

Australian Standard[®]

**Low-voltage switchgear and
controlgear**

**Part 4.2: Contactors and
motor-starters — A.C. semiconductor
motor controllers and starters**

This Australian Standard was prepared by Committee EL/6, Industrial Switchgear and Controlgear. It was approved on behalf of the Council of Standards Australia on 15 May 1997 and published on 5 August 1997.

The following interests are represented on Committee EL/6:

Australasian Railway Association
Australian British Chamber of Commerce
Australian Electrical and Electronic Manufacturers Association
Bureau of Steel Manufacturers of Australia
Electricity Supply Association of Australia
Independent Electrical Switchboard Manufacturers Association
Institution of Engineers, Australia
Ministry of Commerce, New Zealand
National Electrical Contractors Association of Australia
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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EL/6 on Industrial Switchgear and Controlgear.

This Standard is the result of a consensus among representatives on the Joint Committee to produce it as an Australian Standard.

This Standard is Section 2 of Part 4 of a series which consists of the following:

AS

- 3947 Low voltage switchgear and controlgear
- 3947.1 Part 1: General rules
- 3947.2 Part 2: Circuit breakers
- 3947.3 Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units
- 3947.4 Part 4: Contactors and motor-starters
- 3947.5 Part 5: Control circuit devices and switching elements
- 3947.6 Part 6: Multiple function equipment
- 3947.7 Part 7: Ancillary equipment

This Standard is identical with and has been reproduced from IEC 947-4-2:1995, *Low-voltage switchgear and controlgear Part 4: Contactors and motor-starters Section 2: AC semiconductor motor controllers and starters* and supersedes AS 1202.5 —1985, *A.C. motor starters (up to and including 1000 V)*, Part 5: *Semiconductor (solid state) starters*.

The objective of this Standard, in addition to that stated in Clause 1, is to bring the superseded Standard into agreement with IEC 947-4-2 and to renumber it as part of a series of Standards for low-voltage switchgear and controlgear.

As this Standard is reproduced from an international Standard, the following applies:

- (a) Its number does not appear on each page of text and its identity is shown only on the cover and title page.
- (b) In the source text ‘this International Standard’ should read ‘this Australian Standard’.
- (c) A full point substitutes for a comma when referring to a decimal marker.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the annex to which they apply. A ‘normative’ annex is an integral part of a Standard, whereas an ‘informative’ annex is only for information and guidance.

References to International Standards should be replaced by equivalent Australian Standards, as follows:

<i>References to International Standard</i>		<i>Australian Standard</i>	
IEC		AS	
50	International Electrotechnical Vocabulary (IEV)		
50(161)	Chapter 161: Electromagnetic compatibility	—	
410	Sampling plans and procedures for inspection by attributes	—	
439	Low-voltage switchgear and controlgear assemblies	3439	Low-voltage switchgear and controlgear assemblies
439-1	Part 1: Type-tested and partially type-tested assemblies	3439.1	Part 1: Type-tested and partially type-tested assemblies

IEC		AS	
801	Electromagnetic compatibility for industrial-process measurement and control equipment		
801-1	Part 1: General introduction	—	
801-2	Part 2: Electrostatic discharge requirements	—	
801-3	Part 3: Radiated electromagnetic field requirements	—	
801-4	Part 4: Electrical fast transient/burst requirements	—	
947	Low-voltage switchgear and controlgear	3947	Low voltage switchgear and controlgear
947-1	Part 1: General rules	3947.1	Part 1: General rules
1000	Electromagnetic compatibility (EMC)		
1000-2	Part 2: Environment		
1000-2-1	Section 1: Description of the environment—Electromagnetic environment for low-frequency conducted disturbances and signalling in public power supply systems	—	
1000-3	Part 3: Limits		
1000-3-2	Section 2: Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)	—	
1000-4	Part 4: Testing and measurement techniques		
1000-4-3	Section 3: Radiated, radio-frequency, electromagnetic fields immunity tests	—	
1000-4-5	Section 5: Surge immunity tests	—	
1000-4-6	Section 6: Conducted disturbances induced by radio-frequency fields immunity tests	—	
1000-4-11	Section 11: Voltage dips, short interruptions and voltage variation immunity tests—Basic EMC publication	—	
IEC/CISPR		AS/NZS	
11	Limits and methods of measurement of electromagnetic disturbance characteristics of industrial, scientific and medical (ISM) radio-frequency equipment	2064	Limits and methods of measurement of electromagnetic disturbance characteristics of industrial scientific and medical (ISM) radio-frequency equipment
		2064.1	General requirements
		2064.2	Additional requirements for Australia

IEC/CISPR

- 14 Limits and methods of measurement of radio disturbance characteristics of electrical motor-operated and thermal appliances for household and similar purposes, electric tools and electrical apparatus
- 22 Limits and methods of measurement of radio disturbance characteristics of information technology equipment

AS/NZS

- 1044 Limits and methods of measurement of radio disturbance characteristics of electrical motor-operated and thermal appliances for household and similar purposes, electric tools and similar electric apparatus
- 3548 Limits and methods of measurement of radio interference characteristics of information technology equipment

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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.

AUSTRALIAN STANDARD

Low-voltage switchgear and controlgear

Part 4.2:

Contactors and motor-starters—A.C. 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 $\leq 16\text{A}$ 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.

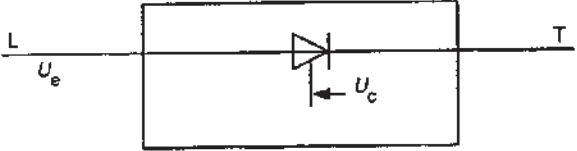
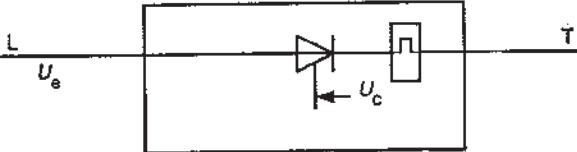
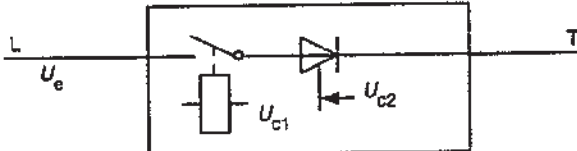
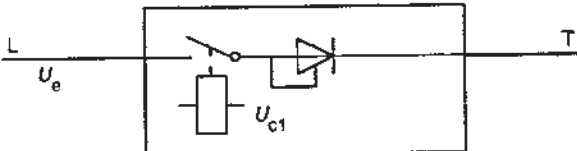
Device			
Semiconductor motor controller (all forms)			
Semiconductor motor starter (all forms)			
Hybrid motor controller HxA* where x = 1, 2 or 3			
Hybrid motor controller HxB**			
Hybrid motor starter	Form H1A or H1B with motor overload protection	Form H2A or H2B with motor overload protection	Form 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.			

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	— OFF state — Starting function — Manoeuvring — Controlled acceleration — Running — FULL ON — Controlled deceleration	— OFF state — Starting function — Controlled acceleration — FULL ON	Not available
Semiconductor DOL motor controller	Not available	Not available	— OFF state — Starting function — FULL ON
Semiconductor motor starter	Form 1 controller with motor overload protection	Form 2 controller with motor overload protection	Not available
Semiconductor DOL motor starter	Not available	Not available	Form 3 DOL motor controller with motor overload protection
Hybrid motor controller HxA* where x = 1, 2 or 3	H1A: — Open — OFF state — Starting function — Manoeuvring — Controlled acceleration — Running — Full ON — Controlled deceleration	H2A: — Open — OFF state — Starting function — Controlled acceleration — FULL ON	H3A: — Open — OFF state — Starting function — FULL ON
Hybrid motor controller HxB** where x = 1, 2 or 3	H1B: — Open — Starting function — Manoeuvring — Controlled acceleration — Running — FULL ON — Controlled deceleration	H2B: — Open — Starting function — Controlled acceleration — FULL ON	H3B: — Open — Starting function — FULL ON
Hybrid motor starter	Form H1A or H1B with motor overload protection	Form H2A or H2B with motor overload protection	Form H3A or H3B with motor overload protection
* 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): 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.

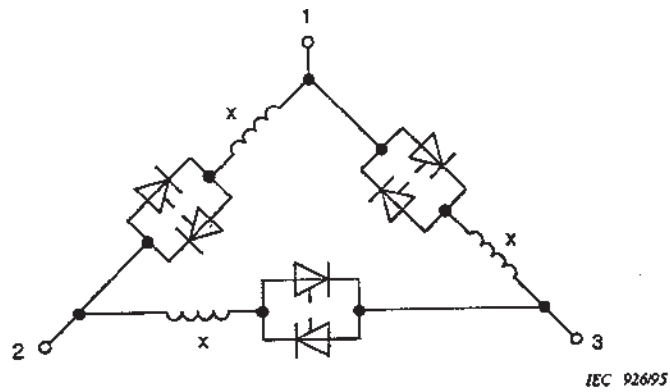


Figure 2a — Motor in delta — Thyristors in series with a winding

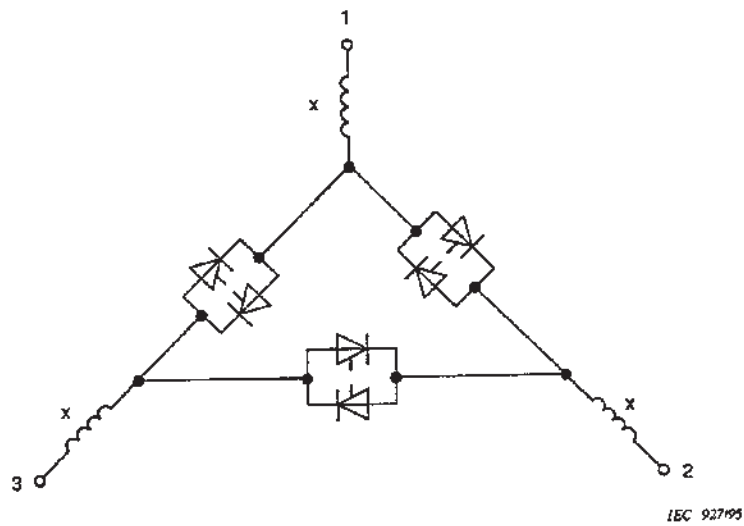


Figure 2b — Motor in star — Thyristors in delta

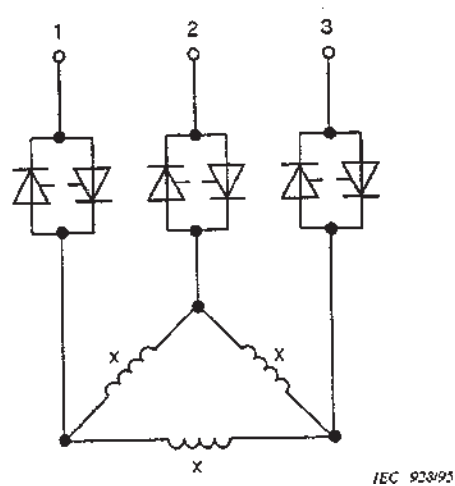


Figure 2c — Motor in delta — Thyristors connected between winding and supply

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.