

Low-voltage switchgear and controlgear —

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

The European Standard EN 60947-4-2:2000, with the incorporation of amendments A1:2002 and A2:2006, has the status of a British Standard

ICS 29.130.20

National foreword

This British Standard was published by BSI. It is the UK implementation of EN 60947-4-2:2000, incorporating amendments A1:2002 and A2:2006. It is identical with IEC 60947-4-2:1999, Edition 2.1:2002 which comprises Edition 1.0:2000 consolidated by the incorporation of amendment 1:2001, amendment 2:2006 and corrigendum March 2002.

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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 PEL/17/2 can be obtained on request to its secretary.

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This British Standard, having been prepared under the direction of the Electrotechnical Sector Committee, was published under the authority of the Standards Committee and comes into effect on 15 June 2002

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Amendments issued since publication

Amd. No.	Date	Comments
13852	11 October 2002	See national foreword
16917	28 February 2007	See national foreword

ISBN 0 580 34917 9

English version

Low-voltage switchgear and controlgear — Part 4-2: Contactors and motor-starters — AC semiconductor motor controllers and starters

Appareillage à basse tension —
Partie 4-2: Contacteurs et démarreurs de
moteurs — Gradateurs et démarreurs à
semiconducteurs de moteurs à courant
alternatif

Neiderspannungsschaltgeräte —
Teil 4-2: Schütze und Motorstarter
Halbleiter-Motor-Steuergeräte und Starter für
Wechselspannung

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CENELEC

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

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Foreword

The text of document 17B/998/FDIS, future edition 2 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 was approved by CENELEC as EN 60947-4-2 on 1999-10-01.

This European Standard, together with EN 60947-4-3:2000, supersedes HD 419.2 S1:1987. This European Standard supersedes EN 60947-4-2:1996, with its corrigendum June 1997 and its amendments A1:1997 and A2:1998.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2000-09-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dop) 2002-12-01

Annexes designated “normative” are part of the body of the standard.

Annexes designated “informative” are given for information only.

In this standard, Annex A, Annex B, Annex C, Annex D and Annex ZA are normative and Annex E, Annex F, Annex G and Annex H are informative. Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60947-4-2:1999 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	NOTE	Harmonized in the EN 60146 series.
IEC 60269-2	NOTE	Harmonized as EN 60269-2:1995 (not modified).
IEC 60269-2-1	NOTE	Harmonized as HD 630.2.1 S4:2000 (modified).
CISPR 22	NOTE	Harmonized as EN 55022:1998 (modified).

Foreword to amendment A1

The text of document 17B/1143/FDIS, future amendment 1 to IEC 60947-4-2:1999, 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 was approved by CENELEC as amendment A1 to EN 60947-4-2:2000 on 2002-03-05.

The following dates were fixed:

- latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2002-12-01
- latest date by which the national standards conflicting with the amendment have to be withdrawn (dop) 2005-03-01

Annexes designated “normative” are part of the body of the standard.

Annexes designated “informative” are given for information only.

In this standard, Annex I and Annex ZA are normative and Annex J is informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of amendment 1:2001 to the International Standard IEC 60947-4-2:1999 was approved by CENELEC as an amendment to the European Standard without any modification.

Foreword to amendment A2

The text of document 17B/1499/FDIS, future amendment 2 to IEC 60947-4-2:1999, 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 was approved by CENELEC as amendment A2 to EN 60947-4-2:2000 on 2006-12-01.

The following dates were fixed:

- latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2007-09-01
- latest date by which the national standards conflicting with the amendment have to be withdrawn (dow) 2009-12-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of amendment 2:2006 to the International Standard IEC 60947-4-2:1999 was approved by CENELEC as an amendment to the European Standard without any modification.

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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.

The provisions of IEC 60947-1, General Rules, are applicable to this standard, where specifically called for. Clauses and subclauses thus applicable, as well as tables, figures, and annexes are identified by reference to IEC 60947-1, for example subclause 1.2.3 of IEC 60947-1, table 4 of IEC 60947-1 or annex A of IEC 60947-1.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

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

1 Scope and object

This standard applies to 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.

A1 This standard characterizes controllers and starters with and without bypass means. **A1**

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 controller or starter.

In this context, this standard gives requirements for 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) controlling non-motor loads;
- electronic a.c. power controllers covered by IEC 60146.

A2 Contactors, overload relays and control circuit devices used in controllers and starters **A2** 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 controllers and starters and associated equipment;
- the conditions with which controllers and starters shall 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.

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

IEC 60050(161):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electro-magnetic compatibility*

 Amendment 1 (1997)

Amendment 2 (1998) 

 IEC 60085:2004, *Electrical insulation – Thermal classification*

IEC 60146 (all parts), *Semiconductor convertors* 

IEC 60269-1:1998, *Low-voltage fuses – Part 1: General requirements*

 Amendment 1 (2005) 

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

 IEC 60439-1:1999, *Low-voltage switchgear and controlgear assemblies – Part 1: Type-tested and partially type-tested assemblies*

Amendment 1 (2004) 

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

 IEC 60947-1:2004, *Low-voltage switchgear and controlgear – Part 1: General rules* 

IEC/TR3 61000-2-1:1990, *Electromagnetic compatibility (EMC) – Part 2: Environment – Section 1: Description of the environment – Electromagnetic environment for low-frequency conducted disturbances and signalling in public power supply systems*

 IEC 61000-3-2:2005, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)* 

IEC 61000-4-2:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 2: Electrostatic discharge immunity test – Basic EMC publication*

 Amendment 1 (1998)

Amendment 2 (2000)

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

IEC 61000-4-4:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test – Basic EMC publication*
 Amendment 1 (2000)
 Amendment 2 (2001)

IEC 61000-4-5:1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 5: Surge immunity test*
 Amendment 1 (2000)

IEC 61000-4-6:2003, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*
 Amendment 1 (2004)

IEC 61000-4-11:1994, *Electromagnetic compatibility (EMC) – Part 4: Testing and measuring techniques – Section 11: Voltage dips, short interruptions and voltage variations immunity tests*
 Amendment 1 (2000)

IEC 61131-2:2003, *Programmable controllers – Part 2: Equipment requirements and tests*

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

CISPR 14-1, *Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 1: Emission*

Text deleted

3 Definitions, symbols and abbreviations

For the purposes of this standard, relevant definitions of clause 2 of IEC 60947-1 and the following additional definitions apply.

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¹⁾ There exists a consolidated edition 3.1 (1999) that includes CISPR 11 (1997) and its amendment 1 (1999).

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3.1 Definitions concerning a.c. semiconductor motor control devices

3.1.1 AC semiconductor motor controllers and starters (see figure 1)

3.1.1.1

a.c. semiconductor motor controller

semiconductor switching device (see 2.2.3 of IEC 60947-1) that provides the starting function for an a.c. motor and an OFF-state

NOTE 1 Because dangerous levels of leakage currents (see 3.1.13) can exist in a semiconductor motor controller in the OFF-state, the load terminals should be considered to be live 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.

3.1.1.1.1

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

3.1.1.1.2

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

3.1.1.1.3

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

3.1.1.2

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

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

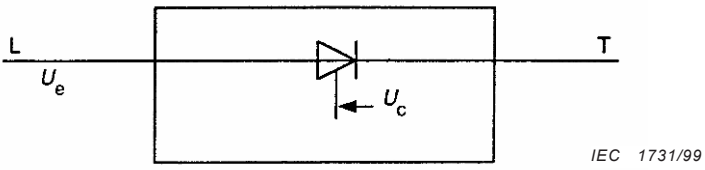
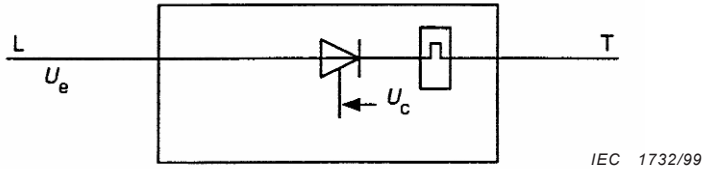
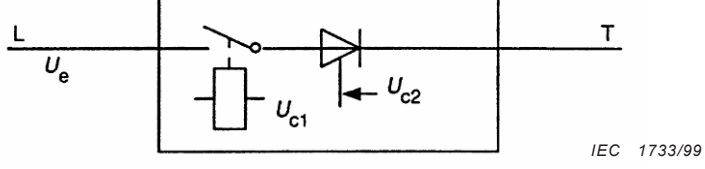
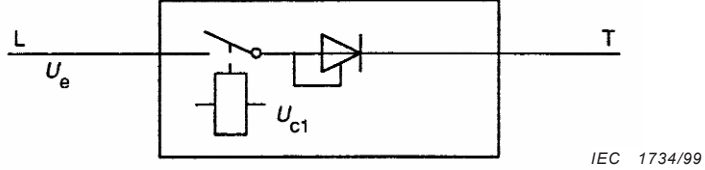
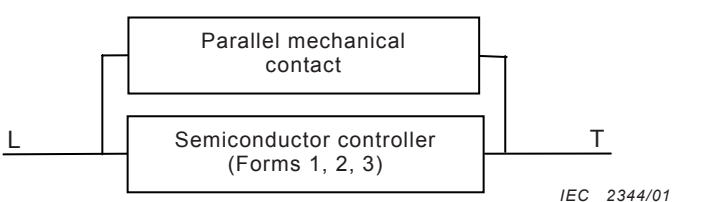
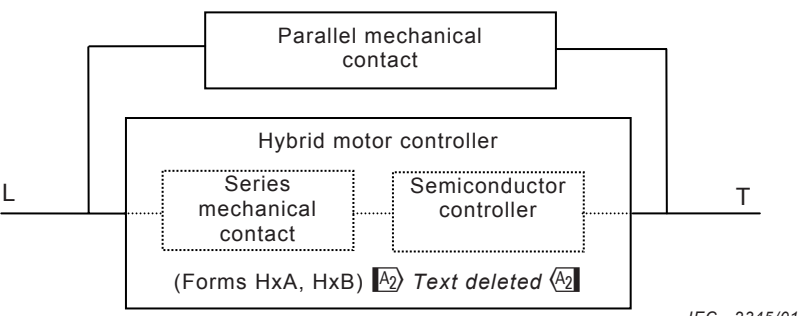
Device	
Semiconductor motor controller (forms 1, 2, 3)	
Semiconductor motor starter (forms 1, 2, 3)	
Hybrid motor controller HxA* where x = 1, 2 or 3	
Hybrid motor controller HxB**	
Bypassed controller	
A2 Bypassed hybrid motor controller^C A2	
Hybrid motor starter	Form H1A or H1B with motor overload protection Form H2A or H2B with motor overload protection Form H3A or H3B with motor overload protection
* Two separate controls for the controller and the series mechanical switching device. ** One control only for the series mechanical switching device. A2 ^C For other configurations, tests may be suitably adapted by agreement between the user and the manufacturer. A2	

Figure 1 –Semiconductor motor control devices

A1

Table 1 – Functional possibilities of semiconductor motor control devices

Device	Form 1	Form 2	Form 3
Semiconductor motor controller	– OFF – Starting function – Manœuvring – 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* where x = 1, 2 or 3	H1A: – Open – OFF state – Starting function – Manœuvring – 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** where x = 1, 2 or 3	H1B: – Open – Starting function – Manœuvring – 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
* Two separate controls for the controller and the series mechanical switching device.			
** One control only for the series mechanical switching device.			

3.1.2 Hybrid motor controllers and starters (see figure 1)

3.1.2.1

hybrid motor controllers or starters, 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. 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

3.1.2.2

hybrid motor controllers or starters, 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. All the control functions appropriate to the form of motor controller specified are provided, with the exception of an OFF state

3.1.2.3

OPEN position

condition of a hybrid semiconductor motor controller or starter when the series mechanical switching device is in the OPEN position (see 2.4.21 of IEC 60947-1)

3.1.3

current-limit function

ability of the controller to limit the motor current to a specified value. It does not include the ability to limit the instantaneous current under conditions of short circuit

3.1.4

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.

3.1.5

controlled acceleration

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

3.1.6

controlled deceleration

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

3.1.7

controlled running

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

3.1.8

prospective locked rotor current, (I_{LRP})

prospective current (see 2.5.5 of IEC 60947-1) that would flow when the rated voltage is applied to the motor with a locked rotor

3.1.9

ON-state

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

3.1.10

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

3.1.11

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.

3.1.12

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

3.1.13

OFF-state leakage current (I_L)

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

3.1.14

operation (of a controller)

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

3.1.15

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.

3.1.16

operating capability

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

3.1.17

overload current profile

current-time co-ordinate specifying the requirement to accommodate overload currents for a period of time (see 5.3.5.1)

3.1.18

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 (see 6.1e))

3.1.19

tripping operation (of a controller or starter)

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

3.1.20

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".

3.1.21

A2 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

3.1.22

under-current relay or release

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

3.1.23

under-voltage relay or release

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

3.1.24

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.

3.1.25

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.

3.1.26

inhibit time

time-delay period during which the tripping function of the relay is inhibited (may be adjustable) A2

A2 3.1.27 A2

ON-time

period of time during which the controller is on-load, for example as in figure F.1 of annex F

A2 3.1.28 A2

OFF-time

the period of time during which the controller is off-load, for example as in figure F.1 of annex F

A2 3.1.29 A2

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

A2 3.1.30

CO operation

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

3.1.31

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 **A2**

3.2 EMC definitions

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

3.2.1

electromagnetic compatibility EMC (abbreviation)

ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment [IEV 161-01-07]

3.2.2

electromagnetic emission

phenomenon by which electromagnetic energy emanates from a source [IEV 161-01-08]

3.2.3

electromagnetic disturbance

any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter [IEV 161-01-05]

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

3.2.4

radio (frequency) disturbance

electromagnetic disturbance having components in the radio frequency range [IEV 161-01-13]

3.2.5

radio frequency interference, RFI (abbreviation)

degradation of the reception of a wanted signal caused by radio frequency disturbance [IEV 161-01-14]

A2 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. **A2**

3.2.6

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 [IEV 161-02-01]

3.2.7

burst (of pulses or oscillations)

sequence of a limited number of distinct pulses or an oscillation of limited duration [IEV 161-02-07]

3.2.8

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 [IEV 161-08-11]

3.3 Symbols and abbreviations

A_f	Final ambient temperature (9.3.3.3.4)
C_f	Final case temperature (9.3.3.3.4)
EMC	Electromagnetic compatibility
EUT	Equipment under test
I_c	Current made and broken (Table 8)
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 (3.1.13)
I_{LRP}	Prospective locked rotor current (3.1.8)
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)
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 6)
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);

 *Text deleted* 

5.2 Type of equipment

The following shall be stated:

5.2.1 Form of equipment

Forms of controllers and starters (see 3.1.1 and 3.1.2).

5.2.2 Number of poles

5.2.2.1 Number of main poles

5.2.2.2 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 applies.

5.3.1.2 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of IEC 60947-1 applies.

5.3.1.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of IEC 60947-1 applies.

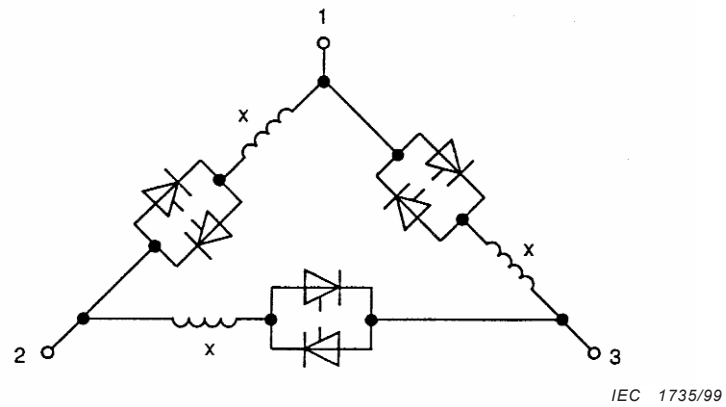


Figure 2a – Motor in delta – Thyristors in series with a winding

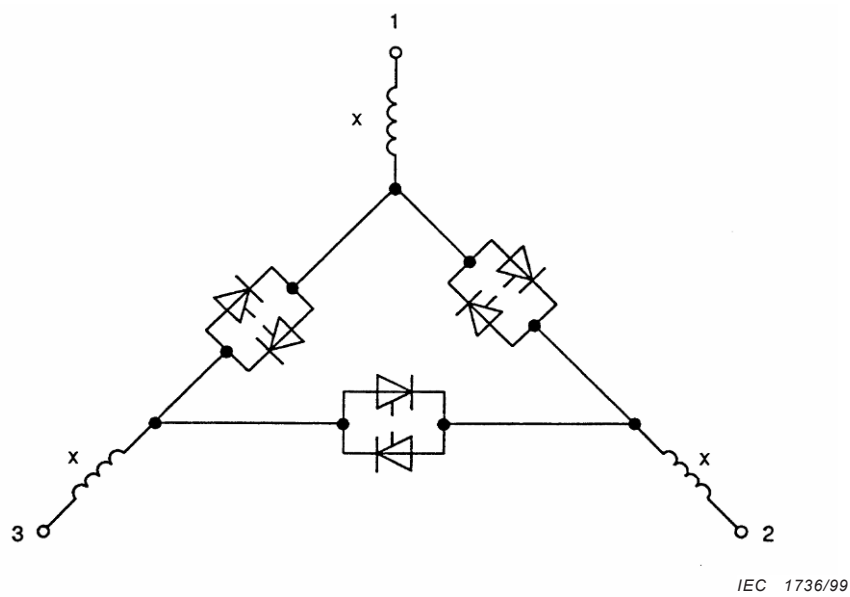


Figure 2b – Motor in star – Thyristors in delta

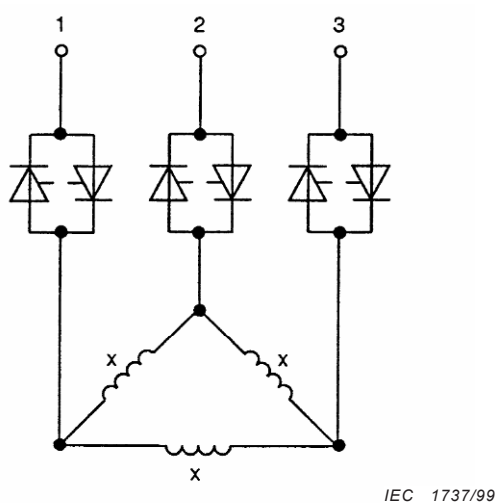


Figure 2c – Motor in delta – Thyristors connected between winding and supply

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 applies.

5.3.2.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of IEC 60947-1 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 of IEC 60947-1 applies.

5.3.3 Rated frequency

Subclause 4.3.3 of IEC 60947-1 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 of IEC 60947-1 applies, except that the first paragraph is changed to read:

"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:

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 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:

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

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

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

A2 For a starter, T_x is the minimum operating time allowed by the tolerances of the overload relay. **A2**

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:

- rated operational voltage (see 5.3.1.1);
- rated operational current (see 5.3.2.3);
- rated duty (see 5.3.4);
- overload current profile (see 5.3.5.1);
- 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 6.

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 applies.

5.4 Utilization category

Subclause 4.4 of IEC 60947-1 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 tables 3, 4, 5 and 6, and by the test conditions specified in this standard.

A₂ The first digit of the utilization category identification designates a semiconductor switching device (e.g. within this standard a semiconductor motor controller or starter). **A₂** 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.

5.4.1 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 dependent 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.

Table 3 – Relative levels of severity

Severity level	Utilization category	Overload current profile ($X \cdot T_x$)	Time related requirement
Most severe	AC-52a AC-53a AC-58a	Highest value of $(X I_e)^2 \times T_x$ (note 1)	Highest value of $F \times S$ (note 2)
	AC-52b AC-53b AC-58b	Highest value of $(X I_e)^2 \times T_x$ (note 1)	Lowest value of OFF-time (note 3)

NOTE 1 When the highest value of $(X I_e)^2 \times T_x$ occurs at more than one value of $X I_e$, then the highest value of $X I_e$ shall apply.

NOTE 2 When the highest value of $F \times S$ occurs at more than one value of S , then the highest value of S shall apply.

NOTE 3 When the highest value of $(X I_e)^2 \times T_x$ occurs at more than one value of OFF-time, then the lowest value of OFF-time shall apply.

5.5 Control circuits

Subclause 4.5.1 of IEC 60947-1 applies, with the following additions:

Refer to annex G for examples and illustrations. The characteristics of electronic control circuits are:

- kind of current;
- power consumption;
- rated frequency (or d.c.);
- rated control circuit voltage, U_c (nature: a.c./d.c.);
- rated control supply voltage, U_s (nature: a.c./d.c.);
- nature of control circuit devices (contacts, sensors).

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

5.6 Auxiliary circuits

Subclause 4.6 of IEC 60947-1 applies, with the following additions:

Electronic auxiliary circuits perform useful functions (for example monitoring, data acquisition, etc.) that are not necessarily relevant to the direct task of governing 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. If the auxiliary functions include unusual performance features, the manufacturer should be consulted to define the critical characteristics.

 Digital inputs and/or digital outputs contained in controllers and starters, and intended to be compatible with PLCs shall fulfil the requirements of IEC 61131-2. 

5.7 Characteristics of relays and releases (overload relays)

 NOTE In the remainder of this standard, 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

- a) Under-voltage and under-current opening relay or release.
- b) Overload time-delay relay the time-lag of which is:
 - 1) dependent on previous load (e.g. thermal or electronic overload relay);
 - 2) dependent on previous load (e.g. thermal or electronic overload relay) and also sensitive to phase loss (see 3.1.21);
 - 3) independent of previous load (without thermal memory).
- c) Instantaneous over-current relay or release (e.g. jam sensitive, see 3.1.25).
- d) Other relays or releases (e.g. control relay associated with devices for the thermal protection of the starter).
- e) Stall relay or release. 

5.7.3 Characteristic values

- a) 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;
 - trip class according to classification in Table 19, or the value of the maximum tripping time, in seconds, under the conditions specified in 8.2.1.5.1.1.1 and Table 20, column *D*, when this time exceeds 30 s;
 - number of poles;
 - nature of the relay: thermal, electronic or electronic without thermal memory;
 - nature of the reset: manual or automatic.
- c) Release with residual current sensing relay:
- rated current;
 - operating current;
 - operating time or time-current characteristic according to Table K.1;
 - inhibit time (when applicable);
 - type designation (see Annex K). 

 Table 19 – 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 20, column D ^a	Tripping time T_p under the conditions specified in 8.2.1.5.1.1.1 and Table 20, 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	–	$30 < T_p \leq 40$
^a The manufacturer shall add the letter E to trip classes to indicate compliance with the band E.		
NOTE 1 Depending on the nature of the relay, the tripping conditions are given in 8.2.1.5.		
NOTE 2 The lower limiting values of T_p are selected to allow for differing heater characteristics and manufacturing tolerances.		

5.7.4 Designation and current settings of overload relays

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

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

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

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

A2 5.7.5 Time-current characteristics of overload relays

Typical time-current characteristics shall be given in the form of curves supplied by the manufacturer. These curves shall indicate how the tripping time, starting from the cold state (see 5.7.6), varies with the current up to a value of at least maximum ($X \cdot I_e$) value. The manufacturer shall be prepared to indicate, by suitable means, the general tolerances applicable to these curves and the conductor cross-sections used for establishing these curves (see 9.3.3.6.5, item c)).

NOTE It is recommended that the current be plotted as abscissae and the time as ordinates, using logarithmic scales. It is recommended that the current be plotted as multiples of the setting current and the time in seconds on the standard graph sheet detailed in IEC 60269-1.

5.7.6 Influence of ambient air temperature

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

The overload relays shall be able to operate within the ambient air temperature range of 0 °C to +40 °C, and the manufacturer shall be prepared to state the effect of variation in ambient air temperature on the characteristics of overload relays. **A2**

5.8 Co-ordination with short-circuit protective devices (SCPD)

Controllers and starters are characterized by the type, ratings, and characteristics of the SCPD to be used to provide overcurrent discrimination between starter and SCPD, and adequate protection of controllers and starters against short-circuit currents.

Requirements are given in 8.2.5 of this standard and in 4.8 of IEC 60947-1.

A2 Text deleted **A2**

6 Product information

6.1 Nature of information

The following information shall be given by the manufacturer:

Identification

- a) the manufacturer's name or trademark;
- b) type designation or serial number;
- c) number of this standard.

Characteristics, basic rated values and utilization

- d) rated operational voltages (see 5.3.1.1);