

BS EN 60947-4-2:2012

Incorporating Corrigendum July 2012



BSI Standards Publication

Low-voltage switchgear and controlgear

Part 4-2: Contactors and motor-starters
— AC semiconductor motor controllers
and starters

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National foreword

This British Standard is the UK implementation of EN 60947-4-2:2012. It is identical to IEC 60947-4-2:2011, incorporating corrigendum July 2012. It supersedes BS EN 60947-4-2:2000, which will be withdrawn on 22 June 2014.

The UK participation in its preparation was entrusted by Technical Committee PEL/17, Switchgear, controlgear, and HV-LV co-ordination, to Subcommittee PEL/17/2, Low voltage switchgear and controlgear.-

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

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31 August 2012	Implementation of IEC corrigendum July 2012: Table 19 modified

**Low-voltage switchgear and controlgear -
Part 4-2: Contactors and motor-starters -
AC semiconductor motor controllers and starters
(IEC 60947-4-2:2011)**

Appareillage à basse tension -
Partie 4-2: Contacteurs et démarreurs de
moteurs -
Gradateurs et démarreurs à
semiconducteurs de moteurs à courant
alternatif
(CEI 60947-4-2:2011)

Niederspannungsschaltgeräte -
Teil 4-2: Schütze und Motorstarter -
Halbleiter-Motor-Steuergeräte und -Starter
für Wechselspannungen
(IEC 60947-4-2:2011)

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Foreword

The text of document (17B/1734/FDIS), future edition 3 of IEC 60947-4-2, prepared by SC 17B, "Low-voltage switchgear and controlgear", of IEC TC 17, "Switchgear and controlgear", was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60947-4-2:2012.

The following dates are fixed:

- | | | |
|--|-------|------------|
| • latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement | (dop) | 2012-12-29 |
| • latest date by which the national standards conflicting with the document have to be withdrawn | (dow) | 2014-06-22 |

This European Standard supersedes EN 60947-4-2:2000 + A1:2002 + A2:2006.

EN 60947-4-2:2012 includes the following significant technical changes with respect to EN 60947-4-2:2000 + A1:2002 + A2:2006:

- updated EMC normative references and associated requirements,
- new references to EN 60947-1,
- marking of electronic relays without thermal memory,
- marking of tripping time at 0 °C ambient or below,
- new test requirements for limits of operation of time-delay overload relays,
- new classes of overload current withstand time,
- damp heat, salt mist, vibration and shock tests,
- short-circuit test in the smallest enclosure,
- update of the routine and sampling tests.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and CENELEC shall not be held responsible for identifying any or all such patent rights.

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

This standard covers the Principle Elements of the Safety Objectives for Electrical Equipment Designed for Use within Certain Voltage Limits (LVD - 2006/95/EC).

This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For the relationship with EU Directive(s) see informative Annex ZZ, which is an integral part of this document.

Endorsement notice

The text of the International Standard IEC 60947-4-2:2011 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60146 series	NOTE Harmonized in EN 60146 series (not modified).
IEC 60255 series	NOTE Harmonized in EN 60255 series (partially modified).
IEC 60947-5 series	NOTE Harmonized in EN 60947-5 series (partially modified).
IEC 61000-3-2:2005 + A1: 2008 + A2: 2009	NOTE Harmonized as EN 61000-3-2:2006 + A1:2009 + A2:2009 (not modified).
IEC 61000-4-2:2008	NOTE Harmonized as EN 61000-4-2:2009 (not modified).
IEC 61000-4-3:2006 + A1: 2007 + A2: 2010	NOTE Harmonized as EN 61000-4-3:2006 + A1:2008 + A2:2010 (not modified).
IEC 61000-4-4:2004 + A1: 2010	NOTE Harmonized as EN 61000-4-4:2004 + A1:2010 (not modified).
IEC 61000-4-5:2005	NOTE Harmonized as EN 61000-4-5:2006 (not modified).
IEC 61000-4-6:2008	NOTE Harmonized as EN 61000-4-6:2009 (not modified).
IEC 61000-4-11:2004	NOTE Harmonized as EN 61000-4-11:2004 (not modified).
IEC 61131-2:2007	NOTE Harmonized as EN 61131-2:2007 (not modified).

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application 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 When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60034-1 (mod)	2010	Rotating electrical machines - Part 1: Rating and performance	EN 60034-1 + corr. October	2010 2010
IEC 60085	2007	Electrical insulation - Thermal evaluation and designation	EN 60085	2008
IEC 60269-1 + A1	2006 2009	Low-voltage fuses - Part 1: General requirements	EN 60269-1 + A1	2007 2009
IEC 60410	1973	Sampling plans and procedures for inspection by attributes	-	-
IEC 60664	Series	Insulation coordination for equipment within low-voltage systems	EN 60664	Series
IEC 60947-1	2007	Low-voltage switchgear and controlgear - Part 1: General rules	EN 60947-1	2007
IEC 61000-4	Series	Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques -	EN 61000-4	Series
CISPR 11 (mod) + A1	2009 2010	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement	EN 55011 + A1	2009 2010

Annex ZZ (informative)

Coverage of Essential Requirements of EU Directives

This European Standard has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association and within its scope the standard covers all relevant essential requirements as given in Article 1 of Annex I of the Directive 2004/108/EC.

Compliance with this standard provides one means of conformity with the specified essential requirements of the Directive concerned.

WARNING - Other requirements and other EU Directives may be applicable to the products falling within the scope of this standard.

CONTENTS

INTRODUCTION	8
1 Scope	9
2 Normative references	10
3 Terms, definitions, symbols and abbreviations	10
3.1 General	10
3.2 Alphabetical index of terms	10
3.3 Terms and definitions concerning a.c. semiconductor motor controllers and starters	12
3.4 Terms and definitions concerning hybrid motor controllers and starters	14
3.5 Terms and definitions concerning EMC definitions	18
3.6 Symbols and abbreviations	19
4 Classification	19
5 Characteristics of a.c. semiconductor motor controllers and starters	20
5.1 Summary of characteristics	20
5.2 Type of equipment	20
5.2.1 Form of equipment	20
5.2.2 Number of poles	20
5.2.3 Kind of current	20
5.2.4 Interrupting medium (air, vacuum, etc.)	20
5.2.5 Operating conditions of the equipment	20
5.3 Rated and limiting values for main circuits	21
5.3.1 Rated voltages	21
5.3.2 Currents	23
5.3.3 Rated frequency	23
5.3.4 Rated duty	23
5.3.5 Normal load and overload characteristics	24
5.3.6 Rated conditional short-circuit current	25
5.4 Utilization category	25
5.4.1 General	25
5.4.2 Assignment of ratings based on the results of tests	26
5.5 Control circuits	27
5.6 Auxiliary circuits	27
5.7 Characteristics of relays and releases (overload relays)	27
5.7.1 Summary of characteristics	28
5.7.2 Types of relay or release	28
5.7.3 Characteristic values	28
5.7.4 Designation and current settings of overload relays	29
5.7.5 Time-current characteristics of overload relays	29
5.7.6 Influence of ambient air temperature	30
5.8 Co-ordination with short-circuit protective devices (SCPD)	30
6 Product information	30
6.1 Nature of information	30
6.2 Marking	31
6.3 Instructions for installation, operation, and maintenance	31
7 Normal service, mounting and transport conditions	32

7.1	Normal service conditions	32
7.1.1	Ambient air temperature	32
7.1.2	Altitude	32
7.1.3	Atmospheric conditions	32
7.1.4	Shock and vibrations	32
7.2	Conditions during transport and storage	32
7.3	Mounting	32
7.4	Electrical system disturbances and influences	32
8	Constructional and performance requirements	33
8.1	Constructional requirements	33
8.1.1	General	33
8.1.2	Materials	33
8.1.3	Current-carrying parts and their connections	33
8.1.4	Clearances and creepage distances	33
8.1.5	Actuator	33
8.1.6	Indication of the contact position	33
8.1.7	Additional requirements for equipment suitable for isolation	33
8.1.8	Terminals	33
8.1.9	Additional requirements for equipment provided with a neutral pole	34
8.1.10	Provisions for protective earthing	34
8.1.11	Enclosures for equipment	34
8.1.12	Degrees of protection of enclosed equipment	34
8.1.13	Conduit pull-out, torque and bending with metallic conduits	34
8.2	Performance requirements	34
8.2.1	Operating conditions	34
8.2.2	Temperature rise	38
8.2.3	Dielectric properties	41
8.2.4	Normal load and overload performance requirements	42
8.2.5	Co-ordination with short-circuit protective devices	47
8.3	EMC requirements	47
8.3.1	General	47
8.3.2	Emission	48
8.3.3	Immunity	48
9	Tests	50
9.1	Kinds of tests	50
9.1.1	General	50
9.1.2	Type tests	50
9.1.3	Routine tests	50
9.1.4	Sampling tests	50
9.1.5	Special tests	51
9.2	Compliance with constructional requirements	51
9.3	Compliance with performance requirements	51
9.3.1	Test sequences	51
9.3.2	General test conditions	52
9.3.3	Performance under no load, normal load, and overload conditions	52
9.3.4	Performance under short-circuit conditions	62
9.3.5	EMC tests	65
9.3.6	Routine and sampling tests	68
Annex A (normative)	Marking and identification of terminals	70

Annex B Vacant	73
Annex C (normative) Co-ordination at the crossover current between the starter and associated SCPD	74
Annex D Vacant	78
Annex E Vacant	79
Annex F (informative) Operating capability	80
Annex G (informative) Examples of control circuit configurations	83
Annex H Vacant	85
Annex I (normative) Modified test circuit for short-circuit testing of semiconductor motor controllers and starters	86
Annex J (informative) Flowchart for constructing bypassed semiconductor controllers tests	88
Annex K (normative) Extended functions within electronic overload relays	89
Bibliography	94
Figure 1 – Semiconductor motor control devices	13
Figure 2 – Connecting methods	22
Figure 3 – Thermal memory test	36
Figure 4 – Multiple of current setting limits for ambient air temperature compensated time-delay overload relays	62
Figure C.1 – Examples of time-current withstand characteristic	77
Figure F.1 – Thermal stability test profile	80
Figure F.2 – Overload capability test profile	81
Figure F.3 – Blocking and commutating capability test profile	82
Figure G.1 – Diagrammatic representation of an ECD	83
Figure G.2 – Single supply and control input	83
Figure G.3 – Single supply and control input	84
Figure G.4 – Controllers with an internal control supply and control input only	84
Figure I.1 – Modified circuit for short-circuit testing of semiconductor devices	86
Figure I.2 – Time line for the short-circuit test of 9.3.4.1.6	87
Figure K.1 – Test circuit for the verification of the operating characteristic of a residual current electronic overload relay	93
Table 1 – Functional possibilities of semiconductor motor control devices	14
Table 2 – Utilization categories	26
Table 3 – Relative levels of severity	27
Table 4 – Trip classes of overload relays	29
Table 5 – Limits of operation of time-delay overload relays when energized on all poles	35
Table 6 – Limits of operation of three-pole time-delay overload relays when energized on two poles only	37
Table 7 – Temperature rise limits for insulated coils in air and in oil	40
Table 8 – Intermittent duty test cycle data	40
Table 9 – Minimum overload current withstand time (T_x) in relation to overload current ratio (X) and corresponding to overload relay trip class (see Table 19)	43
Table 10 – Minimum requirements for thermal stability test conditions ^a	43

Table 11 – Minimum requirements for overload capability test conditions	44
Table 12 – Minimum requirements and conditions for performance testing with an induction motor load	44
Table 13 – Making and breaking capacity test; making and breaking conditions according to utilization categories for the mechanical switching device of hybrid motor controllers H1, H2, H3 and for certain forms of bypassed controllers	46
Table 14 – Conventional operational performance making and breaking conditions according to utilization categories for the mechanical switching device of hybrid motor controllers H1B, H2B, H3B and for certain forms of bypassed controllers	46
Table 15 – Specific acceptance or performance criteria when EM disturbances are present	49
Table 16 – Thermal stability test specifications	57
Table 17 – Initial case temperature requirements	57
Table 18 – Blocking and commutating capability test specifications	59
Table 19 – Terminal disturbance voltage limits for conducted radio-frequency emission	67
Table 20 – Radiated emissions test limits	67
Table A.1 – Main circuit terminal markings	70
Table C.1 – Test conditions	76
Table K.1 – Operating time of residual current electronic overload relays	90

INTRODUCTION

This standard covers low-voltage a.c. semiconductor motor controllers and 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 standard wherever the unique features of the power semiconductor switching elements are the most significant points of interest. The generic term “starter” is used wherever the consequences of operating the power semiconductor switching elements, together with suitable overload protective means, are the most significant points of interest. Specific designations (for example form 1, form HxB, etc.) are used wherever the unique features of various configurations comprise significant points of interest.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 4-2: Contactors and motor-starters – AC semiconductor motor controllers and starters

1 Scope

This standard applies to a.c. semiconductor motor controllers and starters, which may include a series mechanical switching device, intended to be connected to circuits, the rated voltage of which does not exceed 1 000 V a.c.

This standard characterizes a.c. semiconductor motor controllers and starters with and without bypass means.

AC semiconductor motor controllers and starters dealt with in this standard are not normally designed to interrupt short-circuit currents. Therefore, suitable short-circuit protection (see 8.2.5) should form part of the installation, but not necessarily of the a.c. semiconductor motor controller or starter.

In this context, this standard gives requirements for a.c. semiconductor motor controllers and starters associated with separate short-circuit protective devices.

This standard does not apply to

- continuous operation of a.c. motors at motor speeds other than the normal speed;
- semiconductor equipment, including semiconductor contactors (see 2.2.13 of IEC 60947-1:2007) controlling non-motor loads;
- electronic a.c. power controllers covered by IEC 60146 series.

Contactors, overload relays and control circuit devices used in a.c. semiconductor motor controllers and starters should comply with the requirements of their relevant product standard. Where mechanical switching devices are used, they should meet the requirements of their own IEC product standard, and the additional requirements of this standard.

The object of this standard is to state as follows:

- the characteristics of a.c. semiconductor motor controllers and starters and associated equipment;
- the conditions with which a.c. semiconductor motor controllers and starters comply with reference to
 - a) their operation and behaviour;
 - b) their dielectric properties;
 - c) the degrees of protection provided by their enclosures where applicable;
 - d) their construction;
- 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 For the purpose of this standard, the term "controller" may be used instead of "a.c. semiconductor motor controller".

2 Normative references

The following referenced documents are indispensable for the application 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 60034-1:2010, *Rotating electrical machines – Part 1: Rating and performance*

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

IEC 60269-1:2006, *Low-voltage fuses – Part 1: General requirements*
Amendment 1 (2009)

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

IEC 60664 (all parts), *Insulation coordination for equipment within low-voltage systems*

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

IEC 61000-4 (all parts), *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques*

CISPR 11:2009, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*
Amendment 1 (2010)

3 Terms, definitions, symbols and abbreviations

3.1 General

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

3.2 Alphabetical index of terms

	Reference
A	
a.c. semiconductor motor controller	3.3.2
B	
burst (of pulses or oscillations)	3.5.7
bypassed controller.....	3.4.31
C	
CO operation	3.4.32
controlled acceleration.....	3.4.6
controlled deceleration.....	3.4.7
controlled running	3.4.8
current-limit function	3.4.4
E	
electromagnetic compatibility [EMC]	3.5.1
electromagnetic disturbance	3.5.3
electromagnetic emission.....	3.5.2

F	
FULL-ON (state of controllers)	3.4.12
H	
hybrid motor controller or starter, form HxA (where x = 1, 2 or 3)	3.4.1
hybrid motor controller or starter, form HxB	3.4.2
I	
inhibit time	3.4.28
J	
jam sensitive electronic overload relay	3.4.27
M	
manoeuvre	3.4.5
minimum load current	3.4.13
O	
O operation	3.4.33
OFF-state	3.4.14
OFF-state leakage current [I_L]	3.4.15
OFF-time	3.4.30
ON-state	3.4.11
ON-time	3.4.29
OPEN position	3.4.3
operating capability	3.4.18
operating cycle (of a controller)	3.4.17
operation (of a controller)	3.4.16
overload current profile	3.4.19
P	
phase loss sensitive overload relay or release	3.4.23
prospective current (of a circuit and with respect to a switching device or a fuse)	3.4.9
prospective locked rotor current [I_{LRP}]	3.4.10
R	
radio (frequency) disturbance	3.5.4
radio frequency interference [RFI]	3.5.5
rating index	3.4.20
S	
semiconductor direct on line (DOL) motor controller (form 3)	3.3.5
semiconductor motor controller (form 1)	3.3.3
semiconductor motor starter (form 1, form 2, form 3)	3.3.6
semiconductor soft-start motor controller (form 2)	3.3.4
semiconductor switching device	3.3.1
stall sensitive electronic overload relay	3.4.26
T	
transient (adjective and noun)	3.5.6
trip-free controller or starter	3.4.22
tripping operation (of a controller or starter)	3.4.21
U	
under-current relay or release	3.4.24
under-voltage relay or release	3.4.25

V

voltage surge 3.5.8

3.3 Terms and definitions concerning a.c. semiconductor motor controllers and starters

3.3.1

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

[IEC 60947-1:2007, 2.2.3]

3.3.2

a.c. semiconductor motor controller

semiconductor switching device that provides the starting function for an a.c. motor and an OFF-state

NOTE 1 Because dangerous levels of leakage currents can exist in a semiconductor motor controller in the OFF-state, the load terminals should be considered as live parts at all times.

NOTE 2 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.

3.3.3

semiconductor motor controller (form 1)

a.c. semiconductor motor controller, in which the starting function may comprise any starting method specified by the manufacturer, and that provides control functions which may include any combination of manoeuvring, controlled acceleration, running or controlled deceleration of an a.c. motor. A FULL-ON state may also be provided

NOTE See Figure 1 and Table 1.

3.3.4

semiconductor soft-start motor controller (form 2)

special form of a.c. semiconductor motor controller, in which the starting function is limited to a voltage and/or current ramp which may include controlled acceleration, and where the additional control function is limited to providing FULL-ON

NOTE See Figure 1 and Table 1.

3.3.5

semiconductor direct on line (DOL) motor controller (form 3)

special form of a.c. 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 See Figure 1 and Table 1.

3.3.6

semiconductor motor starter (form 1, form 2, form 3)

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

NOTE See Figure 1 and Table 1.

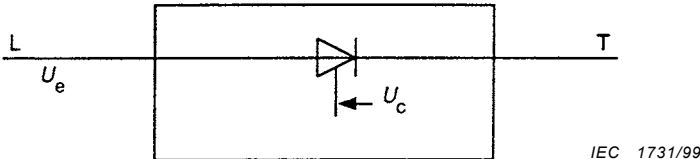
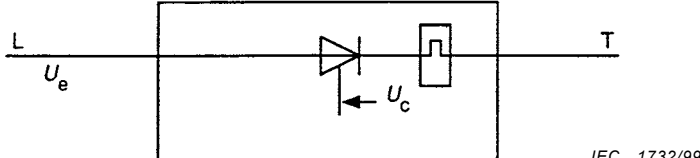
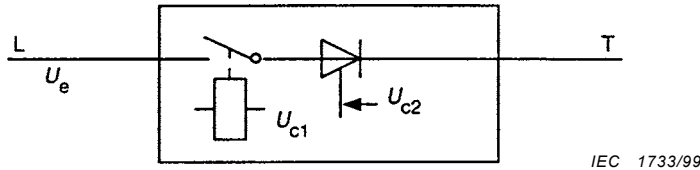
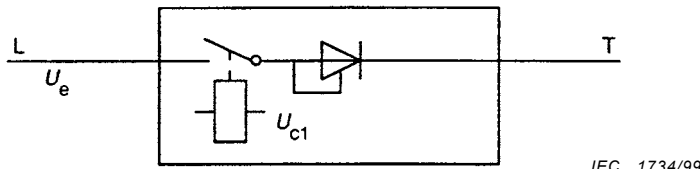
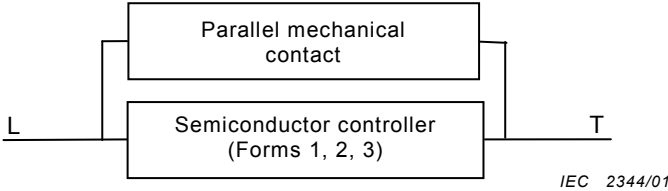
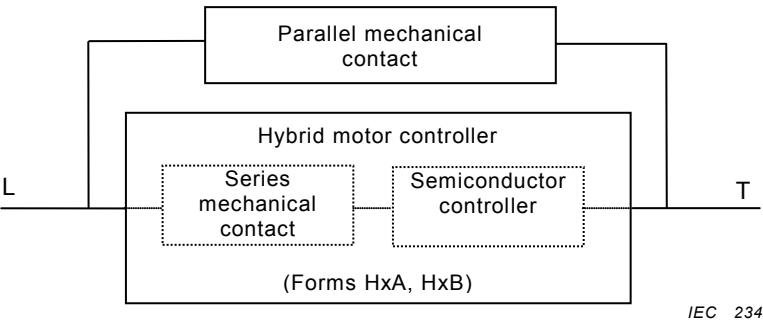
Device			
Semiconductor motor controller (forms 1, 2, 3)			
Semiconductor motor starter (forms 1, 2, 3)			
Hybrid motor controller HxA ^a where x = 1, 2 or 3			
Hybrid motor controller HxB ^b			
Bypassed controller			
Bypassed hybrid motor controller ^c			
Hybrid motor starter	Form H1A or H1B with motor overload protection	Form H2A or H2B with motor overload protection	Form H3A or H3B with motor overload protection
^a Two separate controls for the controller and the series mechanical switching device. ^b One control only for the series mechanical switching device. ^c For other configurations, tests may be suitably adapted by agreement between the user and the manufacturer.			

Figure 1 – Semiconductor motor control devices

Table 1 – Functional possibilities of semiconductor motor control devices

Device	Form 1	Form 2	Form 3
Semiconductor motor controller	– OFF – Starting function – Manoeuvring – Controlled acceleration – Running – FULL ON – Controlled deceleration	– OFF state – Starting function – Controlled acceleration – FULL ON	Not available
Semiconductor DOL motor controller	Not available	Not available	– OFF state – Starting function – FULL ON
Semiconductor motor starter	Form 1 controller with motor overload protection	Form 2 controller with motor overload protection	Not available
Semiconductor DOL motor starter	Not available	Not available	Form 3 DOL motor controller with motor overload protection
Hybrid motor controller HxA ^a where x = 1, 2 or 3	H1A: – Open – OFF state – Starting function – Manoeuvring – Controlled acceleration – Running – Full ON – Controlled deceleration	H2A: – Open – OFF state – Starting function – Controlled acceleration – FULL ON	H3A: – Open – OFF state – Starting function – FULL ON
Hybrid motor controller HxB ^b where x = 1, 2 or 3	H1B: – Open – Starting function – Manoeuvring – Controlled acceleration – Running – FULL ON – Controlled deceleration	H2B: – Open – Starting function – Controlled acceleration – FULL ON	H3B: – Open – Starting function – FULL ON
Hybrid motor starter	Form H1A or H1B with motor overload protection	Form H2A or H2B with motor overload protection	Form H3A or H3B with motor overload protection
^a Two separate controls for the controller and the series mechanical switching device.			
^b One control only for the series mechanical switching device.			

3.4 Terms and definitions concerning hybrid motor controllers and starters

3.4.1

hybrid motor controller or starter, form HxA (where x = 1, 2 or 3)

form 1, 2 or 3 semiconductor motor controller or starter in series with a mechanical switching device, all rated as a unit

NOTE 1 Separate control commands are provided for the series mechanical switching device and the semiconductor motor controller or starter. All the control functions appropriate to the form of motor controller or starter specified are provided, together with an OPEN position.

NOTE 2 See Figure 1.

3.4.2

hybrid motor controller or starter, form HxB

form 1, 2 or 3 semiconductor motor controller or starter in series with a mechanical switching device, all rated as a unit. A single control command is provided for both the series mechanical switching device and the semiconductor motor controller or starter

NOTE 1 All the control functions appropriate to the form of motor controller specified are provided, with the exception of an OFF state.

NOTE 2 See Figure 1.

3.4.3

OPEN position

condition of a hybrid semiconductor motor controller or starter when the series mechanical switching device is in the OPEN position

[2.4.21 of IEC 60947-1:2007, modified]

3.4.4

current-limit function

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

NOTE It does not include the ability to limit the instantaneous current under conditions of short circuit.

3.4.5

manoeuvre

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

NOTE 1 Starting is a mandatory manoeuvre that is recognized separately.

NOTE 2 Braking operations performed by the a.c. semiconductor motor controller or starter are considered to be a manoeuvre within the scope of this standard.

3.4.6

controlled acceleration

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

3.4.7

controlled deceleration

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

3.4.8

controlled running

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

3.4.9

prospective current (of a circuit and 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 The method to be used to evaluate and to express the prospective current is to be specified in the relevant product standard.

[IEC 60947-1:2007, 2.5.5]

3.4.10

prospective locked rotor current

I_{LRP}

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

3.4.11

ON-state

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

3.4.12

FULL-ON (state of controllers)

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

3.4.13

minimum load current

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

NOTE The minimum load current should be given as the r.m.s value.

3.4.14

OFF-state

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

3.4.15

OFF-state leakage current

I_L

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

3.4.16

operation (of a controller)

transition from the ON-state to the OFF-state, or the reverse

3.4.17

operating cycle (of a controller)

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

NOTE A succession of operations not forming an operating cycle is referred to as an operating series.

3.4.18

operating capability

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

3.4.19

overload current profile

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

NOTE See 5.3.5.1.

3.4.20

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 See 6.1e).

3.4.21

tripping operation (of a motor controller or starter)

operation to establish and maintain an OFF-state (or open position in the case of a form HxB motor controller or starter) initiated by a control signal

3.4.22

trip-free controller or starter

controller or starter which establishes and sustains an OFF-state condition, which cannot be overridden in the presence of a trip condition

NOTE In the case of form HxB, the term "OFF-state condition" is replaced by the term "OPEN position".

3.4.23

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

3.4.24

under-current relay or release

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

3.4.25

under-voltage relay or release

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

3.4.26

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 Explanation of stall: rotor locked during start.

3.4.27

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 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.

3.4.28

inhibit time

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

3.4.29

ON-time

period of time during which the controller is on-load

NOTE See the example in Figure F.1.

3.4.30

OFF-time

the period of time during which the controller is off-load

NOTE See the example in Figure F.1.

3.4.31

bypassed controller

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

NOTE See Figure 1.

3.4.32

CO operation

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

3.4.33

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

3.5 Terms and definitions concerning EMC definitions

NOTE For convenience and to avoid confusion, some of the key definitions from IEC 60050-161 are reproduced here. Further explanations are given in IEC 61000-2-1.

3.5.1

electromagnetic compatibility

EMC

ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

[IEC 60050-161:1990, 161-01-07]

3.5.2

electromagnetic emission

phenomenon by which electromagnetic energy emanates from a source

[IEC 60050-161:1990, 161-01-08]

3.5.3

electromagnetic disturbance

any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter

NOTE An electromagnetic disturbance may be an electromagnetic noise, an unwanted signal, or a change in the propagation medium itself.

[IEC 60050-161:1990, 161-01-05]

3.5.4

radio (frequency) disturbance

electromagnetic disturbance having components in the radio frequency range

[IEC 60050-161:1990, 161-01-13]

3.5.5

radio frequency interference

RFI

degradation of the reception of a wanted signal caused by radio frequency disturbance

NOTE The English words "interference" and "disturbance" are often used indiscriminately. The expression 'radio-frequency interference' is also commonly applied to a radio-frequency disturbance or an unwanted signal.

[IEC 60050-161:1990, 161-01-14]

3.5.6

transient, adjective and noun

pertaining to or designating a phenomenon or a quantity which varies between two consecutive steady states during a time interval short compared with the time-scale of interest

[IEC 60050-161:1990, 161-02-01]

3.5.7

burst (of pulses or oscillations)

sequence of a limited number of distinct pulses or an oscillation of limited duration

[IEC 60050-161:1990, 161-02-07]

3.5.8

voltage surge

transient voltage wave propagating along a line or a circuit and characterized by a rapid increase followed by a slower decrease of the voltage

[IEC 60050-161:1990, 161-08-11]

3.6 Symbols and abbreviations

Symbol or abbreviation	Description	Definition or occurrence
A_f	Final ambient temperature	9.3.3.3.4
C_f	Final case temperature	9.3.3.3.4
EMC	Electromagnetic compatibility	3.5.1
EUT	Equipment under test	
I_c	Current made and broken	Table 13
I_e	Rated operational current	5.3.2.3
I_F	Leakage current after the blocking and commutating capability test	9.3.3.6.3
I_{init}	Initial test current	9.3.3.6.2
I_L	OFF-state leakage current	3.4.15
I_{LRP}	Prospective locked rotor current	3.4.10
I_O	Leakage current before the blocking and commutating capability test	9.3.3.6.3
I_{th}	Conventional free air thermal current	5.3.2.1
I_{the}	Conventional enclosed thermal current	5.3.2.2
I_u	Rated uninterrupted current	5.3.2.4
RFI	Radio frequency interference	3.5.5
SCPD	Short-circuit protective device	
U_c	Rated control circuit voltage	5.5
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 11
U_s	Rated control supply voltage	5.5

4 Classification

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

5 Characteristics of a.c. 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);
- types and characteristics of relays and releases (5.7);
- co-ordination with short-circuit protective devices (5.8).

5.2 Type of equipment

The following shall be stated:

5.2.1 Form of equipment

Forms of controllers and starters (see 3.3 and 3.4).

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 of hybrid 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

The rated and limiting values established for controllers and starters shall be stated in accordance with 5.3.1 to 5.3.6, but it may not be necessary to establish all applicable values by tests.

5.3.1 Rated voltages

A controller or starter is defined by the following rated voltages.

5.3.1.1 Rated operational voltage (U_e)

Subclause 4.3.1.1 of IEC 60947-1:2007 applies with the following addition.

The rating of a.c. 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 4.3.1.2 of IEC 60947-1:2007 applies.

5.3.1.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1:2007 applies.

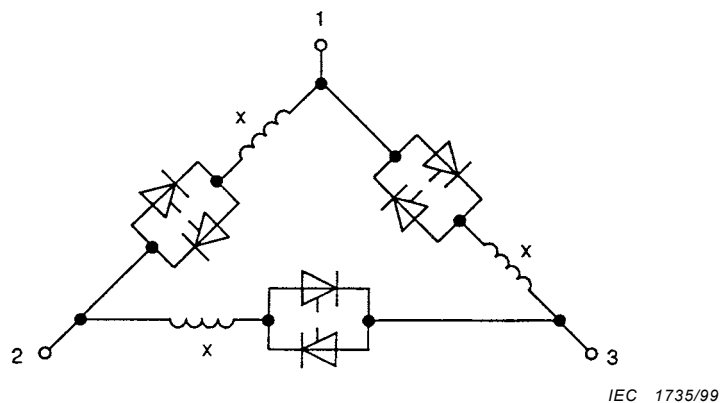


Figure 2a – Motor in delta – Thyristors in series with a winding

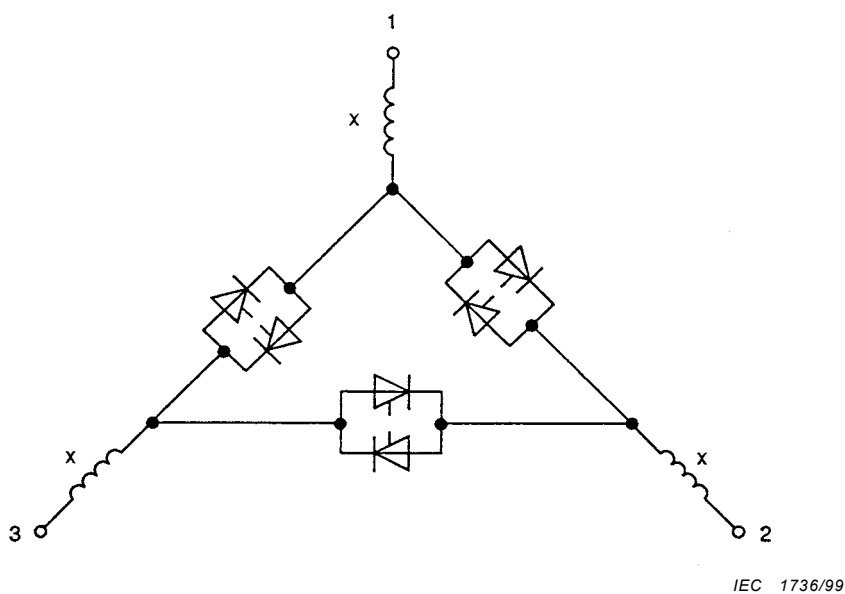


Figure 2b – Motor in star – Thyristors in delta

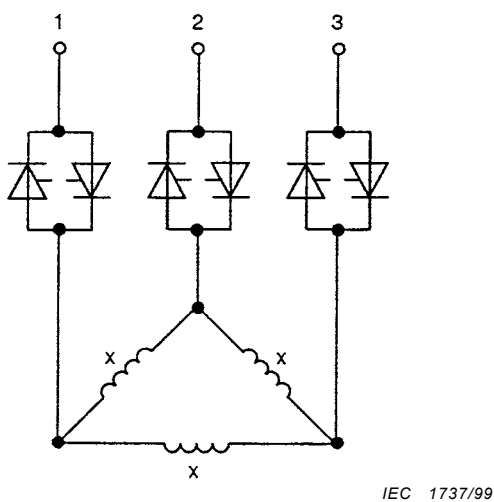


Figure 2c – Motor in delta – Thyristors connected between winding and supply

Figure 2 – Connecting methods

5.3.2 Currents

A controller or starter is defined by the following currents:

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

Subclause 4.3.2.1 of IEC 60947-1:2007 applies.

5.3.2.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of IEC 60947-1:2007 applies.

5.3.2.3 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 rated duty (see 5.3.4), the utilization category (see 5.4), the overload characteristics (see 5.3.5), and the type of protective enclosure, if any.

5.3.2.4 Rated uninterrupted current (I_u)

Subclause 4.3.2.4:2007 of IEC 60947-1:2007 applies.

5.3.3 Rated frequency

Subclause 4.3.3:2007 of IEC 60947-1:2007 applies.

5.3.4 Rated duty

The rated duties considered as normal are as follows:

5.3.4.1 8 h duty

A duty in which the controller or starter remains in the FULL-ON state while carrying a steady current long enough for the equipment to reach thermal equilibrium, but not for more than 8 h, without interruption.

5.3.4.2 Uninterrupted duty

A duty in which the controller or starter remains in the FULL-ON state while carrying a steady current without interruption for periods of more than 8 h (weeks, months, or even years).

5.3.4.3 Intermittent periodic duty or intermittent duty

Subclause 4.3.4.3:2007 of IEC 60947-1:2007 applies, except that the first paragraph is changed as follows:

"A duty with on-load periods in which the controller or starter remains in the FULL-ON state, having a definite relation to off-load periods, both periods being too short to allow the equipment to reach thermal equilibrium."

5.3.4.4 Temporary duty

Duty in which the controller or starter remains in the FULL-ON state for periods of time insufficient to allow the equipment to reach thermal equilibrium, the current-carrying periods being separated by off-load periods of sufficient duration to restore equality of temperature with the cooling medium. Standard values of temporary duty are as follows:

30 s, 1 min, 3 min, 10 min, 30 min, 60 min and 90 min.

5.3.4.5 Periodic duty

Subclause 4.3.4.5 of IEC 60947-1:2007 applies.

5.3.4.6 Duty cycle values and symbols

For the purpose of this standard, the duty cycle is expressed by two symbols, F and S . These describe the duty, and also set the time that must 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 may be declared by the manufacturer.

5.3.5 Normal load and overload characteristics

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

5.3.5.1 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 9, and represents the maximum value of operating current due to starting, operating, or manoeuvring under overload conditions. $X = I_{LRP}/I_e$ 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 9.

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

5.3.5.2 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 rated duty (see 5.3.4);

- the overload current profile (see 5.3.5.1);
- the utilization category (see 5.4).

Requirements are given in 8.2.4.1.

5.3.5.3 Starting, stopping and manoeuvring characteristics

Typical service conditions for controllers and starters controlling squirrel cage and hermetic refrigeration motors are as follows:

5.3.5.3.1 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-53a, AC-58a).
- 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 intermittent duty only (AC-53b, AC-58b); for example after starting, the motor may be connected into a circuit that bypasses the power semiconductors.

Two directions of rotation may be accomplished by reversing the connections to the controller or motor by means that are beyond the scope of this standard, but are covered by the relevant product standard for the selected means.

Two directions of rotation may also be accomplished by phase reversing within the controller or starter. The requirements for this operation will vary with each application. Therefore, this is subject to agreement between manufacturer and user.

Due to the control capability of controllers and starters, the current during starting, stopping, and any manoeuvre will differ from the conventional values of the prospective locked rotor current listed in Table 11.

5.3.5.3.2 Starting characteristics of rheostatic rotor starters with controllers energizing the stator (AC-52a, AC-52b)

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.

NOTE Starters and controllers covered by this standard are not intended for use in the rotor circuit and therefore, the rotor circuit must be controlled by traditional means. The relevant product standards for the rotor circuits of rheostatic rotor starters should apply.

5.3.6 Rated conditional short-circuit current

Subclause 4.3.6.4 of IEC 60947-1:2007 applies.

5.4 Utilization category

5.4.1 General

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

For controllers and starters, the utilization categories as given in Table 2 are considered standard. Any other type of utilization shall be based on agreement between manufacturer and user, but information given in the manufacturer's catalogue or tender may constitute such an agreement.

Each utilization category (see Table 2) is characterized by the values of the currents, voltages, power-factors and other data of Table 3, Table 9, Table 10 and Table 11, and by the test conditions specified in this standard.

The first digit of the utilization category identification designates a semiconductor switching device (for example within this standard a semiconductor motor controller or starter). The second digit designates a typical application. The a-suffix designates the capability of a controller to perform any of the functional possibilities listed in Table 1. The b-suffix designates the capability of a controller where it is restricted to performing a transition from an OFF-state to a starting function of duration T_x , and immediately returning to the OFF-state to comprise a duty cycle in accordance with the requirements of 8.2.4.1.

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 3;
- 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 3. Only values of X lower than the tested value of X may be assigned without testing.

Table 2 – Utilization categories

Utilization category	Typical application
AC-52a	Control of slip ring motor stators: 8 h duty with on-load currents for start, acceleration, run
AC-52b	Control of slip ring motor stators: intermittent duty
AC-53a	Control of squirrel cage motors: 8 h duty with on-load currents for start, acceleration, run
AC-53b	Control of squirrel cage motors: intermittent duty
AC-58a	Control of hermetic refrigerant compressor motors with automatic resetting of overload releases: 8 h duty with on-load currents for start, acceleration, run
AC-58b	Control of hermetic refrigerant compressor motors with automatic resetting of overload releases: intermittent duty
NOTE 1 The means of bypassing the semiconductor controller or starter may be integral with the controller/starter or installed separately. It also may be dependant or unrestricted as specified in 8.2.1.7 and 8.2.1.8. NOTE 2 A hermetic refrigerant compressor motor is a combination consisting of a compressor and motor, both of which are enclosed in the same housing, with no external shaft or shaft seals, the motor operating in the refrigerant.	