 A and ≤ 75 A per phase*

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

 IEC 63404:2024, *Switchgear and controlgear and their assemblies for low voltage – Integration of radiocommunication device above 380 MHz into an equipment* 

 IEC TS 63058, *Environmental aspects for low-voltage switchgear and controlgear and their assemblies* 

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

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

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60947-1:2020, as well as the following terms, definitions, symbol and abbreviations apply.

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

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

3.1.1 Terms and definitions concerning the types of semiconductor motor controllers and starters

3.1.1.1

semiconductor switching device

switching device designed to make and/or break the current in an electric circuit by means of the controlled conductivity of a semiconductor

Note 1 to entry: This definition differs from IEC 60050-441:1984, 441-14-03 since a semiconductor switching device is also designed for breaking the current.

[SOURCE: IEC 60947-1:2020, 3.4.3, modified – Note 1 to entry added.]

3.1.1.2

semiconductor controller

semiconductor switching device that provides a switching function for an AC electrical load and an OFF-state

Note 1 to entry: Because hazardous levels of the OFF-state current (3.1.2.12) exist in a semiconductor controller, the load terminals should be considered as live parts at all times.

Note 2 to entry: In a circuit where the current passes through zero (alternately or otherwise), the effect of "not making" the current following such a zero value is equivalent to breaking the current.

Note 3 to entry: See 3.4.3 of IEC 60947-1:2020 for the definition of semiconductor switching device.

Note 4 to entry: This device can include internal electromechanical switching device(s) bypassing or in series with the semiconductor at the manufacturer's discretion.

3.1.1.3

semiconductor motor controller

semiconductor controller that provides the starting function for an AC motor and an OFF-state

Note 1 to entry: This device can include any starting method specified by the manufacturer, control functions which can have any combination of manoeuvring, controlled acceleration, running or controlled deceleration of an AC motor. A FULL-ON state can also be provided.

Note 2 to entry: See Figure 1.

3.1.1.4

direct-on-line semiconductor motor controller

DOL semiconductor motor controller

semiconductor motor controller, in which the starting function is limited to a full-voltage, unramped starting method only, and where the additional control function is limited to providing FULL-ON

Note 1 to entry: This device can include a very short controlled ramp time of a few cycles which contribute to limit the inrush current of the motor to the level of Table 9.

Note 2 to entry: See Figure 1.

3.1.1.5 semiconductor motor-starter soft-starter

semiconductor motor controller with suitable overload protection, rated as a unit

Note 1 to entry: The term “soft-starter” is often used on the market to designate a semiconductor motor controller with or without overload protection but, in this document, it is a type of starter which by definition includes an overload protection.

3.1.1.6 direct-on-line semiconductor motor-starter DOL semiconductor motor-starter

direct-on-line semiconductor motor controller with suitable overload protection, rated as a unit

Device	Functional unit diagram
Semiconductor motor controller	
Semiconductor motor-starter	
Semiconductor motor controller or starter in series with a mechanical switching device	
Bypassed semiconductor motor controller	
Bypassed semiconductor motor-starter	

Figure 1 – Semiconductor motor control devices

3.1.2 Terms and definitions concerning semiconductor motor controllers and starters

3.1.2.1 current-limit function

ability of the controller to limit the motor current to a specified value

Note 1 to entry: This does not include the ability to limit the instantaneous current under conditions of short-circuit.

3.1.2.2

manoeuvre

any deliberate operation that causes current changes which shall be characterized and controlled (for example jogging, braking)

Note 1 to entry: Starting is a mandatory manoeuvre that is recognized separately.

Note 2 to entry: Braking operations performed by the semiconductor motor controller or starter are considered to be a manoeuvre within the scope of this document.

3.1.2.3

controlled acceleration

control of motor performance while increasing motor speed by acting on the motor supply

3.1.2.4

controlled deceleration

control of motor performance while decreasing motor speed by acting on the motor supply

3.1.2.5

controlled running

control of motor performance by acting on the motor supply while the motor is running at normal speed (for example, energy saving)

3.1.2.6

prospective current

<circuit with respect to a switching device or a fuse> current that would flow in the circuit if each pole of the switching device or the fuse were replaced by a conductor of negligible impedance

Note 1 to entry: The method to be used to evaluate and to express the prospective current is to be specified in the relevant product standard.

[SOURCE: IEC 60947-1:2020, 3.7.5]

3.1.2.7

prospective locked rotor current

I_{LRP}

prospective current that would flow when the rated voltage is applied to the motor with a locked rotor

Note 1 to entry: The test current of I_{LRP} for overload capability is given by Table 9.

3.1.2.8

ON-state

the condition of a controller when the conduction current can flow through its main circuit

3.1.2.9

FULL-ON

<state of controllers> condition of a controller when the controlling functions are set to provide normal full voltage excitation to the load

3.1.2.10

minimum load current

minimum operational current in the main circuit which is necessary for correct action of a controller in the ON-state

Note 1 to entry: The minimum load current is given as the RMS value.

3.1.2.11**OFF-state**

the condition of a controller when no control signal is applied, and no current exceeding the OFF-state current flows through the main circuit

3.1.2.12**OFF-state current**

the current which flows through the main circuit of a controller in the OFF-state

3.1.2.13**operation**

<controller> transition from the ON-state to the OFF-state, or the reverse

3.1.2.14**operating cycle**

<controller> succession of operations from one state to the other and back to the first state

Note 1 to entry: A succession of operations not forming an operating cycle is referred to as an operating series.

3.1.2.15**operating capability**

under prescribed conditions, the ability to perform a series of operating cycles without failure

3.1.2.16**overload current profile**

current-time co-ordinate specifying the requirement to accommodate overload currents for a period of time

Note 1 to entry: See 5.3.5.2.

3.1.2.17**rating index**

rating information organized in a prescribed format, unifying rated operational current and the corresponding utilization category, overload current profile, and the duty cycle or OFF-time

Note 1 to entry: See 6.1 e).

3.1.2.18**tripping operation**

<of a motor controller or starter> operation to establish and maintain an OFF-state (or open position in the case of series mechanical switching device) initiated by a control signal

3.1.2.19**phase loss sensitive overload relay or release**

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

3.1.2.20**under-current relay or release**

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

3.1.2.21**under-voltage relay or release**

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

3.1.2.22

stall sensitive electronic overload relay

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

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

3.1.2.23

jam sensitive electronic overload relay

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

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

3.1.2.24

inhibit time

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

3.1.2.25

ON-time

period of time during which the controller is on-load

Note 1 to entry: See the example in Figure F.1.

3.1.2.26

OFF-time

period of time during which the controller is off-load

Note 1 to entry: See the example in Figure F.1.

3.1.2.27

bypassed semiconductor motor controller

bypassed semiconductor motor-starter

equipment wherein the main circuit contacts of a mechanical switching device are connected in parallel with the main circuit terminals of a semiconductor switching device, and wherein the operating means of the two switching devices are co-ordinated, tested and rated as a unit

Note 1 to entry: See rows 4 and 5 of Figure 1.

3.1.2.28

CO operation

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

3.1.2.29

O operation

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

3.1.2.30

semiconductor motor controller power losses

power consumed by the semiconductor motor controller or starter at FULL-ON at the maximum power rating

3.1.2.31

galvanic separation

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

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

[SOURCE: IEC 60050-151:2001-07, 151-12-26]

3.1.3 Terms and definitions concerning safety aspects

3.1.3.1

abnormal operating condition

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

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

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

3.1.3.2

accessible part

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

[SOURCE: IEC 60050-442:1998-11, 442-01-15, modified – removal of “a” at the beginning]

3.1.3.3

hazardous-live-part

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

[SOURCE: IEC 60050-195:1998-08, 195-06-05]

3.1.3.4

limited energy source

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

3.1.3.5

protective impedance

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

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

3.1.3.6

reasonably foreseeable misuse

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

[SOURCE: ISO/IEC Guide 51:2014, 3.7, modified – Deletion of Notes to entry]

3.1.3.7

single fault condition

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

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

Note 2 to entry: Reinforced protection is defined in IEC 60050-903:2013, 903-02-08.

[SOURCE: IEC Guide 104:2019-07, 3.8]

3.1.4 Alphabetical index of terms

	Reference
A	
abnormal operating condition	3.1.3.1
accessible part.....	3.1.3.2
B	
bypassed semiconductor motor controller	3.1.2.27
bypassed semiconductor motor-starter.....	3.1.2.27
C	
CO operation	3.1.2.28
controlled acceleration	3.1.2.3
controlled deceleration	3.1.2.4
controlled running	3.1.2.5
current-limit function	3.1.2.1
D	
direct-on-line semiconductor motor controller.....	3.1.1.4
DOL semiconductor motor controller	3.1.1.4
direct-on-line semiconductor motor-starter	3.1.1.6
DOL semiconductor motor-starter	3.1.1.6
F	
FULL-ON	3.1.2.9
G	
galvanic separation	3.1.2.31
H	
hazardous-live part	3.1.3.3
I	
inhibit time	3.1.2.24
J	
jam sensitive electronic overload relay	3.1.2.23
L	
limited energy source	3.1.3.4
M	
manoeuvre.....	3.1.2.2
minimum load current.....	3.1.2.10

O

O operation	3.1.2.29
OFF-state	3.1.2.11
OFF-state current	3.1.2.12
OFF-time	3.1.2.26
ON-state	3.1.2.8
ON-time	3.1.2.25
operating capability	3.1.2.15
operating cycle	3.1.2.14
operation	3.1.2.13
overload current profile	3.1.2.16

P

phase loss sensitive overload relay or release	3.1.2.19
prospective current	3.1.2.6
prospective locked rotor current	3.1.2.7
protective impedance	3.1.3.5

R

rating index	3.1.2.17
reasonably foreseeable misuse	3.1.3.6

S

semiconductor controller	3.1.1.2
semiconductor motor controller	3.1.1.3
semiconductor motor controller power losses	3.1.2.30
semiconductor motor-starter	3.1.1.5
semiconductor switching device	3.1.1.1
single fault condition	3.1.3.7
stall sensitive electronic overload relay	3.1.2.22
soft-starter	3.1.1.5

T

tripping operation	3.1.2.18
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U

under-current relay or release	3.1.2.20
under-voltage relay or release	3.1.2.21

3.2 Symbols and abbreviated terms

Symbol and abbreviated term	Description	Definition or occurrence
A_f	Final ambient temperature	9.3.3.3.4
C_f	Final case temperature	9.3.3.3.4
I_c	Current made and broken	Table 11
I_e	Rated operational current	5.3.2.3
I_F	OFF-state current after the blocking and commutating capability test	9.3.3.6.4
I_{init}	Initial test current	9.3.3.6.3
I_{LRP}	Prospective locked rotor current	3.1.2.7
I_O	OFF-state current before the blocking and commutating capability test	9.3.3.6.4
I_{Lm}	Maximum OFF-state current	5.3.2.5
I_q	Maximum conditional short-circuit test current	9.3.4.3.2
I_{lim}	Current setting of the current-limit function	8.2.4.1
I_{th}	Conventional free air thermal current	5.3.2
I_{the}	Conventional enclosed thermal current	5.3.2.2
I_u	Rated uninterrupted current	5.3.2.4
SCPD	Short-circuit protective device	5.8
U_c	Rated control circuit voltage	6.1
U_e	Rated operational voltage	5.3.1.1
U_i	Rated insulation voltage	5.3.1.2
U_{imp}	Rated impulse withstand voltage	5.3.1.3
U_r	Power frequency recovery voltage	Table 10
U_s	Rated control circuit supply voltage	6.1

4 Classification

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

5 Characteristics of semiconductor motor controllers and starters

5.1 Summary of characteristics

The characteristics of controllers and starters shall be stated in the following terms, where such terms are applicable:

- type of equipment (5.2);
- rated and limiting values for main circuits (5.3);
- utilization category (5.4);
- control circuits (5.5);
- auxiliary circuits (5.6);
- characteristics of relays and releases (5.7);
- coordination with short-circuit protective devices (5.8).

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

5.2 Type of equipment

5.2.1 Kind of equipment

The type of semiconductor controllers and starters shall be stated in the following terms:

- a) Type of semiconductor motor controller
 - semiconductor motor controller; or
 - semiconductor motor-starter: with suitable overload protection, rated as a unit
- b) Bypassed semiconductor motor controller or starter, if relevant
- c) Type of control (not limited to)
 - FULL-ON;
 - controlled acceleration;
 - controlled deceleration;
 - current-limit function.

5.2.2 Number of poles

- Number of main poles;
- Number of main poles where the operation is controlled by a semiconductor switching element.

5.2.3 Kind of current

AC only.

5.2.4 Interrupting medium (air, vacuum, etc.)

Applicable only to mechanical switching devices used in controllers and starters.

5.2.5 Operating conditions of the equipment

5.2.5.1 Method of operation

For example:

- symmetrically controlled controller (such as a semiconductor with fully controlled phases);
- non-symmetrically controlled controller (such as thyristors and diodes).

5.2.5.2 Method of control

For example:

- automatic (by pilot switch or sequence control);
- non-automatic (that is push-buttons);
- semi-automatic (that is partly automatic, partly non-automatic).

5.2.5.3 Method of connecting

For example (see Figure 2):

- motor in delta, thyristors in series with a winding;
- motor in star, thyristors in delta;

- motor in delta, thyristors connected between winding and supply.

5.3 Rated and limiting values for main circuits

5.3.1 Rated voltages

5.3.1.1 Rated operational voltage (U_e)

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

The rating of AC equipment shall include the number of phases except that the rating of equipment obviously intended for single-phase use only is not required to include the number of phases.

5.3.1.2 Rated insulation voltage (U_i)

Subclause 5.3.1.2 of IEC 60947-1:2020 applies.

5.3.1.3 Rated impulse withstand voltage (U_{imp})

Subclause 5.3.1.3 of IEC 60947-1:2020 applies.

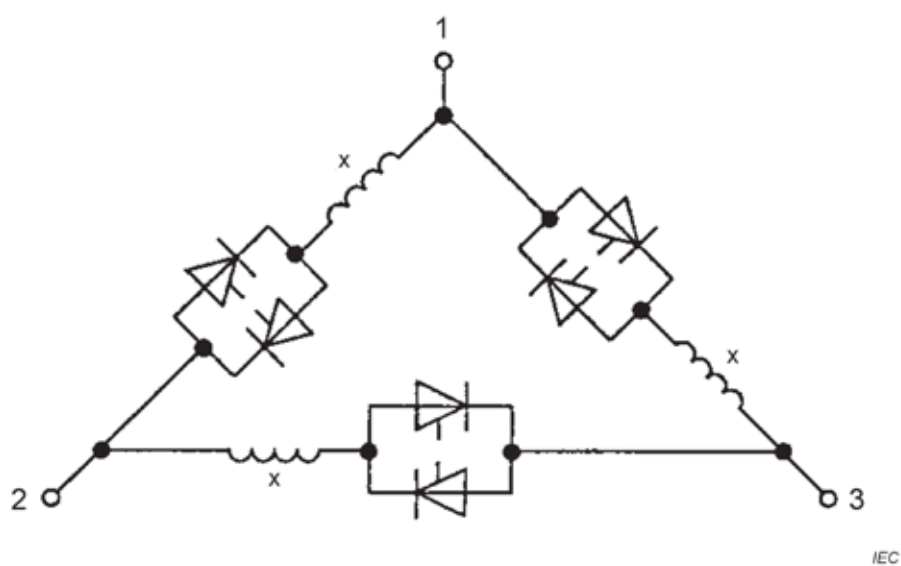


Figure 2a – Motor in delta – Thyristors in series with a winding

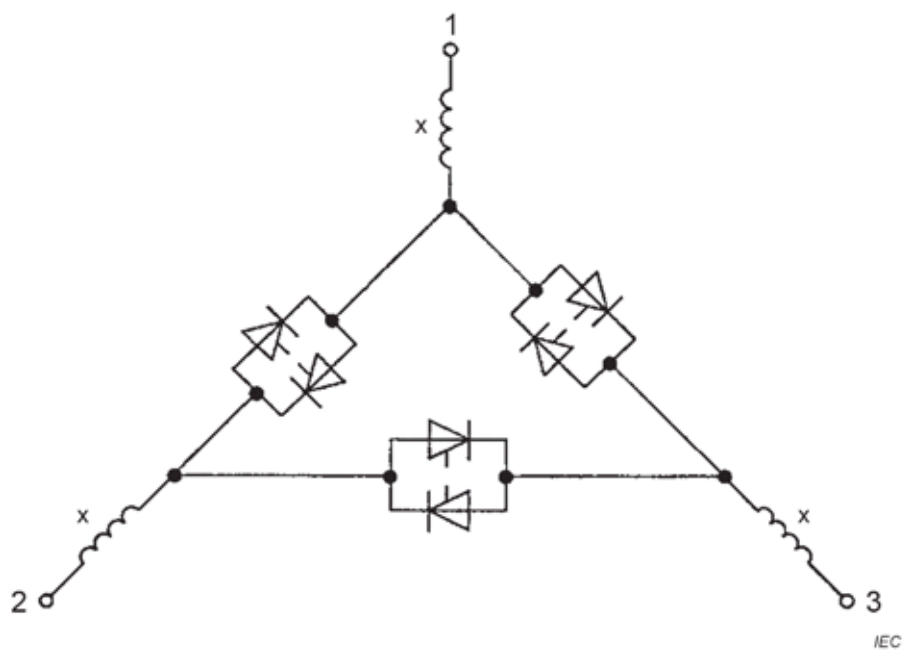


Figure 2b – Motor in star – Thyristors in delta

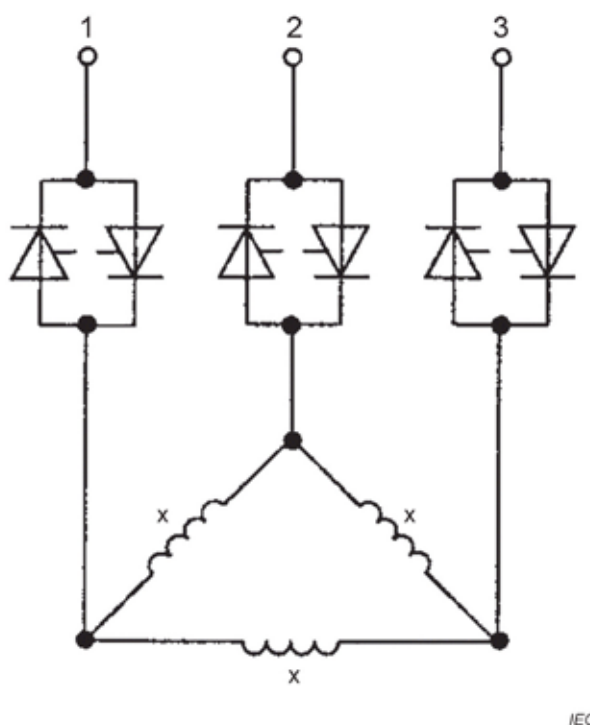


Figure 2c – Motor in delta – Thyristors connected between winding and supply

Figure 2 – Connecting methods

5.3.2 Currents

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

Subclause 5.3.2.1 of IEC 60947-1:2020 applies.

5.3.2.2 Conventional enclosed thermal current (I_{the})

Subclause 5.3.2.2 of IEC 60947-1:2020 applies.

5.3.2.3 Rated operational current (I_e)

The rated operational current, I_e , of controllers and starters is the normal operating current when the device is in the FULL-ON state, and takes into account the rated operational voltage (see 5.3.1.1), the rated frequency (see 5.3.3), the duty cycle values and sequences (see 5.3.4), the utilization category (see 5.4), the normal load and overload characteristics (see 5.3.5), and the type of protective enclosure, if any.

The indication of a rated operational current may be replaced or supplemented by an indication of the maximum rated power output, at the rated operational voltage considered, of the motor for which the equipment is intended.

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

5.3.2.4 Rated uninterrupted current (I_u)

Subclause 5.3.2.4 of IEC 60947-1:2020 applies.

5.3.2.5 Maximum OFF-state current (I_{Lm})

The maximum OFF-state current (I_{Lm}) is the maximum current flowing through the main circuit of the controller when it is in the OFF state, in the test condition of [A1](#) 9.3.3.6.4 [A1](#).

5.3.3 Rated frequency

Subclause 5.3.3 of IEC 60947-1:2020 applies.

5.3.4 Duty cycle values and sequences

5.3.4.1 Duty cycle values and symbols

For the purpose of this document, the duty cycle is expressed by two symbols, F and S . These describe the duty, and also set the time that shall be allowed for cooling.

F is the ratio of the on-load period to the total period expressed as a percentage.

The preferred values of F are as follows:

$F = 1 \%, 5 \%, 15 \%, 25 \%, 40 \%, 50 \%, 60 \%, 70 \%, 80 \%, 90 \%, 99 \%$.

S is the number of operating cycles per hour. The preferred values of S are as follows:

$S = 1, 2, 3, 4, 5, 6, 10, 20, 30, 40, 50, 60$ operating cycles per hour.

NOTE Other values of F and/or S can be declared by the manufacturer.

5.3.4.2 Duty cycle sequences

Two duty cycle sequences are defined in relation with the suffix of the designation of a utilisation category as follows:

- Sequence A: complete duty cycles, where the semiconductor motor controller or starter is carrying the motor current during all the phases of “starting”, “running” and “stopping” of the motor load. It includes the capability to continuously carry the rated current until and after thermal equilibrium;
- Sequence B: starting and stopping duty cycles, where the semiconductor motor controller or starter is carrying the motor current only during the phases of “starting” and/or “stopping” of the motor load.

5.3.5 Normal load and overload characteristics

5.3.5.1 General

Subclause 5.3.5 of IEC 60947-1:2020 applies with the following additions.

5.3.5.2 Overload current profile

The overload current profile gives the current-time co-ordinates for the controlled overload current. It is expressed by two symbols, X and T_X .

X denotes the overload current as a multiple of I_e selected from the array of values in Table 7, and represents the maximum value of operating current due to starting, operating, or manoeuvring under overload conditions. $X = I_T/I_e$ as tested according to Table 10 when no current limit function is provided.

Deliberate overcurrents not exceeding 10 cycles (for example boost, kickstart, etc.), which may exceed the stated value of $X \times I_e$, are disregarded for the overload current profile.

T_x denotes the sum of duration times for the controlled overload currents during starting, operating, and manoeuvring. See Table 7.

For a starter, T_x is the minimum operating time allowed by the tolerances of the overload relay.

5.3.5.3 Operating capability

Operating capability represents the combined capabilities of

- current commutation and current carrying in the ON-state; and
- establishing and sustaining the OFF-state (blocking),
at full voltage under normal load and overload conditions in accordance with utilization category, overload current profile and specified duty cycles.

Operating capability is characterized by

- the rated operational voltage (see 5.3.1.1);
- the rated operational current (see 5.3.2.3);
- the duty cycle values and sequences (see 5.3.4);
- the overload current profile (see 5.3.5.2);
- the utilization category (see 5.4);
- the availability of a current-limit function;
- the availability of a motor inrush current limiting function.

Requirements are given in 8.2.4.1.

5.3.5.4 Starting, stopping and manoeuvring characteristics

5.3.5.4.1 Starting characteristics of squirrel cage and hermetic refrigeration motors

- a) One direction of rotation with the inclusion of phase-control capability to provide any combination of controlled acceleration to normal speed, controlled deceleration to standstill, or an occasional manoeuvre without de-energizing the controller (AC-3a, AC-8a).
- b) One direction of rotation with the inclusion of phase-control capability to provide controlled acceleration to normal speed. Controllers and starters are rated for starting and stopping duty cycles only (AC-3b, AC-8b); for example, after starting, the motor may be connected into a circuit that bypasses the semiconductor motor controller or starter.

 Two directions of rotation are not covered by this document.   Text deleted. 

Due to the control capability of controllers and starters, the current during starting, stopping, and any operation will differ from the conventional values of the prospective locked rotor current listed in Table 9.

5.3.5.4.2 Starting characteristics of rheostatic rotor starters with controllers energizing the stator (AC-2a, AC-2b)

Starters can be used to provide reduced voltage excitation to the stator windings of a slip ring motor, and thereby reduce the number of switching steps required in the rotor circuit. For most applications, one or two starting steps are adequate depending upon load torque and inertia, and the severity of start required.

5.3.6 Rated conditional short-circuit current

Subclause 5.3.6.4 of IEC 60947-1:2020 applies.

5.3.7 Semiconductor motor controller power losses

5.3.7.1 General

The power consumption of the semiconductor motor controller or starter may be stated by the manufacturer and is determined by calculating the power losses of the power semiconductor components.

A motor controller consists of two or three power semiconductor controlled phases and the semiconductor controlling device. These power semiconductors are bypassed or not bypassed after run up of the motor.

The power semiconductor losses during start-up (and soft stop or braking mode) occur for a very short period of time (seconds) and are therefore not considered.

5.3.7.2 Power semiconductor losses (main circuit)

For continuous operation the power semiconductor losses can be calculated as follows:

a) Formula for non-bypassed operation

$$P_{vnb} = n \cdot I_e \cdot 1V$$

with:

- n number of controlled phases,
- I_e rated operational current,
- P_{vnb} power losses non-bypassed operation,
- 1V one volt as typical voltage drop of a power semiconductor.

NOTE 1 The typical factor of 1 V can be changed appropriately by the manufacturer.

b) Formula for bypassed operation

$$P_{vb} = n \cdot 0,1 \cdot I_e \cdot 1V = 0,1 \cdot P_{vnb}$$

with (in addition to the key of the previous formula):

- P_{vb} power losses in bypassed operation,

NOTE 2 The factor of 0,1 is based on the typical voltage drop of the bypass contact in comparison to the voltage drop of the semiconductor.

5.3.7.3 Semiconductor controlling device losses

The power consumption of semiconductor controlling device, including the fans if any, is obtained by measurement according to 9.3.3.2.

5.4 Utilization category

5.4.1 General

Subclause 5.4 of IEC 60947-1:2020 applies, with the following addition.

A1) For semiconductor motor controllers, starters and soft-starters, the utilization categories are given in Table 1. **A1**

Each utilization category (see Table 1) is characterized by the values of the currents, voltages, power-factors and other data of Table 2, Table 7, Table 8, Table 9 and Table 10, and by the test conditions specified in this document.

The utilization categories AC-2a, AC-3a and AC-8a (with a-suffix) are defined for the complete duty cycles according to 5.3.4.2a).

The utilization categories AC-2b, AC-3b and AC-8b (with b-suffix) are defined for the starting and stopping duty cycles according to 5.3.4.2b).

5.4.2 Assignment of ratings based on the results of tests

A designated controller or starter with a rating for one utilization category which has been verified by testing can be assigned other ratings without testing, provided that

- the rated operational current and voltage that are verified by testing shall not be less than the ratings that are to be assigned without testing;
- the utilization category and duty cycle requirements for the tested rating shall be equal to or more severe than the rating that is to be assigned without testing; the relative levels of severity are given in Table 2;
- the overload current profile for the tested rating shall be equal to or more severe than the rating that is to be assigned without testing, in accordance with the relative levels of severity in Table 2. Only values of X lower than the tested value of X may be assigned without testing.

Table 1 – Utilization categories

Specific utilisation category	Harmonised utilization category ^a	Typical motor load	Duty cycle sequence ^b
AC-52a	AC-2a	Slip ring motor	A ^c
AC-52b	AC-2b		B ^d
AC-53a	AC-3a	Squirrel-cage motors	A ^c
AC-53b	AC-3b		B ^d
AC-58a	AC-8a	Hermetic refrigerant compressor	A ^c
AC-58b	AC-8b		B ^d
^a The new utilisation categories according to Annex A of IEC 60947-1:2020 are proposed to replace the specific ones but the specific utilisation categories are remaining valid.			
^b Includes the whole starter or controller.			
^c Sequence A as complete.			
^d Sequence B as starting and stopping.			

Table 2 – Relative levels of severity

Severity level	Utilization category	Overload current profile ^{a, c}	ON-time/OFF-time requirements ^b
Most severe	AC-2a	Highest value of $(XI_e)^2 \cdot T_x$	Highest value of $F \cdot S$
	AC-3a		
	AC-8a		
	AC-2b	Highest value of $(XI_e)^2 \cdot T_x$	Lowest value of OFF-time
	AC-3b		
	AC-8b		
^a When the highest value of $(XI_e)^2 \cdot T_x$ occurs at more than one value of XI_e , then the highest value of XI_e applies.			
^b When the highest value of $F \cdot S$ occurs at more than one value of S , then the highest value of S applies.			
^c When the highest value of $(XI_e)^2 \cdot T_x$ occurs at more than one value of OFF-time, then the lowest value of OFF-time applies.			

5.5 Control circuits

Subclause 5.5.1 of IEC 60947-1:2020 applies with the following additions.

The list of characteristics given in 5.5.1 of IEC 60947-1:2020 shall be completed by:

- limited energy (if the source is in accordance with 8.1.14);
- SELV (PELV) supply (in accordance with Annex N of IEC 60947-1:2020).

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

5.6 Auxiliary circuits

Subclause 5.6 of IEC 60947-1:2020 applies, with the following additions.

Electronic auxiliary circuits perform useful functions (for example monitoring, data acquisition, etc.) that are not necessarily functions involved with the intended performance characteristics.

Under normal conditions, auxiliary circuits are characterized in the same way as control circuits, and are subject to the same kinds of requirements. A1 *Text deleted.* A1

Digital inputs and/or digital outputs contained in controllers and motor-starters, and intended to be compatible with PLCs, shall fulfil the requirements of Annex S of IEC 60947-1:2020.

5.7 Characteristics of relays and releases (overload relays)

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

5.7.1 Summary of characteristics

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

- types of relay or release (see 5.7.2);
- characteristic values (see 5.7.3);
- designation and current settings of overload relays (see 5.7.4);
- time-current characteristics of overload relays (see 5.7.5);
- influence of ambient air temperature (see 5.7.6).

5.7.2 Types of relay or release

- Under-voltage and under-current opening relay or release.
- Overload time-delay relay, the time-lag of which is
 - substantially independent of previous load;
 - dependent on previous load;
 - dependent on previous load and also sensitive to phase loss.
- Instantaneous over-current relay or release (for example jam sensitive).
- Other relays or releases (for example control relay associated with devices for the thermal protection of the starter).
- Stall sensitive electronic overload relay or release.

5.7.3 Characteristic values

- Release with shunt coil, under-voltage (under-current), over-voltage (instantaneous over-current), current or voltage asymmetry and phase reversal opening relay or release:
 - rated voltage (current);

- rated frequency;
- operating voltage (current);
- operating time (when applicable);
- inhibit time (when applicable).

b) Overload relay:

- designation and current settings (see 5.7.4);
- rated frequency, when necessary (for example in the case of a current transformer operated overload relay);
- time-current characteristics (or range of characteristics), when necessary;
- operating time of ground/earth fault electronic overload relays according to Table T.1 of IEC 60947-1:2020 if applicable;
- trip class according to classification in Table 4, or the value of the maximum tripping time, in seconds, under the conditions specified in 8.2.1.5.1.1.1 and Table 4, column D, when this time exceeds 40 s;
- nature of the relay: thermal, electronic or electronic without thermal memory;
electronic relay without thermal memory shall be marked ~~Thm~~;
- type designation for overload relays with extended functions (see Annex T of IEC 60947-1:2020) if applicable;
- nature of the reset: manual or manual/automatic; in case of manual/automatic, the set position shall be indicated;
- tripping time of overload relays class 10A where higher than 2 min at 0 °C or below (see 8.2.1.5.1.1.1, item c).

c) Release with residual current sensing relay:

- rated current;
- operating current;
- operating time or time-current characteristic according to Table T.1 of IEC 60947-1:2020;
- inhibit time (when applicable);
- type designation (see Annex T of IEC 60947-1:2020).

Table 3 – Trip classes of overload relays

Trip class	Tripping time T_p under the conditions specified in 8.2.1.5.1.1.1 and Table 4, column D ^a	Tripping time T_p under the conditions specified in 8.2.1.5.1.1.1 and Table 4, column D for tighter tolerances (tolerance band E) ^a
	s	s
2	–	$T_p \leq 2$
3	–	$2 < T_p \leq 3$
5	$0,5 < T_p \leq 5$	$3 < T_p \leq 5$
10A	$2 < T_p \leq 10$	–
10	$4 < T_p \leq 10$	$5 < T_p \leq 10$
20	$6 < T_p \leq 20$	$10 < T_p \leq 20$
30	$9 < T_p \leq 30$	$20 < T_p \leq 30$
40	–	$30 < T_p \leq 40$