

**Specification for**

# **Low-voltage switchgear and controlgear —**

**Part 4: Contactors and motor-starters —**

**Section 2: A.C. semiconductor motor  
controllers and starters**

The European Standard EN 60947-4-2:1996 with the incorporation of amendments A1:1997 and A2:1998 has the status of a British Standard

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## Committees responsible for this British Standard

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Association of Manufacturers Allied to the Electrical and Electronic Industry (BEAMA Ltd.)  
 ASTA Certification Services  
 British Railways Board  
 Copper Development Association  
 Electricity Association  
 ERA Technology Ltd.  
 GAMBICA (BEAMA Ltd.)  
 Health and Safety Executive  
 Ministry of Defence  
 Transmission and Distribution Association (BEAMA Ltd.)

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Association of Consulting Engineers  
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 Electrical Installation Equipment Manufacturers' Association (BEAMA Ltd.)  
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## National foreword

This British Standard has been prepared by Technical Committee PEL/17 and is the English language version of EN 60947-4-2:1996 *Low-voltage switchgear and controlgear Part 4: Contactors and motor-starters Section 2: A.C. semiconductor motor controllers and starters* including, amendments A1:1997 and A2:1998, published by the European Committee for Electrotechnical Standardization (CENELEC). It is identical with IEC 60947-4-2:1995 including amendments 1:1997 and 2:1998 (and corrigendum March 1999 to amendment 2) published by the International Electrotechnical Commission (IEC).

NOTE The CENELEC common modifications have been adopted by IEC and issued as amendment 2:1998 to IEC 60947-4-2:1995.

### Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled “International Standards Correspondence Index ”or using the “Find” facility of the BSI Standards Electronic Catalogue.

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### Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 71 and a back cover.

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Low-voltage switchgear and controlgear —  
Part 4: Contactors and motor-starters —  
Section 2: A.C. semiconductor motor controllers and starters

(including amendments A1: 1997 and A2:1998)  
(IEC 60947-4-2:1995, modified + A1:1997 + A2:1998)

Appareillage à basse tension —  
Partie 4: Contacteurs et démarreurs de moteurs —  
Section 2: Gradateurs et démarreurs à  
semiconducteurs de moteurs à courant alternatif  
(inclut les amendements A1:1997 et A2:1998)  
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Niederspannung-Schaltgeräte —  
Teil 4: Schütze und Motorstarter —  
Hauptabschnitt 2: Halbleiter-Motor-Steuergeräte  
und Starter für Wechselspannung  
(enthält Änderungen A1:1997 und A2:1998)  
(IEC 60947-4-2:1995, modifiziert  
+ A1:1997 + A2:1998)

This European Standard was approved by CENELEC on 1996-03-05; amendment A1 was approved by CENELEC on 1997-07-01 and A2 on 1998-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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**CENELEC**

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

**Central Secretariat: rue de Stassart 35, B-1050 Brussels**

Foreword

The text of the International Standard IEC 947-4-2 : 1995, prepared by SC 17B, Low-voltage switchgear and controlgear, of IEC TC 17, Switchgear and controlgear, together with common modifications prepared by the Technical Committee CENELEC TC 17B, Low-voltage switchgear and controlgear including dimensional standardization, was submitted to the formal vote and was approved by CENELEC as EN 60947-4-2 on 1996-03-05.

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) 1997-03-01
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 1999-03-01

For products which have complied with the relevant national standard before 1997-03-01, as shown by the manufacturer or by a certification body, this previous standard may continue to apply for production until 2002-03-01.

Annexes designated 'normative' are part of the body of the standard. Annexes designated 'informative' are given for information only. In this standard, annexes A, B, C, D and ZA are normative and annexes E, F, G and H are informative. Annex ZA has been added by CENELEC.

Foreword to amendment A1

The text of document 17B/785/FDIS, future amendment 1 to IEC 60947-4-2 : 1995, 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 : 1996 on 1997-07-01.

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Foreword to amendment A2

The text of document 17B/919/FDIS, future amendment 2 to IEC 60947-4-2:1995, 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 60947-4-2:1996 on 1998-10-01.

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- latest date by which the national standards conflicting with the amendment have to be withdrawn (dow) 2001-07-01

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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 947-1, 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 947-1, for example subclause 1.2.3, table 4 of IEC 947-1 or annex A of IEC 947-1.

## LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR

### Part 4: Contactors and motor-starters Section 2: 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.

This standard characterizes controllers and starters for use with and without bypass switching devices.

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 947-1) controlling non-motor loads;
- electronic a.c. power controllers covered by IEC 146.

Contactors and control circuit devices used in 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 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 normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 947. At the time of publication the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 947 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(161): 1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

IEC 410: 1973, *Sampling plans and procedures for inspection by attributes*

IEC 439-1: 1992, *Low-voltage switchgear and controlgear assemblies – Part 1: Type-tested and partially type-tested assemblies*

IEC 801-1: 1984, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 1: General introduction*

IEC 801-2: 1991, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 2: Electrostatic discharge requirements*

IEC 801-3: 1984, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 3: Radiated electromagnetic field requirements*

IEC 801-4: 1988, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 4: Electrical fast transient/burst requirements*

IEC 947-1: 1988, *Low-voltage switchgear and controlgear – Part 1: General rules*  
Amendment 1 (1994)

IEC 1000-2-1: 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 1000-3-2: 1995, *Electromagnetic compatibility (EMC) – Part 3: Limits – Section 2: Limits for harmonic current emissions (equipment input current  $\leq 16$  A per phase)*

IEC 1000-4-3: 1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 3: Radiated, radio-frequency, electromagnetic fields immunity tests*

IEC 1000-4-5: 1995, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 5: Surge immunity tests*

IEC/DIS 1000-4-6, *Electromagnetic compatibility (EMC) – Part 4: Testing and measuring techniques – Section 6: Conducted disturbances induced by radio-frequency fields immunity tests*

IEC 1000-4-11: 1994, *Electromagnetic compatibility (EMC) – Part 4: Testing and measuring techniques – Section 11: Voltage dips, short interruptions and voltage variation immunity tests – Basic EMC publication*

CISPR 11: 1990, *Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific and medical (ISM) radio-frequency equipment*

CISPR 14: 1993, *Limits and methods of measurement of radio disturbance characteristics of electrical motor-operated and thermal appliances for household and similar purposes, electric tools and electric apparatus*

CISPR 22: 1993, *Limits and methods of measurement of radio disturbance characteristics of information technology equipment*

### 3 Definitions

For the purpose of this standard, relevant definitions of clause 2 of IEC 947-1 apply, with the following additional definitions.

#### 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:** A semiconductor switching device (see 2.2.3 of IEC 947-1) that provides the starting function for an a.c. motor and an OFF-state.

**NOTE** – 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.

**3.1.1.1.1 semiconductor motor controller (form 1):** An 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):** A 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):** A 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):** An a.c. semiconductor motor controller with suitable overload protection, rated as a unit.

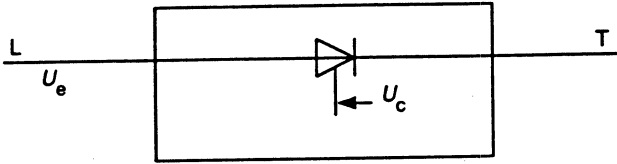
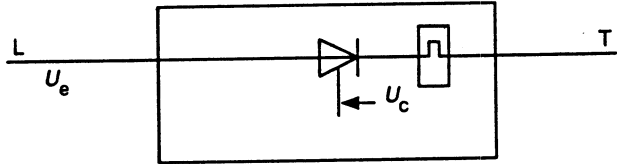
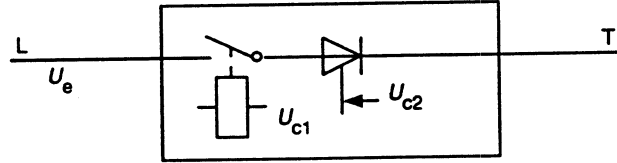
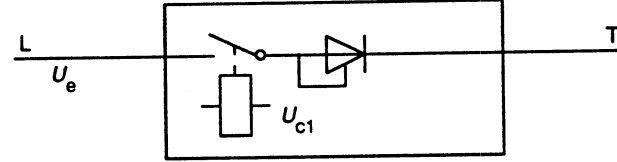
| Device                                                                                                                                                            |                                                                                      |                                                   |                                                   |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|---------------------------------------------------|---------------------------------------------------|
| Semiconductor motor controller<br>(all forms)                                                                                                                     |    |                                                   |                                                   |
| Semiconductor motor starter<br>(all forms)                                                                                                                        |    |                                                   |                                                   |
| Hybrid motor controller<br>HxA*<br>where x = 1, 2 or 3                                                                                                            |  |                                                   |                                                   |
| Hybrid motor controller<br>HxB**                                                                                                                                  |  |                                                   |                                                   |
| Hybrid motor starter                                                                                                                                              | Form H1A or H1B<br>with motor overload protection                                    | Form H2A or H2B<br>with motor overload protection | Form H3A or H3B<br>with motor overload protection |
| <p>* Two separate controls for the controller and the series mechanical switching device.<br/>** One control only for the series mechanical switching device.</p> |                                                                                      |                                                   |                                                   |

Figure 1 – Graphical possibilities of semiconductor motor control devices

**Table 1 – Functional possibilities of semiconductor motor control devices**

| Device                                                                                                                                                    | Form 1                                                                                                                                                                                                                                             | Form 2                                                                                                                                                                | Form 3                                                                                                                             |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------|
| Semiconductor motor controller                                                                                                                            | <ul style="list-style-type: none"> <li>– OFF state</li> <li>– Starting function</li> <li>– Manoeuvring</li> <li>– Controlled acceleration</li> <li>– Running</li> <li>– FULL ON</li> <li>– Controlled deceleration</li> </ul>                      | <ul style="list-style-type: none"> <li>– OFF state</li> <li>– Starting function</li> <li>– Controlled acceleration</li> <li>– FULL ON</li> </ul>                      | Not available                                                                                                                      |
| Semiconductor DOL motor controller                                                                                                                        | Not available                                                                                                                                                                                                                                      | Not available                                                                                                                                                         | <ul style="list-style-type: none"> <li>– OFF state</li> <li>– Starting function</li> <li>– FULL ON</li> </ul>                      |
| 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*<br>where x = 1, 2 or 3                                                                                                       | H1A: <ul style="list-style-type: none"> <li>– Open</li> <li>– OFF state</li> <li>– Starting function</li> <li>– Manoeuvring</li> <li>– Controlled acceleration</li> <li>– Running</li> <li>– Full ON</li> <li>– Controlled deceleration</li> </ul> | H2A: <ul style="list-style-type: none"> <li>– Open</li> <li>– OFF state</li> <li>– Starting function</li> <li>– Controlled acceleration</li> <li>– FULL ON</li> </ul> | H3A: <ul style="list-style-type: none"> <li>– Open</li> <li>– OFF state</li> <li>– Starting function</li> <li>– FULL ON</li> </ul> |
| Hybrid motor controller HxB**<br>where x = 1, 2 or 3                                                                                                      | H1B: <ul style="list-style-type: none"> <li>– Open</li> <li>– Starting function</li> <li>– Manoeuvring</li> <li>– Controlled acceleration</li> <li>– Running</li> <li>– FULL ON</li> <li>– Controlled deceleration</li> </ul>                      | H2B: <ul style="list-style-type: none"> <li>– Open</li> <li>– Starting function</li> <li>– Controlled acceleration</li> <li>– FULL ON</li> </ul>                      | H3B: <ul style="list-style-type: none"> <li>– Open</li> <li>– Starting function</li> <li>– FULL ON</li> </ul>                      |
| 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.<br>** 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):** A 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:** A 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:** The 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 947-1).

**3.1.3 current-limit function:** The 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).

#### NOTES

1 Starting is a mandatory manoeuvre that is recognized separately.

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:** The control of motor performance while increasing motor speed by acting on the motor supply.

**3.1.6 controlled deceleration:** The control of motor performance while decreasing motor speed by acting on the motor supply.

**3.1.7 controlled running:** The 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, ( $I_{LRP}$ ):** The prospective current (see 2.5.5 of IEC 947-1) 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:** The 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):** The transition from the ON-state to the OFF-state, or the reverse.

**3.1.15 operating cycle (of a controller):** A 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:** A 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):** An 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:** A 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 phase loss sensitive thermal overload relay or release:** A multipole thermal 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 ON-time:** The period of time during which the controller is on-load for example as in figure F.1 of annex F.

**3.1.23 OFF-time:** The period of time during which the controller is off-load for example as in figure F.1 of annex F.

### 3.2 EMC definitions

Various EMC definitions are given in IEC 50, particularly Chapter 161. Further explanations are given in IEC 1000-2-1. For convenience and to avoid confusion, some of the key definitions from IEC 50(161) are reproduced here.

**3.2.1 electromagnetic compatibility EMC (abbreviation):** The 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:** The 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]

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 of an unwanted signal.

**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):** A sequence of a limited number of distinct pulses or an oscillation of limited duration. [IEV 161-02-07]

**3.2.8 voltage surge:** A 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]

## 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);
- switching overvoltages (5.9).

### 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 947-1 applies.

##### 5.3.1.2 *Rated insulation voltage ( $U_i$ )*

Subclause 4.3.1.2 of IEC 947-1 applies.

##### 5.3.1.3 *Rated impulse withstand voltage ( $U_{imp}$ )*

Subclause 4.3.1.3 of IEC 947-1 applies.

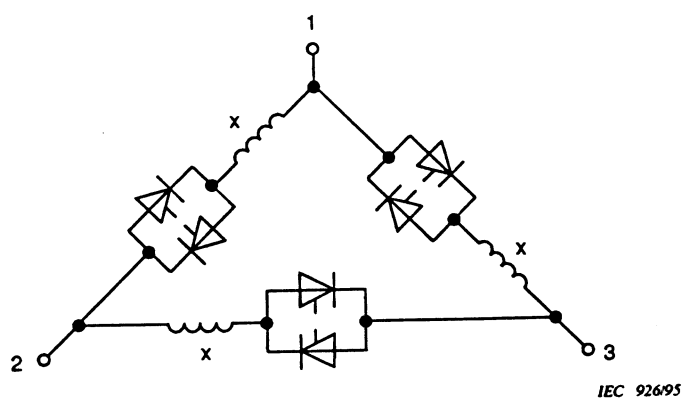


Figure 2a – Motor in delta – Thyristors in series with a winding

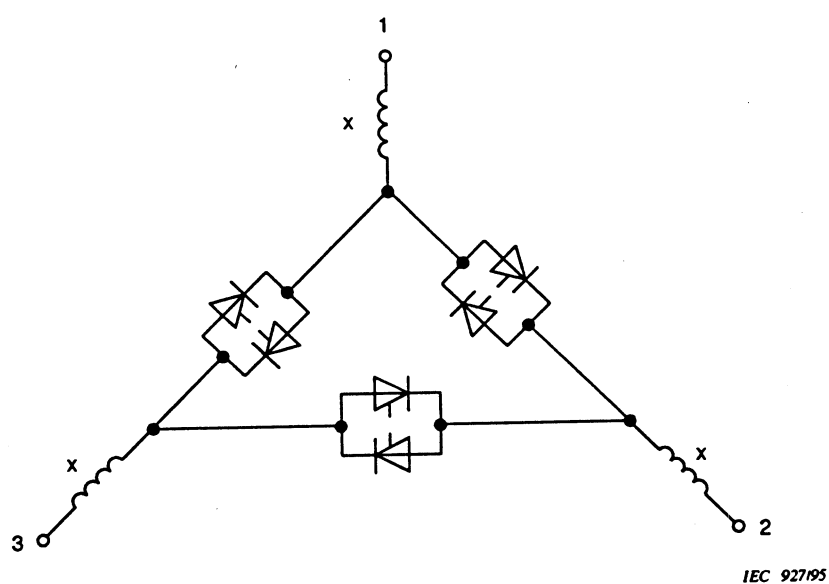


Figure 2b – Motor in star – Thyristors in delta

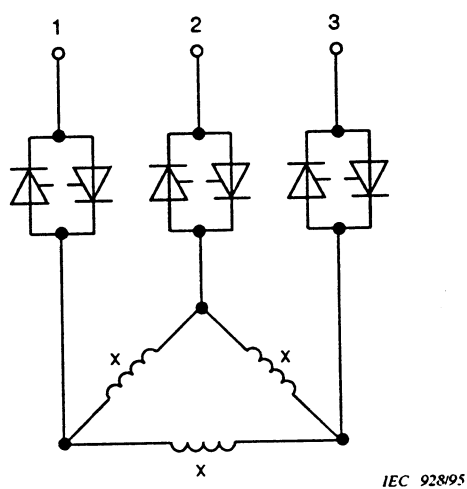


Figure 2c – Motor in delta – Thyristors connected between winding and supply

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 947-1 applies.

#### 5.3.2.2 *Conventional enclosed thermal current ( $I_{the}$ )*

Subclause 4.3.2.2 of IEC 947-1 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 947-1 applies.

### 5.3.3 *Rated frequency*

Subclause 4.3.3 of IEC 947-1 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 947-1 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 947-1 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 947-1 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  $X \cdot I_e$ , 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.

For a starter,  $T_x$  is the minimum operating time allowed by the tolerances of the overload relay for the current  $X \cdot I_e$  in the cold state.

#### 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 starting duty only; for example after starting, the supply to the motor is connected into a circuit that bypasses the power semiconductors (AC-53b, AC-58b).

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 947-1 applies.

**5.4 Utilization category**

Subclause 4.4 of IEC 947-1 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.

The first digit of the utilization category identification designates 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.

**5.4.1 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                                                                                                              |
| AC-52b                                                                                                                                                                                                                                                                                                                                                                                     | Control of slip ring motor stators with the controller bypassed during running                                                                  |
| AC-53a                                                                                                                                                                                                                                                                                                                                                                                     | Control of squirrel cage motors                                                                                                                 |
| AC-53b                                                                                                                                                                                                                                                                                                                                                                                     | Control of squirrel cage motors with the controller bypassed during running                                                                     |
| AC-58a                                                                                                                                                                                                                                                                                                                                                                                     | Control of hermetic refrigerant compressor motors with automatic resetting of overload releases                                                 |
| AC-58b                                                                                                                                                                                                                                                                                                                                                                                     | Control of hermetic refrigerant compressor motors with the controller bypassed during running and with automatic resetting of overload releases |
| <p><b>NOTES</b></p> <p>1 The means of bypassing the semiconductor controller may be integral with the controller/starter or installed separately.</p> <p>2 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.</p> |                                                                                                                                                 |

Table 3 – Relative levels of severity

| Severity level                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Utilization category       | Overload current profile<br>( $X \cdot T_x$ )            | Time related requirements                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|----------------------------------------------------------|-------------------------------------------|
| Most severe                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | AC-52a<br>AC-53a<br>AC-58a | Highest value of<br>$(X I_{\phi})^2 \times T_x$ (note 1) | Highest value of<br>$F \times S$ (note 2) |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | AC-52b<br>AC-53b<br>AC-58b | Highest value of<br>$(X I_{\phi})^2 \times T_x$ (note 1) | Lowest value of<br>OFF-time (note 3)      |
| <p><b>NOTES</b></p> <p>1 When the highest value of <math>(X I_{\phi})^2 \times T_x</math> occurs at more than one value of <math>X I_{\phi}</math>, then the highest value of <math>X I_{\phi}</math> shall apply.</p> <p>2 When the highest value of <math>F \times S</math> occurs at more than one value of <math>S</math>, then the highest value of <math>S</math> shall apply.</p> <p>3 When the highest value of <math>(X I_{\phi})^2 \times T_x</math> occurs at more than one value of OFF-time, then the lowest value of OFF-time shall apply.</p> |                            |                                                          |                                           |

### 5.5 Control circuits

Subclause 4.5.1 of IEC 947-1 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.);