

Australian/New Zealand Standard™

Low-voltage switchgear and controlgear

**Part 4.1: Contactors and motor-
starters—Electromechanical contactors
and motor-starters**



Standards Australia



AS/NZS 3947.4.1:2001

This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee EL-006, Industrial Switchgear and Controlgear. It was approved on behalf of the Council of Standards Australia on 18 June 2001 and on behalf of the Council of Standards New Zealand on 1 August 2001. It was published on 12 October 2001.

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This Standard was issued in draft form for comment as DR 01052.

Australian/New Zealand Standard™

Low-voltage switchgear and controlgear

Part 4.1: Contactors and motor-starters—Electromechanical contactors and motor-starters

Originated as part of AS C165—1961, AS C63—1965, AS C364—1967 and AS C381—1967.

Previous edition AS 3947.4.1—1995.

Jointly revised and redesignated as AS/NZS 3947.4.1:2001.

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Jointly published by Standards Australia International Ltd, GPO Box 5420, Sydney, NSW 2001 and Standards New Zealand, Private Bag 2439, Wellington 6020

ISBN 0 7337 4045 6

PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EL-006, Industrial Switchgear and Controlgear to supersede AS 3947.4.1—1995.

The objective of this Standard, in addition to that stated in Clause 1, is to bring Australian and New Zealand requirements into line with IEC 60947-4-1:2000.

This Standard is Part 4.1 of a series which, when complete, will consist of the following:

AS/(NZS) 3947	Low-voltage switchgear and controlgear
AS/NZS 3947.1	Part 1: General rules
AS 3947.2	Part 2: Circuit-breakers
AS/NZS 3947.3	Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units
AS/NZS 3947.3 Suppl	Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units, Supplement 1: Fuse-switch-disconnectors and switch-disconnectors for use with low-voltage aerial bundled cables
AS/NZS 3947.4.1	Part 4.1: Contactors and motor-starters—Electromechanical contactors and motor-starters (this Standard)
AS/NZS 3947.4.2	Part 4.2: Contactors and motor-starters—A.C. semiconductor motor controllers and starters
AS/NZS 3947.4.3	Part 4.3: Contactors and motor-starters—A.C. semiconductor controllers and contactors for non-motor loads
AS/NZS 3947.5.1	Part 5.1: Control circuit devices and switching elements—Electromechanical control circuit devices
AS/NZS 3947.5.2	Part 5.2: Control circuit devices and switching elements—Proximity switches
AS/NZS 3947.5.3	Part 5.3: Control circuit devices and switching elements—Requirements for proximity devices with defined behaviour under fault conditions
AS/NZS 3947.5.4	Part 5.4: Control circuit devices and switching elements—Methods of assessing the performance of low-energy contacts—Special tests
AS/NZS 3947.5.5	Part 5.5: Control circuit devices and switching elements—Electrical emergency stop devices with mechanical latching function
AS/NZS 3947.5.6	Part 5.6: Control circuit devices and switching elements—D.C. interface for proximity sensors and switching amplifiers (NAMUR)
AS/NZS 3947.6.1	Part 6.1: Multiple function equipment—Automatic transfer switching equipment
AS/NZS 3947.6.2	Part 6.2: Multiple function equipment—Control and protective switching devices (or equipment) (CPS)
AS/NZS 3947.7.1	Part 7.1: Ancillary equipment—Terminal blocks for copper conductors
AS 3947.7.2	Part 7.2: Ancillary equipment—Protective conductor terminal blocks for copper conductors
AS/NZS 3947.7.3	Part 7.3: Ancillary equipment—Safety requirements for terminal blocks for the reception of cartridge fuse-links

This Standard is identical in technical content with and has been reproduced from IEC 60947-4-1:2000, *Low-voltage switchgear and controlgear—Part 4.1: Contactors and motor-starters—Electromechanical contactors and motor-starters*.

The provisions of AS/NZS 3947.1, *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. IEC 60947-1 is also referred to as Part 1.

This Standard differs from AS 3947.4.1—1995 in the following areas:

- (a) All Australian variations have been removed.
- (b) Requirements and tests for electromagnetic compatibility have been added.
- (c) Special tests in Appendix B for discrimination between overload relays and SCPDs have been redefined as ‘Co-ordination at the crossover current between the starter and associated SCPD’ and an indirect method of verification has been added.

A reference to an International Standard identified in the Normative References Clause by strikethrough (~~example~~) is replaced by a reference to the Australian or Australian/New Zealand Standard(s) listed immediately thereafter and identified by shading (**example**). Where the struck-through referenced document and the referenced Australian or Australian/New Zealand Standard are identical, this is indicated in parenthesis after the title of the latter.

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 standard’ should read ‘this Australian/New Zealand Standard’.
- (c) A full point should be substituted 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.

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Australian/New Zealand Standard**Low-voltage switchgear and controlgear****Part 4.1: Contactors and motor-starters—Electromechanical contactors and motor-starters**

Any IEC table, figure or passage of text that is struck-through is not part of this Standard. Any Australian/New Zealand table, figure or passage of text that is added (and identified by shading) is part of this Standard.

1 Scope and object

This part of IEC 60947 applies to the types of equipment listed in 1.1 and 1.2 whose main contacts are intended to be connected to circuits the rated voltage of which does not exceed 1 000 V a.c. or 1 500 V d.c.

Starters and/or contactors dealt with in this standard are not normally designed to interrupt short-circuit currents. Therefore, suitable short-circuit protection (see 9.3.4) shall form part of the installation but not necessarily of the contactor or the starter.

In this context, this standard gives requirements for:

- contactors associated with overload and/or short-circuit protective devices;
- starters associated with separate short-circuit protective devices and/or with separate short-circuit and integrated overload protective devices;
- contactors or starters combined, under specified conditions, with their own short-circuit protective devices. Such combinations, e.g. combination starters (see 3.2.7) or protected starters (see 3.2.8) are rated as units.

Circuit-breakers and fuse-combination units used as short-circuit protective devices in combination starters and in protected starters shall comply with the requirements of IEC 60947-2 and IEC 60947-3, as the case may be.

Equipment covered by this standard is as follows.

1.1 AC and d.c. contactors

AC and d.c. contactors intended for closing and opening electric circuits and, if combined with suitable relays (see 1.2), for protecting these circuits against operating overloads which may occur therein.

NOTE Contactors combined with suitable relays and which are intended to provide short-circuit protection shall additionally satisfy the relevant conditions specified for circuit-breakers (IEC 60947-2).

This standard applies also to the actuators of contactor relays and to the contacts dedicated exclusively to the coil circuit of a contactor.

1.2 AC motor-starters

AC motor-starters intended to start and accelerate motors to normal speed, to ensure continuous operation of motors, to switch off the supply from the motor and to provide means for the protection of motors and associated circuits against operating overloads.

Starters the operation of which depends on thermal electrical relays for motor protection complying with IEC 60255-8, or motor-incorporated thermal protective devices dealt with in IEC 60034-11 do not necessarily meet all the relevant requirements of this standard.

Overload relays for starters, including those based on solid state technology, shall meet the requirements of this standard.

1.2.1 Direct-on-line (full voltage) a.c. starters

Direct-on-line starters intended to start and accelerate a motor to normal speed, to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.

This standard applies also to reversing starters.

1.2.2 Reduced voltage a.c. starters

Reduced voltage a.c. starters intended to start and accelerate a motor to normal speed by connecting the line voltage across the motor terminals in more than one step or by gradually increasing the voltage applied to the terminals, to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.

Automatic change-over devices may be used to control the successive switching operations from one step to the others. Such automatic change-over devices are, for example, time-delay contactor relays or specified time all-or-nothing relays, under-current devices and automatic acceleration control devices (see 5.10).

1.2.2.1 Star-delta starters

Star-delta starters intended to start a three-phase motor in the star connection, to ensure continuous operation in the delta connection, to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.

The star-delta starters dealt with in this standard are not intended for reversing motors rapidly and, therefore, utilization category AC-4 does not apply.

NOTE In the star connection, the current in the line and the torque of the motor are about one-third of the corresponding values for delta connection. Therefore, star-delta starters are used when the inrush current due to the starting is to be limited, or when the driven machine requires a limited torque for starting. Figure 1 indicates typical curves of starting current, of starting torque of the motor and of torque of the driven machine.

1.2.2.2 Two-step auto-transformer starters

Two-step auto-transformer starters, intended to start and accelerate an a.c. induction motor from rest with reduced torque to normal speed and to provide means for the protection of the motor and its associated circuits against operating overloads, and to switch off the supply from the motor.

This standard applies to auto-transformers which are part of the starter or which constitute a unit specially designed to be associated with the starter.

Auto-transformer starters with more than two steps are not covered by this standard.

The auto-transformer starters dealt with in this standard are not intended for inching duty or reversing motors rapidly and, therefore, utilization category AC-4 does not apply.

NOTE In the starting position, the current in the line and the torque of the motor related to the motor starting with rated voltage are reduced approximately as the square of the ratio (starting voltage):(rated voltage). Therefore, auto-transformer starters are used when the inrush current due to the starting is to be limited or when the driven machine requires a limited torque for starting. Figure 2 indicates typical curves of starting current, of starting torque of the motor and of torque of the driven machine.

1.2.3 Rheostatic rotor starters

Starters intended to start an a.c. induction motor having a wound rotor by cutting out resistors previously inserted in the rotor circuit, to provide means for the protection of the motor against operating overloads and to switch off the supply from the motor.

In the case of asynchronous slip-ring motors (wound-rotors), the highest voltage between open slip-rings shall be not greater than twice the rated insulation voltage of the switching devices inserted in the rotor circuit (see 5.3.1.1.2).

NOTE This requirement is based on the fact that the electric stresses are less severe in the rotor than in the stator and are of short duration.

This standard applies also to starters for two directions of rotation when reversal of connections is made with the motor stopped (see 5.3.5.5). Operations including inching and plugging necessitate additional requirements and shall be subject to agreement between manufacturer and user.

This standard applies to resistors which are part of the starter or constitute a unit specially designed to be associated with the starter.

1.3 Exclusions

This standard does not apply to:

- d.c. starters;
- star-delta starters, rheostatic rotor starters, two-step auto-transformer starters intended for special applications and designed for continuous operation in the starting position;
- unbalanced rheostatic rotor starters, i.e. where the resistances do not have the same value in all phases;
- equipment designed not only for starting, but also for adjustment of speed;
- liquid starters and those of the 'liquid-vapour' type;
- semiconductor contactors and starters making use of semiconductor contactors in the main circuit;
- rheostatic stator starters;
- contactors or starters designed for special applications;
- auxiliary contacts of contactors and contacts of contactor relays. These are dealt with in IEC 60947-5-1.

1.4 Object

The object of this standard is to state:

- a) the characteristics of contactors and starters and associated equipment;
- b) the conditions with which contactors or starters shall comply with reference to:
 - 1) their operation and behaviour,
 - 2) their dielectric properties,
 - 3) the degrees of protection provided by their enclosures, where applicable,
 - 4) their construction;

- c) the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests;
- d) 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 60947. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 60947 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

References to International Standards that are struck through in this Clause are replaced by references to equivalent Australian or Australian/New Zealand Standards that are listed immediately thereafter and identified by shading. Any Australian or Australian/New Zealand Standard that is identical to the International Standard it replaces is appropriately identified.

~~IEC 60034-1:1996, *Rotating electrical machines — Part 1: Rating and performance*~~

AS 1359.101, *Rotating electrical machines—General requirements, Part 101: Rating and performance* (identical to IEC 60034-1:1996)

IEC 60034-11:1978, *Rotating electrical machines — Part 11: Built-in thermal protection — Chapter 1: Rules for protection of rotating electrical machines*

~~IEC 60050(441):1984, *International Electrotechnical Vocabulary (IEV)—Chapter 441: Switchgear, controlgear and fuses*~~

AS 1852.441, *International electrotechnical vocabulary, Chapter 441: Switchgear, controlgear and fuses* (identical to IEC 60050 (441):1984)

~~IEC 60076-1:1993, *Power transformers — Part 1: General*~~

AS 2374.1, *Power transformers, Part 1: General*

~~IEC 60085:1984, *Thermal evaluation and classification of electrical insulation*~~

AS 2768, *Electrical insulating materials—Evaluation and classification based on thermal endurance*

~~IEC 60112:1979, *Method for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions*~~

AS/NZS 4695.112, *Fire hazard testing of electrotechnical products, Part 112: Method for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions* (identical to IEC 60112:1979)

IEC 60255-8:1990, *Electrical relays — Part 8: Thermal electrical relays*

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

AS/NZS 60269.1, *Low-voltage fuses, Part 1: General requirements* (identical to IEC 60269-1:1998)

~~IEC 60269-2:1986, Low-voltage fuses — Part 2: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application)~~

AS/NZS 60269.2.0, Low-voltage fuses, Part 2.0: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) (identical to IEC 60269-2:1986 and including IEC Amendment 1:1995 and Corrigendum:1996)

~~IEC 60269-2-1:1998, Low-voltage fuses — Part 2-1: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application) — Sections I to V: Examples of types of standardized fuses~~

AS/NZS 60269.2.1, Low-voltage fuses, Part 2.1: Supplementary requirements for fuses for use by authorized persons (fuses mainly for industrial application)—Sections I to V: Examples of types of standardized fuses (identical to IEC 60269-2-1:1998)

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

~~IEC 60947-1:1999, Low-voltage switchgear and controlgear — Part 1: General rules~~

AS/NZS 3947.1, Low-voltage switchgear and controlgear, Part 1: General rules (identical to IEC 60947-1:1999 and incorporating IEC Amendment 1:2000)

~~IEC 60947-2:1995, Low-voltage switchgear and controlgear — Part 2: Circuit-breakers*~~

AS 3947.2, Low-voltage switchgear and controlgear, Part 2: Circuit-breakers (identical to IEC 60947-2:1995 and including IEC Amendment 1:1997)

~~IEC 60947-3:1999, Low-voltage switchgear and controlgear — Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units~~

AS/NZS 3947.3, Low-voltage switchgear and controlgear, Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units (identical to IEC 60947-3:1999 and including IEC Amendment 1:2000)

~~IEC 60947-5-1:1997, Low-voltage switchgear and controlgear — Part 5: Control circuit devices and switching elements — Section 1: Electromechanical control circuit devices**~~

AS/NZS 3947.5.1, Low-voltage switchgear and controlgear, Part 5: Control circuit devices and switching elements — Section 1: Electromechanical control circuit devices (identical to IEC 60947-5-1:1997 and including IEC Amendment 1:1999 and Amendment 2:1999)

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

~~IEC 61000-4-3:1995, Electromagnetic compatibility (EMC) — Part 4: Testing and measurement techniques — Section 3: Radiated radio-frequency electromagnetic field immunity test****~~

AS/NZS 61000.4.3, Electromagnetic compatibility (EMC), Part 4: Testing and measurement techniques—Section 3: Radiated radio-frequency electromagnetic field immunity test (identical to IEC 61000-4-3:1995 and including IEC Amendment 1:1998)

* There is a consolidated edition 2.1 (1998) that includes IEC 60947-2 (1995) and its amendment 1 (1997).

** There is a consolidated edition 2.1 (1999) that includes IEC 60947-5-1 (1997) and its amendment 1 (1999).

*** There is a consolidated edition 1.1 (1999) that includes IEC 61000-4-2 (1995) and its amendment 1 (1998).

**** There is a consolidated edition 1.1 (1998) that includes IEC 61000-4-3 (1995) and its amendment 1 (1998).

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*

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

AS/NZS 61000.4.5, *Electromagnetic compatibility (EMC), Part 4: Testing and measurement techniques – Section 5: Surge immunity test* (identical to IEC 61000-4-5:1995)

IEC 61095:1992, *Electromechanical contactors for household and similar purposes*

IEC 61810-1:1998, *Electromechanical all-or-nothing relays – Part 1: General requirements*

CISPR 11:1997, *Industrial, scientific and medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement*

3 Definitions

For the purpose of this part of IEC 60947, the definitions of clause 2 of IEC 60947-1 together with the following additional definitions apply.

3.1 Definitions concerning contactors

3.1.1

contactor (mechanical)

mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions

NOTE Contactors may be designated according to the method by which the force for closing the main contacts is provided.

[IEV 441-14-33]

The following notes are not included in IEV 441-14-33:

NOTE 1 The term 'operated otherwise than by hand' means that the device is intended to be controlled and kept in working position from one or more external supplies.

NOTE 2 In French, a contactor the main contacts of which are closed in the position of rest is usually called a 'rupteur'. The word 'rupteur' has no equivalent in the English language.

NOTE 3 A contactor is usually intended to operate frequently.

3.1.2

electromagnetic contactor

contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by an electromagnet

3.1.3

pneumatic contactor

contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by a device using compressed air, without the use of electrical means

3.1.4

electro-pneumatic contactor

contactor in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by a device using compressed air under the control of electrically operated valves

3.1.5**latched contactor**

contactor, the moving elements of which are prevented by means of a latching arrangement from returning to the position of rest when the operating means are de-energized

NOTE 1 The latching, and the release of the latching, may be mechanical, electromagnetic, pneumatic, etc.

NOTE 2 Because of the latching, the latched contactor actually acquires a second position of rest and, according to the definition of a contactor, it is not, strictly speaking, a contactor. However, since the latched contactor in both its utilization and its design is more closely related to contactors in general than to any other classification of switching device, it is considered proper to require that it complies with the specifications for contactors wherever they are appropriate.

[IEV 441-14-34]

3.1.6**vacuum contactor (or starter)**

contactor (or starter) in which the main contacts open and close within a highly evacuated envelope

3.1.7**position of rest (of a contactor)**

position which the moving elements of the contactor take up when its electromagnet or its compressed-air device is not energized [IEV 441-16-24]

3.2 Definitions concerning starters**3.2.1****starter**

combination of all the switching means necessary to start and stop a motor in combination with suitable overload protection [IEV 441-14-38]

3.2.2**direct-on-line starter**

starter which connects the line voltage across the motor terminals in one step [IEV 441-14-40]

3.2.3**reversing starter**

starter intended to cause the motor to reverse the direction of rotation by reversing the motor primary connections while the motor may be running

3.2.4**two-direction starter**

starter intended to cause the motor to reverse the direction of rotation by reversing the motor primary connections only when the motor is not running

3.2.5**reduced voltage starter**

starter which connects the line voltage across the motor terminals in more than one step or by gradually increasing the voltage applied to the terminals

3.2.5.1**star-delta starter**

starter for a three-phase induction motor such that in the starting position the stator windings are connected in star and in the final running position they are connected in delta [IEV 441-14-44]

3.2.5.2

auto-transformer starter

starter for an induction motor which uses for starting one or more reduced voltages derived from an auto-transformer [IEV 441-14-45]

NOTE (*not included in IEV 441-14-45*) An auto-transformer is defined as follows in 3.1.2 of IEC 60076-1:

'A transformer in which at least two windings have a common part.'

3.2.6

rheostatic starter

starter utilizing one or several resistors for obtaining, during starting, stated motor torque characteristics and for limiting the current [IEV 441-14-42]

NOTE (*not included in IEV 441-14-42*) A rheostatic starter generally consists of three basic parts which may be supplied either as a composite unit or as separate units to be connected at the place of utilization:

- the mechanical switching devices for supplying the stator (generally associated with an overload protective device);
- the resistor(s) inserted in the stator or rotor circuit;
- the mechanical switching devices for cutting out the resistor(s) successively.

3.2.6.1

rheostatic stator starter

rheostatic starter for a squirrel cage motor which, during the starting period, cuts out successively one or several resistors previously provided in the stator circuit

3.2.6.2

rheostatic rotor starter

rheostatic starter for an asynchronous wound-rotor motor which, during the starting period, cuts out successively one or several resistors previously provided in the rotor circuit [IEV 441-14-43]

3.2.7

combination starter (see figure 3)

equipment consisting of a starter, a manual externally operated switching device and a short-circuit protective device, mounted and wired in a dedicated enclosure. The switching and short-circuit protective devices may be a fuse combination unit, a switch with fuses or a circuit-breaker with or without an isolating function

NOTE 1 A dedicated enclosure is an enclosure specifically designed and dimensioned for its application in which all tests are conducted.

NOTE 2 The manually operated switching device and the short-circuit protective device may be just one device and may incorporate the overload protection as well.

3.2.8

protected starter

equipment consisting of a starter, a manually operated switching device and a short-circuit protective device, mounted and wired, enclosed or unenclosed according to the instructions of the starter manufacturer

NOTE The manually operated switching device and the short-circuit protective device may be one single device and may incorporate the overload protection as well.

3.2.9

manual starter

starter in which the force for closing the main contacts is provided exclusively by manual energy [IEV 441-14-39]

3.2.10

electromagnetic starter

starter in which the force for closing the main contacts is provided by an electromagnet

3.2.11**motor-operated starter**

starter in which the force for closing the main contacts is provided by an electric motor

3.2.12**pneumatic starter**

starter in which the force for closing the main contacts is provided by using compressed air, without the use of electrical means

3.2.13**electro-pneumatic starter**

starter in which the force for closing the main contacts is provided by using compressed air under the control of electrically operated valves

3.2.14**single-step starter**

starter in which there is no intermediate accelerating position between the OFF and ON positions

NOTE This starter is a direct-on-line starter (see 3.2.2).

3.2.15**two-step starter**

starter in which there is only one intermediate accelerating position between the OFF and ON positions

Example: A star-delta starter is a two-step starter.

3.2.16***n*-step starter** (see figure 4)

starter in which there are (*n*-1) intermediate accelerating positions between the OFF and ON positions

Example: A three-step rheostatic starter has two sections of resistors used for starting.

[IEV 441-14-41]

3.2.17**phase loss sensitive thermal overload relay or release**

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

3.2.18**under-current (under-voltage) relay or release**

measuring relay or release which operates automatically when the current through it (or the voltage applied to it) is reduced below a pre-determined value

3.2.19**starting time (of a rheostatic starter)**

period of time during which the starting resistors or parts of them carry current

3.2.20**starting time (of an auto-transformer starter)**

period of time during which the auto-transformer carries current

NOTE to 3.2.19 and 3.2.20 The starting time of a starter is shorter than the total starting time of the motor which takes into account the last period of acceleration following the switching operation ON position.

3.2.21**open transition (with an auto-transformer starter or star-delta starter)**

circuit arrangement such that the supply to the motor is interrupted and reconnected when changing over from one step to another

NOTE The transition stage is not considered an additional step.

3.2.22**closed transition (with an auto-transformer starter or star-delta starter)**

circuit arrangement such that the supply to the motor is not interrupted (even momentarily) when changing over from one step to another

NOTE The transition stage is not considered an additional step.

3.2.23**inching (jogging)**

energizing a motor or solenoid repeatedly for short periods to obtain small movements of the driven mechanism

3.2.24**plugging**

stopping or reversing a motor rapidly by reversing the motor primary connections while the motor is running

3.3 Characteristic quantities**3.3.1 Transient recovery voltage (abbreviation: TRV) [IEV 441-17-26]**

Subclause 2.5.34 of part 1 applies with the following addition.

NOTE 3 (*not included in IEV 441-17-26*) In a vacuum contactor or starter, the highest transient recovery voltage may occur on an other pole than the first pole to clear.

4 Classification

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

5 Characteristics of contactors and starters**5.1 Summary of characteristics**

The characteristics of a contactor or starter 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);
- types and characteristics of automatic change-over devices and automatic acceleration control devices (5.10);
- types and characteristics of auto-transformers for two-step auto-transformer starters (5.11);
- types and characteristics of starting resistors for rheostatic rotor starters (5.12)

5.2 Type of equipment

The following shall be stated (see also clause 6).

5.2.1 Kind of equipment

- contactor;
- direct-on-line a.c. starter;
- star-delta starter;
- two-step auto-transformer starter;
- rheostatic rotor starter;
- combination or protected starter.

5.2.2 Number of poles

5.2.3 Kind of current (a.c. or d.c.)

5.2.4 Interrupting medium (air, oil, gas, vacuum, etc.)

5.2.5 Operating conditions of the equipment

5.2.5.1 Method of operation

For example: manual, electromagnetic, motor-operated, pneumatic, electro-pneumatic.

5.2.5.2 Method of control

For example:

- automatic (by pilot switch or sequence control);
- non-automatic (such as by hand operation or by push-buttons);
- semi-automatic (i.e. partly automatic, partly non-automatic).

5.2.5.3 Method of change-over for particular types of starters

The change-over for star-delta starters, rheostatic rotor starters or auto-transformer starters may be automatic, non-automatic or semi-automatic (see figures 4 and 5).

5.2.5.4 Method of connecting for particular types of starters

For example: open transition starter, closed transition starter (see figure 5).

5.3 Rated and limiting values for main circuits

The rated values established for a contactor or starter shall be stated in accordance with subclauses 5.3.1 to 5.4, and 5.8 and 5.9, but it may not be necessary to specify all the values listed.

NOTE The rated values established for a rheostatic rotor starter are stated in accordance with 5.3.1.2, 5.3.2.3, 5.3.2.4, 5.3.2.6, 5.3.2.7 and 5.3.5.5 but it is not necessary to specify all the values listed.

5.3.1 Rated voltages

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

5.3.1.1 Rated operational voltage (U_e)

Subclause 4.3.1.1 of part 1 applies.

5.3.1.1.1 Rated stator operational voltage (U_{es})

For rheostatic rotor starters, a rated stator operational voltage is a value of voltage which, when combined with a rated stator operational current, determines the application of the stator circuit including its mechanical switching devices and to which are referred the making and breaking capacities, the type of duty and the starting characteristics. In no case shall the maximum rated operational voltage exceed the corresponding rated insulation voltage.

NOTE The rated stator operational voltage is expressed as the voltage between phases.

5.3.1.1.2 Rated rotor operational voltage (U_{er})

For rheostatic rotor starters, the value of rated operational voltage is that of the voltage which, when combined with a rated rotor operational current, determines the application of the rotor circuit including its mechanical switching devices and to which are referred the making and breaking capacities, the type of duty and the starting characteristics.

This voltage is taken as equal to the voltage measured between slip-rings, with the motor stopped and the rotor open-circuited, when the stator is supplied at its rated voltage.

The rated rotor operational voltage is only applied for a short duration during the starting period. For this reason, it is permissible that the rated rotor operational voltage exceed the rated rotor insulation voltage by 100%.

The maximum voltage between the different live parts (e.g. switching devices, resistors, connecting parts, etc.) of the rotor circuit of the starter will vary and account may be taken of this fact in choosing the equipment and its disposition.

5.3.1.2 Rated insulation voltage (U_i)

Subclause 4.3.1.2 of part 1 applies.

5.3.1.2.1 Rated stator insulation voltage (U_{is})

For rheostatic rotor starters, the rated stator insulation voltage is the value of voltage which is designated for the devices inserted in the stator supply as well as the unit they are part of, and to which dielectric tests and creepage distances are referred.

Unless otherwise stated, the rated stator insulation voltage is the value of the maximum rated stator operational voltage of the starter.

5.3.1.2.2 Rated rotor insulation voltage (U_{ir})

For rheostatic rotor starters, the rated rotor insulation voltage is the value of voltage which is designated to the devices inserted in the rotor circuit as well as the unit they are part of (connecting links, resistors, enclosure), and to which dielectric tests and creepage distances are referred.

5.3.1.3 Rated impulse withstand voltage (U_{imp})

Subclause 4.3.1.3 of part 1 applies.

5.3.1.4 Rated starting voltage of an auto-transformer starter

The rated starting voltage of an auto-transformer starter is the reduced voltage derived from the transformer.

Preferred values of rated starting voltage are 50%, 65% or 80% of the rated operational voltage.

5.3.2 Currents or powers

A contactor or a starter is defined by the following currents.

NOTE In the case of a star-delta starter, these currents relate to the delta connection and, in the case of a two-step auto-transformer or rheostatic rotor starter, to the ON position.

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

Subclause 4.3.2.1 of part 1 applies.

5.3.2.2 Conventional enclosed thermal current (I_{the})

Subclause 4.3.2.2 of part 1 applies.

5.3.2.3 Conventional stator thermal current (I_{ths})

The conventional stator thermal current of a starter may be either free air current I_{ths} or enclosed current I_{thes} , in line with 5.3.2.1 and 5.3.2.2.

For a rheostatic rotor starter, the stator thermal current is the maximum current it can carry on eight-hour duty (see 5.3.4.1) without the temperature rise of its several parts exceeding the limits specified in 8.2.2 when tested in accordance with 9.3.3.3.

5.3.2.4 Conventional rotor thermal current (I_{thr})

The conventional rotor thermal current of a starter may be either free air current I_{thr} or enclosed current I_{ther} , in line with 5.3.2.1 and 5.3.2.2.

For rheostatic rotor starters, the rotor thermal current is the maximum current that those parts of the starter through which the rotor current flows in the ON position, viz. after cutting out resistors, can carry on eight-hour duty (see 5.3.4.1) without their temperature rise exceeding the limits specified in 8.2.2 when tested in accordance with 9.3.3.3.

NOTE 1 For those elements (switching devices, connecting links, resistors) through which a current of practically no value flows in the ON position, it should be verified that, for the rated duties (see 5.3.4) stated by the manufacturer, the value of integral

$$\int_0^t i^2 dt$$

does not lead to temperature rises higher than those appearing in 8.2.2.

NOTE 2 When resistors are built-in into the starter, the temperature rise should be taken into account.

5.3.2.5 Rated operational currents (I_e) or rated operational powers

A rated operational current of a contactor or a starter is stated by the manufacturer and takes into account the rated operational voltage (see 5.3.1.1), the conventional free air or enclosed thermal current, the rated current of the overload relay, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the utilization category (see 5.4) and the type of protective enclosure, if any.

In the case of equipment for direct switching of individual motors, the indication of a rated operational current may be replaced or supplemented by an indication of the maximum rated power output, at the rated operational voltage considered, of the motor for which the equipment is intended. The manufacturer shall be prepared to state the relationship assumed between the current and the power.

For starters, the rated operational current (I_e) is the current in the ON position of the starter.

5.3.2.6 Rated stator operational current (I_{es}) or rated stator operational power

For rheostatic rotor starters, a rated stator operational current is stated by the manufacturer and takes into account the rated current of the overload relay installed in this starter, the rated stator operational voltage (see 5.3.1.1.1), the conventional free air or enclosed thermal current, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the starting characteristics (see 5.3.5.5) and the type of protective enclosure.

The indication of a rated stator operational current may be replaced by the indication of the maximum rated power output, at the rated stator operational voltage considered, of the motor for which the stator elements of the starter are intended. The manufacturer shall be prepared to state the relationship assumed between the motor power and the stator current.

5.3.2.7 Rated rotor operational current (I_{er})

For rheostatic rotor starters, a rated rotor operational current is stated by the manufacturer and takes into account the rated rotor operational voltage (see 5.3.1.1.2), the conventional free air or enclosed rotor thermal current, the rated frequency (see 5.3.3), the rated duty (see 5.3.4), the starting characteristics (see 5.3.5.5) and the type of protective enclosure.

It is taken as equal to the current flowing in the connections to the rotor when the latter is short-circuited and the motor is running at full load and the stator is supplied at its rated voltage and rated frequency.

When the rotor part of a rheostatic rotor starter is rated separately, the indication of a rated rotor operational current may be supplemented by the maximum rated power output, for motors having the rated rotor operational voltage considered, of the motor for which that part of the starter (switching devices, connecting links, relays, resistors) is intended. This power varies in particular with the breakaway torque foreseen and consequently takes into account the starting characteristics (see 5.3.5.5).

5.3.2.8 Rated uninterrupted current (I_u)

Subclause 4.3.2.4 of part 1 applies.

5.3.3 Rated frequency

Subclause 4.3.3 of part 1 applies.

5.3.4 Rated duties

Subclause 4.3.4 of part 1 applies.

5.3.4.1 Eight-hour duty (continuous duty)

Subclause 4.3.4.1 of part 1 applies with the following addition.

For a star-delta starter, a two-step auto-transformer starter or a rheostatic rotor-starter, the continuous duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it, which are closed in this position, remain closed while each of them carries a steady current long enough for the starter to reach thermal equilibrium, but not for more than 8 h without interruption.

5.3.4.2 Uninterrupted duty

Subclause 4.3.4.2 of part 1 applies with the following addition.

For a star-delta starter, a two-step auto-transformer starter or a rheostatic rotor starter, the uninterrupted duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it, which are closed in this position, remain closed without interruption while each of them carries a steady current 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 part 1 applies with the following addition.

For a reduced voltage starter, the intermittent duty is the duty in which the starter is in the ON position and the main contacts of the switching devices which constitute it remain closed for periods bearing a definite relation to the no-load periods, both periods being too short to allow the starter to reach thermal equilibrium.

Preferred classes of intermittent duty are:

- for contactors: 1, 3, 12, 30, 120, 300 and 1 200 (operating cycles per hour);
- for starters: 1, 3, 12 and 30 (operating cycles per hour).

It is recalled that an operating cycle is a complete working cycle comprising one closing operation and one opening operation.

For starters, an operating cycle comprises starting, running to full speed and switching off the supply from the motor.

NOTE In the case of starters for intermittent duty, the difference between the thermal time-constant of the overload relay and that of the motor may render a thermal relay unsuited for overload protection. It is recommended that, for installations intended for intermittent duty, the question of overload protection be subject to agreement between manufacturer and user.

5.3.4.4 Temporary duty

Subclause 4.3.4.4 of part 1 applies.

5.3.4.5 Periodic duty

Subclause 4.3.4.5 of part 1 applies.

5.3.5 Normal load and overload characteristics

Subclause 4.3.5 of part 1 applies with the following additions.

5.3.5.1 Ability to withstand motor switching overload currents

Requirements to meet these conditions are given for contactors in 8.2.4.4.

5.3.5.2 Rated making capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.1. The rated making and breaking capacities are only valid when the contactor or the starter is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.5.3 Rated breaking capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.1. The rated making and breaking capacities are only valid when the contactor or the starter is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.5.4 Conventional operational performance

This performance is specified as a series of making and breaking operations in 8.2.4.2.

5.3.5.5 Starting and stopping characteristics of starters (see figure 6)

Typical service conditions for starters are:

- a) one direction of rotation with the motor being switched off during running in normal service conditions (utilization categories AC-2 and AC-3);
- b) two directions of rotation, but the running in the second direction is realized after the starter has been switched off and the motor has completely stopped (utilization categories AC-2 and AC-3);
- c) one direction of rotation, or two directions of rotation as in item b), but with the possibility of infrequent inching (jogging). For this service condition, direct-on-line starters are usually employed (utilization category AC-3);
- d) one direction of rotation with frequent inching (jogging). Usually direct-on-line starters (utilization category AC-4) are used for this duty;
- e) one or two directions of rotation, but with the possibility of infrequent plugging for stopping the motor, plugging being associated, if so provided, with rotor resistor braking (reversing starter with braking). Usually a rheostatic rotor starter is used for this duty condition (utilization category AC-2);
- f) two directions of rotation, but with the possibility of reversing the supply connections to the motor while it is running in the first direction (plugging), in order to obtain its rotation in the other direction, with switching off the motor running in normal service conditions. Usually a direct-on-line reversing starter is used for this duty condition (utilization category AC-4).

Unless otherwise stated, starters are designed on the basis of the starting characteristics of the motors compatible with the making capacities of table 7. These making capacities cover both the transient and steady-state starting currents of the great majority of standard motors. However, the starting currents for some large motors may attain peak values corresponding to power factors considerably lower than those specified for the test circuit in table 7. In these cases, the operational current of the contactor or starter should be decreased to a value lower than its rated value such that the making capacity of the contactor or starter is not exceeded.

5.3.5.5.1 Starting characteristics of rheostatic rotor starters

A distinction shall be drawn between the currents and voltages in the stator and rotor circuits of slip-ring motors. However, the changes of the current values in stator and rotor circuits, caused by the various steps of the starting process, are nearly proportional under normal operating conditions.

The following definitions deal mainly with the characteristics of the rotor circuit:

U_{er} = rated rotor operational voltage;

I_{er} = rated rotor operational current;

Z_r = characteristic impedance of the rotor of an a.c. slip-ring induction motor;

where

$$Z_r = \frac{U_{er}}{\sqrt{3} \cdot I_{er}};$$

I_1 is the current in the rotor circuit immediately before shorting out a resistor section;

I_2 is the current in the rotor circuit immediately after shorting out a resistor section;

$I_m = 1/2 (I_1 + I_2)$;

T_e is the rated motor operational torque;

t_s is the starting time (see 3.2.19);

k is the severity of start = $\frac{I_m}{I_{er}}$.

It is recognized that many rheostatic rotor starter applications have very specific starting requirements which may result not only in a different number of starting steps and different values of I_1 and I_2 , but also in the values of I_1 and I_2 being different for individual resistor sections. Therefore, no attempt has been made to lay down standard parameters, but the following factors should be taken into consideration:

- for most applications, between two and six starting steps are adequate depending upon load torque, inertia and the severity of start required;
- the resistor sections should be designed to have adequate thermal ratings bearing in mind the starting time of the drive, which will be dependent upon load torque and load inertia.

5.3.5.5.2 Standard conditions for making and breaking corresponding to the starting characteristics for rheostatic rotor starters

These conditions are given in table 7 and apply to starting with high torque. (For the designation of the mechanical switching devices, see figure 4).

NOTE Conditions for starting with full torque and half torque are under consideration.

The conditions for making and breaking as given in table 7 for AC-2 utilization category are considered as standard.

The starter circuit shall be designed to open all rotor resistor switching devices before or approximately simultaneously with the opening of the stator switching device. Otherwise, the stator switching device shall comply with AC-3 requirements.

5.3.5.5.3 Starting characteristics for two-step auto-transformer starters

Unless otherwise stated, the auto-transformer starters and specifically the auto-transformers are designed on the condition that the starting time (see 3.2.20) for all classes of duty (see 5.3.4) shall not exceed 15 s. The number of starting cycles per hour assumes equal periods between starts except that, in the event of two operating cycles being made in rapid succession, the starter and the auto-transformer shall be allowed to cool to ambient air temperature before a further start is made.

When a starting time in excess of 15 s is required, this shall be the subject of agreement between manufacturer and user.

5.3.6 Rated conditional short-circuit current

Subclause 4.3.6.4 of part 1 applies.

5.4 Utilization category

Subclause 4.4 of part 1 applies with the following additions.

For contactors and starters, the utilization categories as given in table 1 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 is characterized by the values of the currents, voltages, power-factors or time-constants and other data of tables 7 and 8, and by the test conditions specified in this standard.

For contactors or starters defined by their utilization category, it is therefore unnecessary to specify separately the rated making and breaking capacities as these values depend directly on the utilization category as shown in table 7.

The voltage for all utilization categories is the rated operational voltage of a contactor or a starter other than a rheostatic rotor starter, and the rated stator operational voltage for a rheostatic rotor starter.

All direct-on-line starters belong to one or more of the following utilization categories: AC-3, AC-4, AC-7b, AC-8a and AC-8b.

All star-delta and two-step auto-transformer starters belong to utilization category AC-3.

Rheostatic rotor starters belong to utilization category AC-2.

5.4.1 Assignment of utilization categories based on the results of tests

- a) A contactor or starter which has been tested for one utilization category or at any combination of parameters (such as highest operational voltage and current, etc.) can be assigned other utilization categories without testing provided that the test currents, voltages, power-factors or time-constants, number of operating cycles, on and off times given in tables 7 and 8, and the test circuit for the assigned utilization categories are not more severe than those at which the contactor or starter has been tested and the temperature rise has been verified at a current not less than the highest assigned rated operational current in continuous duty.

For example, when tested for utilization category AC-4, a contactor may be assigned utilization category AC-3 provided I_e for AC-3 is not higher than 1,2 I_e for AC-4 at the same rated operational voltage.

- b) DC-3 and DC-5 contactors are assumed to be capable of opening and closing loads other than those on which they have been tested provided that:
- the voltage and current do not exceed the specified values of U_e and I_e ;
 - the energy J stored in the actual load is equal to or less than the energy J_c stored in the load with which they were tested.

The values of the energy stored in the test circuit are as follows:

Utilization category	Stored energy J_c
DC-3	$0,00525 \times U_e \times I_e$
DC-5	$0,0315 \times U_e \times I_e$

The values of the constants 0,00525 and 0,0315 are derived from:

$$J_c = 1/2 L I^2$$

where the time-constant has been replaced by:

$2,5 \times 10^{-3}$ s (DC-3) and:

15×10^{-3} s (DC-5)

and where $U = 1,05 U_e$, $I = 4 I_e$ and L is the inductance of the test circuit.

(See table 7 of this standard.)

Table 1 – Utilization categories

Kind of current	Utilization categories	Typical applications
AC	AC-1	Non-inductive or slightly inductive loads, resistance furnaces
	AC-2	Slip-ring motors: starting, switching off
	AC-3	Squirrel-cage motors: starting, switching off motors during running ¹⁾
	AC-4	Squirrel-cage motors: starting, plugging, inching
	AC-5a	Switching of electric discharge lamp controls
	AC-5b	Switching of incandescent lamps
	AC-6a	Switching of transformers
	AC-6b	Switching of capacitor banks
	AC-7a ³⁾	Slightly inductive loads in household appliances and similar applications
	AC-7b ³⁾	Motor-loads for household applications
	AC-8a	Hermetic refrigerant compressor motor ²⁾ control with manual resetting of overload releases
	AC-8b	Hermetic refrigerant compressor motor ²⁾ control with automatic resetting of overload releases
DC	DC-1	Non-inductive or slightly inductive loads, resistance furnaces
	DC-3	Shunt-motors: starting, plugging, inching Dynamic breaking of d.c. motors
	DC-5	Series-motors: starting, plugging, inching Dynamic breaking of d.c. motors
	DC-6	Switching of incandescent lamps
1) AC-3 category may be used for occasional inching (jogging) or plugging for limited time periods such as machine set-up; during such limited time periods, the number of such operations should not exceed five per minute or more than ten in a 10-min period. 2) A hermetic refrigerant compressor motor is a combination consisting of a compressor and a motor, both of which are enclosed in the same housing, with no external shaft or shaft seals, the motor operating in the refrigerant. 3) For AC-7a and AC-7b, see IEC 61095.		

5.5 Control circuits

Subclause 4.5 of part 1 applies.

5.6 Auxiliary circuits

Subclause 4.6 of part 1 applies.

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) Release with shunt coil (shunt trip).
- b) Under-voltage and under-current opening relay or release.
- c) Overload time-delay relay the time-lag of which is:
 - 1) substantially independent of previous load (e.g. time-delay magnetic overload relay);
 - 2) dependent on previous load (e.g. thermal overload relay);
 - 3) dependent on previous load (e.g. thermal overload relay) and also sensitive to phase loss (see 3.2.17).
- d) Instantaneous over-current relay or release (when applicable).
- e) Other relays or releases (e.g. phase loss sensitive relay, control relay associated with devices for the thermal protection of the starter).

NOTE Types referred to in items d) and e) require consultation between manufacturer and user according to the particular application.

5.7.3 Characteristic values

- a) Release with shunt coil, under-voltage (under-current) opening relay or release:
 - rated voltage (current);
 - rated frequency;
 - operating voltage (current).
- 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 2, or the value of the maximum tripping time, in seconds, under the conditions specified in 8.2.1.5.1, table 3, column D, when this time exceeds 30 s;
 - number of poles;
 - nature of the relay: thermal, magnetic or solid state.