

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Low-voltage switchgear and controlgear –
Part 4-1: Contactors and motor-starters – Electromechanical contactors and
motor-starters**

**Appareillage à basse tension –
Partie 4-1: Contacteurs et démarreurs de moteurs – Contacteurs et démarreurs
électromécaniques**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

**Part 4-1: Contactors and motor-starters –
Electromechanical contactors and motor-starters**

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This fifth edition cancels and replaces the fourth edition published in 2018. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) objective in the scope;
- b) instantaneous only motor protective switching device IMPSD (3.5.33);
- c) kinds of equipment (5.2.1);

- d) methods of overload protection of motors (5.2.6);
- e) adoption of the AC-7d from IEC 61095:2023 (in 5.4.2);
- f) separately mounted overload relay of a starter (in 5.7.3 b));
- g) starter and contactor suitable for use downstream to basic drive module (6.1.2 w));
- h) reference to IEC TS 63058 for environmental aspects (in 6.4);
- i) wiring subject to movement (in 8.1.3);
- j) use of voltage transient limiting device (8.1.18);
- k) accessible parts subject to temperature limits (in 8.2.2.3);
- l) reference to Annex X of IEC 60947-1:2020 for the co-ordination of MPSD with SCPD (8.2.5.4);
- m) reference to IEC TR 63216 with different EMC environments (8.3.1);
- n) reference to IEC TR 63201 for the embedded software design (8.4);
- o) reference to IEC TS 63208 for cybersecurity aspects (8.5);
- p) update and completion of the measurement method of the power consumption of the electromagnet (9.3.3.2.1.2);
- q) update of Annex C including rational about AC-3e;
- r) determination of the critical load current for photovoltaic applications (M.8.7).

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This document shall be read in conjunction with IEC 60947-1:2020, *Low voltage switchgear and controlgear – Part 1: General rules*. The provisions of the general rules are applicable to this document, where specifically called for.

The provisions of the general rules dealt with IEC 60947-1 are applicable to this part of IEC 60947 series where specifically called for. Clauses and subclauses, tables, figures and annexes of the general rules thus applicable are identified by reference to IEC 60947-1:2020. For example, 5.3.4.1 of IEC 60947-1:2020, Table 4 of IEC 60947-1:2020, or Annex A of IEC 60947-1:2020.

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters

1 Scope

This part of IEC 60947 is applicable to the following equipment:

- electromechanical contactors and starters including motor protective switching devices (MPSD and IMPSD);
- actuators of contactor relays;
- contacts dedicated exclusively to the coil circuit of the contactor or the contactor relay;
- dedicated accessories (e.g. dedicated wiring, dedicated latch accessory);

intended to be connected to distribution circuits, motors circuits and other load circuits, the rated voltage of which does not exceed 1 000 V AC or 1 500 V DC.

This document does not apply to:

- starters for DC motors;
- auxiliary contacts of contactors and contacts of contactor relays. These are covered by IEC 60947-5-1;
- the short-circuit protective device integrated within starters, other than MPSDs. This is covered by IEC 60947-2 and IEC 60947-3;
- motor overload protection function performed by control units for built-in thermal protection (PTC). They are covered by IEC 60947-8;
- the use of the equipment with additional measures within explosive atmospheres. These are given in IEC 60079 series;

The objective of this document is to state:

- the characteristics and composition of the equipment (Clause 5);
- the conditions applicable to the equipment with reference to:
 - its operation (5.2.5) and protection functions (5.2.6, 5.7, 5.8),
 - its intended environments (6.5, 8.3.1) and applications (5.4, Annex C, Annex D, Annex G, Annex H, Annex I, Annex M, Annex O) including safety applications (Annex F, Annex K, Annex L),
 - its construction and performance (Clause 8) including requirements to reduce risks of electric shock, thermal hazard, energy hazard, fire hazard and mechanical hazard, reasonably foreseeable misuse, electromagnetic compatibility (EMC) issues, software errors and security issues;
- the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests (Clause 9);
- the information to be included with the equipment or in the product documentation (Clause 6).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034-1:2022, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-12:2016, *Rotating electrical machines – Part 12: Starting performance of single-speed three-phase cage induction motors*

IEC 60034-30-1:2014, *Rotating electrical machines – Part 30-1: Efficiency classes of line operated AC motors (IE code)*

IEC 60068-2-14:2023, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60079-14, *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*

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

IEC 60364-1:2005, *Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions*

IEC 60715:2017, *Dimensions of low-voltage switchgear and controlgear – Standardized mounting on rails for mechanical support of switchgear, controlgear and accessories*

IEC 60730-1, *Automatic electrical controls – Part 1: General requirements*

IEC 60947-1:2020, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 60947-2:2016, *Low-voltage switchgear and controlgear – Part 2: Circuit-breakers*

IEC 60947-5-1:2016, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

IEC 61051-2, *Varistors for use in electronic equipment – Part 2: Sectional specification for surge suppression varistors*

IEC 61095:2023, *Electromechanical contactors for household and similar purposes*

IEC 61140:2016, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61439 (all parts), *Low-voltage switchgear and controlgear assemblies*

IEC 61643-331, *Components for low-voltage surge protection – Part 331: Performance requirements and test methods for metal oxide varistors (MOV)*

IEC 61800-5-1:2022, *Adjustable speed electrical power drive systems – Part 5-1: Safety requirements – Electrical, thermal and energy*

IEC 61810-1, *Electromechanical elementary relays – Part 1: General and safety requirements*

IEC TS 63058, *Switchgear and controlgear and their assemblies for low voltage – Environmental aspects*

IEC TS 63208, *Low-voltage switchgear and controlgear – Security aspects*

IEC TR 63216:2019, *Low-voltage switchgear and controlgear – Electromagnetic compatibility assessment for switchgear and controlgear and their assemblies*

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

CISPR 11:2015/AMD1:2016

CISPR 11:2015/AMD2:2019

ISO 2859-1:1999, *Sampling procedures for inspection by attributes – Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

ISO 3864-2, *Graphical symbols – Safety colours and safety signs – Part 2: Design principles for product safety labels*

3 Terms, definitions, symbols and abbreviated terms

3.1 General

For the purposes of this document, the terms and definitions of Clause 3 of IEC 60947-1:2020, as well as the following terms, definitions, symbols and abbreviated terms apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

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3.3 Terms and definitions concerning contactors

3.3.1

mechanical contactor

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 1 to entry: Mechanical contactors can be designated according to the method by which the force for closing the main contacts is provided.

Note 2 to entry: 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 3 to entry: 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 4 to entry: A contactor is usually intended to operate frequently.

Note 5 to entry: A mechanical contactor can provide a galvanic opening (3.6.13) but is not suitable for isolation unless the additional requirements defined under 8.1.7 are fulfilled. In this case the equipment can be marked in accordance with IEC 60417-6169-1 "Disconnector; isolator" (2012-08).

[SOURCE: IEC 60050-441:1984, 441-14-33, modified – Term "contactor" added as synonymous; "may" replaced by "can" in Note 1 to entry; Notes to entry 2 to 5 have been added.]

3.3.2

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

Note 1 to entry: The electromagnet can be electronically controlled.

3.3.3

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

3.3.4

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

3.3.5

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 to entry: The latching, and the release of the latching, can be mechanical, electromagnetic, pneumatic, etc.

Note 2 to entry: 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.

[SOURCE: IEC 60050-441:1984, 441-14-34, modified – "may" replaced by "can" in Note 1 to entry.]

3.3.6**vacuum contactor**

contactor in which the main contacts open and close within a highly evacuated envelope

3.3.7**position of rest**

<contactor> position which the moving elements of the contactor take up when its electromagnet or its compressed-air device is not energized

[SOURCE: IEC 60050-441:1984, 441-16-24]

3.3.8**electronically controlled electromagnet**

electromagnet in which the coil is controlled by a circuit with active electronic elements

3.3.9**holding power**

<contactor> power needed to maintain the operation of the electromagnet

3.3.10**pick-up power**

<contactor> power needed to operate the contactor from the de-energized state to the energized state

3.4 Terms and definitions of the functions of starters**3.4.1****switching**

<motor starter> capability to make and break the current of a motor in normal operation according to the appropriate motor load utilization category

3.4.2**overload protection**

<motor starter> detection of the overload condition of a motor intended to control mechanically or electrically the opening of the switching function of the starter

3.4.3**electromechanical overload protection**

protection of a rotating electrical machine in case of excessive temperatures resulting from certain conditions of overload by means of thermo mechanical detection that initiate the interruption of the motor load circuit

Note 1 to entry: Electromechanical overload protection is typically provided by thermal overload relays or motor protective switching devices (MPSD).

3.4.4**isolating**

<motor starter> ability to provide in an indicated open position adequate isolation between the motor circuits and the supply circuits

3.4.5**electronic overload relay with control functions**

multipole electronic relay with motor control operations through its inputs and outputs

Note 1 to entry: Example of control functions: reversing control, two speed control, star-delta control, etc.

3.4.6**electronic overload relay with under-voltage restarting function**

electronic relay which operates when the voltage applied to the main circuit or control circuit is reduced below a predetermined value and automatically resets (with or without time delay) when the voltage is recovered

3.4.7**electronic overload relay with main circuit undervoltage restarting function**

electronic overload relay with under-voltage restarting function monitoring only the main circuit

3.4.8**electronic overload relay with control circuit undervoltage restarting function**

electronic overload relay with under-voltage restarting function monitoring only the control circuit

Note 1 to entry: The automatic restarting function can be de-activated.

3.5 Terms and definitions concerning starters**3.5.1****motor starter
starter**

combination of all the switching means necessary to start and stop a motor in combination with suitable overload protection

[SOURCE: IEC 60050-441:1984, 441-14-38, modified – "motor starter" added as the first term and Note 1 to entry has been deleted.]

3.5.2**direct-on-line starter**

starter which connects the line voltage across the motor terminals in one step

[SOURCE: IEC 60050-441:1984, 441-14-40]

3.5.3**reversing starter**

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

Note 1 to entry: An application where reversing the motor primary connections while the motor is running is called plugging (see 3.5.25).

3.5.4**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

3.5.4.1**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

[SOURCE: IEC 60050-441:1984, 441-14-44]

3.5.4.2**auto-transformer starter**

starter for an induction motor which uses for starting one or more reduced voltages derived from an auto-transformer

[SOURCE: IEC 60050-441:1984, 441-14-45]

3.5.4.3**auto-transformer**

transformer in which at least two windings have a common part

[SOURCE: IEC 60050-421:1990, 421-01-11]

3.5.5**rheostatic starter**

starter utilizing one or several resistors for obtaining, during starting, stated motor torque characteristics and for limiting the current

Note 1 to entry: A rheostatic starter generally consists of three basic parts which can 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.

Note 2 to entry: It applies also to starters for two directions of rotation when reversal of connections is made with the motor stopped.

[SOURCE: IEC 60050-441:1984, 441-14-42, modified – Notes to entry have been added]

3.5.5.1**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

3.5.5.2**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

[SOURCE: IEC 60050-441:1984, 441-14-43]

3.5.6**protected starter**

equipment consisting of a starter, a manually-operated switching device and a short-circuit protective device, rated as a unit by the manufacturer

Note 1 to entry: The protected starter can be enclosed.

Note 2 to entry: In the context of this document, the term "manufacturer" means any person, company or organization with ultimate responsibility as follows:

- to verify compliance with the appropriate standard;
- to provide the equipment information according to Clause 6.

Note 3 to entry: A manually protected starter as one unit can be a MPSP.

3.5.7

combination starter

equipment consisting of a protected starter incorporating an isolating function

Note 1 to entry: Also called "combination motor controller".

Note 2 to entry: See Figure C.7.

3.5.8

manual starter

starter in which the force for closing the main contacts is provided exclusively by manual energy

[SOURCE: IEC 60050-441:1984, 441-14-39]

3.5.9

electromagnetic starter

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

3.5.10

motor-operated starter

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

3.5.11

pneumatic starter

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

3.5.12

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

3.5.13

single-step starter

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

Note 1 to entry: This starter is a direct-on-line starter.

3.5.14

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.

3.5.15

***n*-step starter**

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

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

[SOURCE: IEC 60050-441:1984, 441-14-41, modified – "OFF" and "ON" in capital; Example added]

3.5.16

vacuum starter

starter in which the main contacts open and close within a highly evacuated envelope

3.5.17**separately mounted overload relay**

overload relays not exclusively dedicated to a switching device

3.5.18**phase loss sensitive overload relay****phase loss sensitive overload release**

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

3.5.19**under-current relay****under-current relay release**

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

3.5.20**starting time**

<rheostatic starter> period of time during which the starting resistors or parts of them carry current

Note 1 to entry: The starting time of a starter is shorter than the total starting time of the motor which also takes into account the last period of acceleration following the switching operation to the ON position.

3.5.21**starting time**

<auto-transformer starter> period of time during which the auto-transformer carries current

Note 1 to entry: The starting time of a starter is shorter than the total starting time of the motor which also takes into account the last period of acceleration following the switching operation to the ON position.

3.5.22**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 1 to entry: The transition stage is not considered as an additional step.

3.5.23**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 1 to entry: The transition stage is not considered as an additional step.

3.5.24**inching****jogging**

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

3.5.25**plugging**

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

3.5.26

protected switching device

equipment (for non-motor loads) consisting of a contactor or a semiconductor controller, overload protection, a manually operated switching device and a short-circuit protective device, rated as a unit by the manufacturer

Note 1 to entry: The protected switching device can be enclosed.

Note 2 to entry: In the context of this document, the term "manufacturer" means any person, company or organization with ultimate responsibility as follows:

- to verify compliance with the appropriate standard;
- to provide the equipment information according to Clause 6.

Note 3 to entry: The manually operated switching device and the short-circuit protective device can be just one device and can incorporate the overload protection as well.

3.5.27

combination switching device

equipment consisting of a protected switching device incorporating an isolating function

3.5.28

stall relay

stall release

electronic overload relay or release which operates when the current has not decreased below a predetermined value for a specific period of time during start-up or when the relay or the release receives the input indicating there is no rotation of the motor after a predetermined time in accordance with specified requirements

Note 1 to entry: Explanation of stall: rotor locked during start.

Note 2 to entry: With appropriate adjustment of the current and starting time settings, such relay or release can be used to detect starts requiring longer than specified times.

3.5.29

jam relay

jam release

electronic overload relay or release which operates in the case of overload and also when the current has increased above a predetermined value for a specific period of time during operation, in accordance with specified requirements

Note 1 to entry: A jam is a high overload occurring after the completion of starting which causes the current to reach the locked rotor current value of the motor being controlled.

3.5.30

inhibit time

time-delay period during which the tripping function of the relay is inhibited

3.5.31

motor management starter

starter including extended functions with communication ability

Note 1 to entry: Interoperable device profiles for motor management starter are defined by IEC 61915-2:2011.

3.5.32**motor protective switching device****MPSD**

manually operated motor starter additionally providing resettable short-circuit protection to the motor and the circuit

Note 1 to entry: A MPSD can also be used as a manual starter, a protected starter or a combination starter.

Note 2 to entry: A MPSD can be used as a SCPD within the motor branch.

Note 3 to entry: In North America, this device can be qualified as a manual motor controller suitable for tap conductor protection.

3.5.33**instantaneous only motor protective switching device****IMPSD**

motor protective switching device (MPSD) without overload protection function

Note 1 to entry: This type of device is typically used in a 3 components starter where the overload protection function is within a separately mounted overload relay.

3.5.34**dedicated wiring accessory**

prefabricated connection wiring system specifically intended for identified switchgear or controlgear

Note 1 to entry: A dedicated wiring accessory can be integrated in the switchgear or controlgear or delivered separately.

Note 2 to entry: A typical dedicated wiring accessory is for example a connection link.

3.5.35**latch accessory**

mechanical device attached to a contactor, the moving elements of which are prevented from returning to the position of rest when the operating means are de-energized

Note 1 to entry: The latching, and the release of the latching, can be mechanical, electromagnetic, pneumatic, etc.

[SOURCE: IEC 60050-441:1984, 441-14-34, modified – Adapted to accessories, and Note 2 to entry deleted]

3.5.36**basic drive module****BDM**

electronic power converter and related control, connected between an electric supply and a motor

Note 1 to entry: The BDM is capable of transmitting power from the electric supply to the motor and may be capable of transmitting power from the motor to the electric supply.

Note 2 to entry: The BDM controls some or all of the following aspects of power transmitted to the motor and motor output: current, frequency, voltage, speed, torque, force.

[SOURCE: IEC 61800-5-1:2022, 3.6]

3.6 Terms and definitions concerning characteristic quantities

3.6.1

product documentation

manufacturer's installation and operations' literature which accompanies the product, the product information contained in the manufacturer's catalogue and other product marketing material-information and, the description, definitions, product literature and usage as presented in electronic format on the manufacturer's (or supplier's) website on the World Wide Web/Internet

[SOURCE: ISO/IEC 14762:2009, 3.1.13, modified — Replacement of two ";" by "," and "and,".]

3.6.2

transient recovery voltage

TRV

recovery voltage during the time in which it has a significant transient character

Note 1 to entry: In a vacuum contactor or vacuum starter, the highest transient recovery voltage can occur on another pole than the first pole to clear.

[SOURCE: IEC 60947-1:2020, 3.7.34, modified — Note 1 to entry has been modified and Note 2 to entry was deleted.]

3.6.3

CO operation

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

3.6.4

O operation

breaking of the circuit by the SCPD resulting from closing the circuit on the equipment under test which is in the closed position

Note 1 to entry: The SCPD is normally in the closed position prior closing the circuit; in some cases, the SCPD closes the circuit (see 9.3.4.2.2, item b)).

3.6.5

I_{cd} current

current representing a fault current equal to or higher than the current corresponding to the crossover point of the mean value of the published curves representing the time-current characteristics of the overload relay and the SCPD respectively

3.6.6

crossover current

I_{co}

current corresponding to the crossover point of the mean or published curves representing the time-current characteristics of the overload relay and the SCPD respectively

Note 1 to entry: The mean curves are the curves corresponding to the average values calculated from the tolerances on the time-current characteristics of the overload relay.

3.6.7

time-current withstand characteristic capability of contactors or starters

locus of the currents a contactor or starter can withstand as a function of time

3.6.8**resetting time**

time elapsed between a circuit-breaker tripping due to an overcurrent and subsequently reaching a condition where it can be reclosed

[SOURCE: IEC 60947-2:2016, 2.19, modified – Insertion of "or a starter" in definition.]

3.6.9**conventional prospective current " I_r "**

specified value of prospective short-circuit current for which the switching device is tested under specified conditions

3.6.10 **I^2t characteristic**

<circuit-breaker or MPSD> information (usually a curve) giving the maximum values of I^2t related to break time as a function of prospective current (RMS symmetrical for AC) up to the maximum prospective current corresponding to the rated service short-circuit breaking capacity and associated voltage

[SOURCE: IEC 60947-2:2016, 2.18, modified – "or MPSD" inserted in context, "service" inserted in definition.]

3.6.11**rated instantaneous short-circuit current setting**

I_i

rated value of the current causing the operation of a release without any intentional time-delay

[SOURCE: IEC 60947-2:2016, 2.20]

3.6.12**overload current setting**

I_r

current setting of an adjustable overload release

[SOURCE: IEC 60947-2:2016, 2.21, modified – Note 1 to entry has been deleted]

3.6.13**galvanic opening**

<circuit> prevention of electric conduction within an electric circuit intended to provide power and/or signals

Note 1 to entry: Galvanic opening can be provided e.g. by a switch or a contactor.

3.6.14**galvanic separation**

prevention of electric conduction between two electric circuits intended to exchange power and/or signals

Note 1 to entry: Galvanic separation can be provided e.g. by an isolating transformer or an opto-coupler.

[SOURCE: IEC 60050-151:2001, 151-12-26]

3.6.15**recurring peak voltage**

maximum peak value of periodic excursions of the voltage waveform resulting from distortions of an AC voltage or from AC components superimposed on a DC voltage

Note 1 to entry: Random overvoltages, for example due to occasional switching, are not considered to be recurring peak voltages.

[SOURCE: IEC 60050-442:2014, 442-09-15]

3.6.16**rated voltage pulse slope** **dV/dt**

maximum admissible value of the voltage slope dV/dt of a pulse, at the ambient air temperature at such a repetition frequency that no significant increase of temperature occurs

[SOURCE: IEC 60384-17:2019, 1.5.3.5, modified — Replacement of dU/dT with dV/dt , and replacement of “rated” with “ambient air”.]

3.6.17**critical load current** **I_{crit}**

value of breaking current, within the range of service conditions, at which the arcing time is significantly extended

Note 1 to entry: This phenomenon, crucial for PV applications, is due to the low magnetic field coming from the arc current, creating a slow moving arc.

[SOURCE: IEC 60947-1:2020, 3.7.16, modified — In Note 1 to entry, replacement of “crucial for direct currents (e.g. photovoltaic (PV) applications)” with “crucial for PV applications”.]

3.6.18**rated conventional switching current** **I_{scI}**

rated current assigned to a contactor for switching the current controlled to a low level by a semiconductor, taking into the account the rated operational voltage, the rated frequency and the rated duty

Note 1 to entry: This current is typically lower than I_e .

3.7 Terms and definitions concerning safety aspects**3.7.1****abnormal operating condition**

temporary operating condition that is not a normal operating condition and is not a single fault condition of the equipment itself

Note 1 to entry: An abnormal operating condition is a temporary condition which can be introduced by the equipment or by a person and can result in a failure of a component, a device or a safeguard.

Note 2 to entry: This definition is used in the context of component failure risk analysis.

3.7.2**accessible part**

part which can be touched by means of the standard test finger

[SOURCE: IEC 60050-442:1998, 442-01-15]

3.7.3**live-part**

conductive part intended to be energized in normal conditions, including a neutral conductor or mid-point conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

[SOURCE: IEC 60050-195:2021, 195-02-19, modified – Addition of a Note 1 to entry.]

3.7.4**hazardous-live-part**

live part which, under certain conditions, can give a harmful electric shock

[SOURCE: IEC 60050-195:2021, 195-06-05 modified – Note 1 to entry deleted.]

3.7.5**limited energy source**

source that is designed and protected that, under both normal operating conditions and single fault conditions, the current that can be delivered is not hazardous with respect to fire hazard

3.7.6**protective impedance**

impedance connected between hazardous-live-parts and accessible conductive parts, of such value that the current, in normal use and under likely fault conditions, is limited to a safe value, and which is so constructed that its ability is maintained throughout the life of the equipment

[SOURCE: IEC 62477-1:2022, 3.60, modified – Replacement of “the PECS” with “the equipment”.]

3.7.7**reasonably foreseeable misuse**

use of a product or system in a way not intended by the supplier, but which can result from readily predictable human behaviour

[SOURCE: ISO/IEC Guide 51:2014, 3.7, modified – Notes to entry have been removed.]

3.7.8**single fault condition**

condition in which there is a fault of a single protection (but not a reinforced protection) or of a single component or a device

Note 1 to entry: If a single fault condition results in one or more other fault conditions, all are considered as one single fault condition.

[SOURCE: IEC Guide 104:2019, 3.8, modified – Deletion of Note 2 to entry.]

3.7.9**touch current**

electric current passing through a human body or through an animal body when it touches one or more accessible parts of an electrical installation or electrical equipment

[SOURCE: IEC 60050-826:2022, 826-11-12, modified – Replacement of “livestock” with “animal body”, and addition of “electrical” (2 occurrences)]

3.7.10

hot functional surface

surface that is intentionally heated by an internal heat source and that has to be hot to carry out the function for which the equipment is intended to be used

[SOURCE: IEC Guide 117:2010, 3.5, modified – NOTE 1 and NOTE 2 have been deleted.]

3.7.11

mirror contact

normally closed auxiliary contact which cannot be in closed position simultaneously with the normally open main contact under conditions defined in Clause F.7

Note 1 to entry: One contactor can have more than one mirror contact.

3.7.12

safe state

state of the safety device which leads to a safe condition of the EUC

Note 1 to entry: In this annex, the safe state is the condition of the interruption of the motor load circuit.

3.7.13

hardware fault tolerance

HFT

ability of a safety device to continue to perform a required function in the presence of faults

3.7.14

SIL-capability

characteristic of functional units that comply with the requirements of IEC 61508-2 and IEC 61508-3 suitable for use in functions which are allocated a SIL 1, 2 or 3 respectively

[SOURCE: IEC 60079-29-3:2014, 3.15]

3.7.15

systematic failure

failure, related in a deterministic way to a certain cause, which can only be eliminated by a modification of the design or of the manufacturing process, operational procedures, documentation or other relevant factors

Note 1 to entry: Corrective maintenance without modification will usually not eliminate the failure cause.

Note 2 to entry: A systematic failure can be induced by simulating the failure cause.

Note 3 to entry: Examples of causes of systematic failures include human error in:

- the safety requirements specification;
- the design, manufacture, installation, operation of the hardware.

[SOURCE: IEC 61508-4:2010, 3.6.6, modified – Third example of Note 3 and Note 4 deleted]

3.7.16

safety integrity level

SIL

discrete level (one out of a possible four), corresponding to a range of safety integrity values, where safety integrity level 4 has the highest level of safety integrity and safety integrity level 1 has the lowest

[SOURCE: IEC 61508-4:2010, 3.5.8, modified – Notes to entry deleted]

3.7.17**risk priority number****RPN**

one of the methods of quantitative determination of criticality

[SOURCE: derived from IEC 60812:2018, Annex B]

3.8 Terms and definitions concerning electric motor characteristics**3.8.1****inrush current**

first maximum value of current peak during motor start (positive or negative)

3.8.2**locked-rotor current**

I_{LRC}

greatest steady state rms current taken from the line with the motor held at rest, over all angular positions of its rotor, at rated voltage and frequency

Note 1 to entry: In the USA, ILRC DOL current is called LRA (Locked Rotor Amps).

Note 2 to entry: IEC 60034-1 provides a tolerance of 20 % of locked rotor direct-on-line current.

3.8.3**kappa factor**

K

ratio of the root-mean-square value of the inrush current to the direct on-line current

Note 1 to entry: A typical value for high efficiency motors is 1,8.

3.8.4**motor rated current**

rated current from the motor name plate

Note 1 to entry: In the USA, motor rated current is called FLA (Full Load Amps).

3.9 Symbols and abbreviated terms

AQL Acceptable quality level

EMC Electromagnetic compatibility

EUC Equipment under control

FMEA Failure mode effect analysis

FRU Field replaceable unit

FTA Fault tree analysis

HFT Hardware Fault Tolerance

MPSD Motor protective switching device

RPN Risk priority number

SCPD Short-circuit protective device

SIL Safety integrity level

$\hat{I}$ Maximum peak value of the pick-up current of an electronically controlled electromagnet

I_c Current made and broken (Table 7)

I_{cd} Maximum crossover breaking current (B.4.5)

I_{cs} Rated service short-circuit breaking capacity (5.3.6.2)

I_{cu}	Rated ultimate short-circuit breaking capacity (5.3.6.1)
I_e	Rated operational current (5.3.2.5)
I_{er}	Rated rotor operational current (5.3.2.7)
I_{es}	Rated stator operational current (5.3.2.6)
I_i	Instantaneous short-circuit current setting
I_{IT}	Short-circuit test current for IT system
I_q	Maximum conditional short-circuit test current
I_r	Overload current setting
I_{th}	Conventional free air thermal current (5.3.2.1)
I_{the}	Conventional enclosed thermal current (5.3.2.2)
I_{thr}	Conventional rotor thermal current (5.3.2.4)
I_{ths}	Conventional stator thermal current (5.3.2.3)
I_u	Rated uninterrupted current (5.3.2.8)
P_c	Nominal holding or pickup power of a conventional direct current controlled electromagnet, or the holding power for an electronically direct current controlled electromagnet
P_p	Pick-up power of a direct current controlled contactor with separate pick-up and hold-on windings
" r "	conventional prospective current
S_h	Holding power of an alternating current controlled electromagnet
S_p	Pick-up power of an alternating current controlled electromagnet
T_p	Tripping time (Table 2)
U_c	Rated control circuit voltage (5.5)
U_d	Voltage drop of a contactor pole
U_e	Rated operational voltage (5.3.1.1)
U_{er}	Rated rotor operational voltage (5.3.1.1.3)
U_{es}	Rated stator operational voltage (5.3.1.1.2)
U_i	Rated insulation voltage (5.3.1.2)
U_{imp}	Rated impulse (withstand) voltage (5.3.1.3)
U_{ir}	Rated rotor insulation voltage (5.3.1.2.3)
U_{is}	Rated stator insulation voltage (5.3.1.2.2)
U_r	Power frequency or DC recovery voltage (Table 7)
U_s	Rated control circuit supply voltage (5.5)
U_v	Maximum continuous operating voltage of the varistor
U_0	Rated supply voltage
Z	Pole impedance of a contactor (5.3.7)

4 Classification

Subclause 5.2 gives all the data which can 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);

NOTE 1 The rated values established for a rheostatic rotor starter are stated in accordance with 5.3.1.1.2, 5.3.1.1.3, 5.3.1.2.2, 5.3.1.2.3, 5.3.2.3, 5.3.2.4, 5.3.2.6, 5.3.2.7 and 5.3.5.5 but specifying all the values listed is optional.

- 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);
- 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);
- items subject to agreement between manufacturer and user; see Annex D.

For information exchange in electronic format, e.g. electronic catalogue, IEC 62683-1 gives the data format of the essential characteristics of motor starters, contactors and their accessories.

NOTE 2 In the case of a star-delta starter, the currents relate to the delta connection and, in the case of a two-step auto-transformer or rheostatic rotor starter, to the ON position.

5.2 Type of equipment

5.2.1 Kind of equipment

This document covers two types of equipment:

- contactor (3.3.1);
- starter (3.5.1).

The following starting methods are described:

- direct-on-line starter (3.5.2);
- star-delta starter (3.5.4.1);
- two-step auto-transformer starter (3.5.4.2);
- rheostatic rotor starter (3.5.5.2).

The following types of starter are specifically specified

- combination starter (3.5.7);
- protected starter (3.5.6);
- reversing starter (3.5.3).
- motor management starter (3.5.31);
- motor protective switching device (MPSD) (3.5.32);
- instantaneous only motor protective switching device (IMPSD) (3.5.33).

NOTE 1 Instantaneous only motor protective switching device (IMPSD) are related to motor protective switching device (MPSD) and usually share the same platform.

In this document, requirements for MPSD are also covering IMPSD where applicable.

5.2.2 Number of poles

5.2.3 Kind of current (AC or DC)

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

The methods of operation described in this document are:

- manually operated,
- powered-operated: electromagnetically operated, pneumatically operated, electro-pneumatic operated.

5.2.5.2 Method of control

The method of control of a starter can be classified as:

- 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 can be automatic, non-automatic or semi-automatic (see Figure C.12 and Figure C.14).

5.2.5.4 Method of connection of a starter

The typical method of connection of a starter covered by this document is the open transition starter defined in 3.5.22 and illustrated in C.4. The closed transition starter defined in 3.5.23 requires particular adaptations of the starting method for avoiding the transients associated with the open transition.

5.2.6 Methods of overload protection of motors

5.2.6.1 Motor overload detection

The detection of the overload condition of the motor is performed by the motor overload relay or release of the starter according to its current setting (5.7.4) and its time-current characteristic (5.7.5).

5.2.6.2 Motor switching

The switching element shall be suitable for breaking the motor overload current detected by the overload relay or release of the starter. In case of an associated switching device, it shall be declared with an appropriate motor utilization category according to 5.4.

The relationship between the overload protection function and the switching function of starter is detailed in C.3.

Typical associations of components and motor starting waveforms of direct-on-line starters are given in C.2 and C.6.

After manual or automatic reset, the switching element shall be capable of making the starting current of the motor as covered by the making conditions of Table 7.

5.3 Rated and limiting values for main circuits

5.3.1 Rated voltages

5.3.1.1 Rated operational voltage (U_e)

5.3.1.1.1 General

Subclause 5.3.1.1 of IEC 60947-1:2020 applies.

When the contactor or starter is declared as suitable for use downstream to a basic drive module, the working voltage value includes recurring peaks.

5.3.1.1.2 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.

5.3.1.1.3 Rated rotor operational voltage (U_{er})

For rheostatic rotor starters, the value of rated rotor 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 insulation voltage of the switching devices inserted in the rotor circuit shall be at least 50 % of the highest voltage between open slip-rings.

NOTE Electrical stresses are lower and shorter in the rotor than in the stator.

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 exceeds 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 can be taken of this fact in choosing the equipment and its disposition.

5.3.1.2 Rated insulation voltage (U_i)

5.3.1.2.1 General

Subclause 5.3.1.2 of IEC 60947-1:2020 applies.

5.3.1.2.2 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.

5.3.1.2.3 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 5.3.1.3 of IEC 60947-1:2020 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

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

Subclause 5.3.2.1 of IEC 60947-1:2020 applies.

5.3.2.2 Conventional enclosed thermal current (I_{the})

Subclause 5.3.2.2 of IEC 60947-1:2020 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, precisely 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 can be verified that, for the rated duties (see 5.3.4) stated in 6.1.2 f), 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 can 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 in 6.1.2 f) 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 product documentation shall state the relationship assumed between the current and the power.

NOTE Annex G gives values concerning the relationship between rated operational currents and rated operational powers.

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 can be stated in the product documentation 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 product documentation 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 can be stated in the product documentation 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 can 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 5.3.2.4 of IEC 60947-1:2020 applies.

5.3.3 Rated frequency

Subclause 5.3.3 of IEC 60947-1:2020 applies.

5.3.4 Rated duties

5.3.4.1 Eight-hour duty (continuous duty)

Subclause 5.3.4.1 of IEC 60947-1:2020 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 5.3.4.2 of IEC 60947-1:2020 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 5.3.4.3 of IEC 60947-1:2020 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 can render a thermal relay unsuited for overload protection. For installations intended for intermittent duty, the question of overload protection is subject to agreement between manufacturer and user.

5.3.4.4 Temporary duty

Subclause 5.3.4.4 of IEC 60947-1:2020 applies.

5.3.4.5 Periodic duty

Subclause 5.3.4.5 of IEC 60947-1:2020 applies.

5.3.5 Normal load and overload characteristics

5.3.5.1 General

Subclause 5.3.5 of IEC 60947-1:2020 applies with the following additions.

5.3.5.2 Ability to withstand motor overload currents

Requirements to meet these conditions are given for contactors or Instantaneous only motor protective switching device (IMPSD) in 8.2.4.4.

5.3.5.3 Ability to make and break load currents

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

5.3.5.5.1 General

Typical service conditions for starters as shown in C.6 are:

- a) one direction of rotation with the motor being switched off during running in normal service conditions (utilization categories AC-2, AC-3 and AC-3e);
- 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, AC-3 and AC-3e);
- 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 and AC-3e);
- 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 while running 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 can 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.

5.3.5.5.2 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} is the rated rotor operational voltage;

I_{er} is the rated rotor operational current;

Z_r is the characteristic impedance of the rotor of an AC slip-ring induction motor;

where

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

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;

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 can 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.

5.3.5.5.3 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.

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.

5.3.5.5.4 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 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 Short-circuit characteristics

5.3.6.1 Rated ultimate short-circuit breaking capacity of a MPSD (I_{cu})

The rated ultimate short-circuit breaking capacity of a MPSD is the value of ultimate short-circuit breaking capacity assigned to that MPSD in 6.1.2 m) for the corresponding rated operational voltage, under the conditions specified in P.3. It is expressed as the value of the prospective breaking current, in kA (RMS value of the AC component in the case of alternating current).

5.3.6.2 Rated service short-circuit breaking capacity of a MPSD (I_{cs})

The rated service short-circuit breaking capacity of a MPSD is the value of service short-circuit breaking capacity assigned to that MPSD in 6.1.2 m) for the corresponding rated operational voltage U_e , under the conditions specified in P.2. It is expressed as a value of prospective breaking current, in kA, or as a % of I_{cu} (for example $I_{cs} = 25 \% I_{cu}$).

I_{cs} shall be at least equal to 25 % of I_{cu} .

5.3.6.3 Rated conditional short-circuit current

Subclause 5.3.6.4 of IEC 60947-1:2020 applies.

5.3.7 Pole impedance of a contactor (Z) or starter

The pole impedance can be stated in 6.1.2 h) and is determined by measuring the voltage drop resulting of the current flowing through the pole.

5.4 Utilization category

5.4.1 General

Subclause 5.4 of IEC 60947-1:2020 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 constitutes such an agreement.

Each utilization category is characterized by the values of the currents, voltages, power-factors or time-constants and other data of Table 7 and Table 10, and by the test conditions specified in this document.

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-3e, 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.

5.4.2 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 to 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 Table 7 and Table 10, 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	$0,005\ 25 \times U_e \times I_e$
DC-5	$0,031\ 5 \times U_e \times I_e$

The values of the constants 0,005 25 and 0,031 5 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).

Table 1 – Utilization categories

Kind of current	Utilization categories	Additional category designation	Typical load
AC	AC-1	General use	Non-inductive or slightly inductive loads
	AC-2		Slip-ring motors or mixed resistive and inductive loads, including moderate overloads
	AC-3		Squirrel-cage motors ^d : starting, switching off motors during running, reversing ^a
	AC-3e ^e		Squirrel-cage motors with higher locked rotor current ^e : starting, switching off motors during running, reversing ^a
	AC-4	Ballast Incandescent	Squirrel-cage motors ^d : starting, plugging, inching
	AC-5a		Discharge lamps
	AC-5b		AC incandescent lamps
	AC-6a		Transformers
	AC-6b or AC-7c ^c		Capacitor banks or compensated electric discharge lamp
	AC-7a ^c		Slightly inductive loads for household appliances and similar applications
	AC-7b ^c		Motor-loads for household applications
	AC-7d ^c		LED lamp
	AC-8a		Hermetic refrigerant compressor motor ^b control with manual resetting of overload releases
	AC-8b		Hermetic refrigerant compressor motor ^b control with automatic resetting of overload releases
DC	DC-1	Incandescent	Non-inductive or slightly inductive loads
	DC-3		Shunt-motors: starting, plugging, inching, dynamic breaking of DC motors
	DC-5		Series-motors: starting, plugging, inching, dynamic breaking of DC motors
	DC-6		DC incandescent lamps
^a 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.			
^b 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.			
^c IEC 61095 provides requirements and tests for the utilization categories.			
^d Asynchronous motor of design N and H according to IEC 60034-12:2016.			
^e Asynchronous motor of design NE and HE, according to IEC 60034-12:2016, having extended / higher locked rotor apparent power and current than design N and H respectively, to achieve a higher efficiency class according to IEC 60034-30-1:2014. The changes related to high efficiency motors are explained in C.1.			

5.5 Control circuits

Subclause 5.5 of IEC 60947-1:2020 applies with the following additions.

The list of characteristics given in 5.5.1 of IEC 60947-1:2020 shall be completed by:

- range of the rated control circuit supply voltage U_s when applicable, expressed in the form min – max V;
- limited energy (if the source is in accordance with 8.1.14);

- SELV (PELV) supply (in accordance with Annex N of IEC 60947-1:2020);
- the power consumption of the electromagnet of a contactor, necessary for determining the characteristics of the power supply of the control circuit, which is given by:
 - holding power,
 - pick-up power.

NOTE In the USA and Canada, control circuits are characterised as Class 2 sources as defined in NFPA 70, National Electrical Code and CSA C22.1, Canadian Electrical Code (CE Code) in lieu of or in addition to SELV (PELV) sources.

5.6 Auxiliary circuits

Subclause 5.6 of IEC 60947-1:2020 applies.

Digital inputs and/or digital outputs contained in contactors and motor-starters and intended to be compatible with PLCs shall fulfil the requirements of Annex S of IEC 60947-1:2020.

5.7 Characteristics of relay and release of overload relays and of motor protective switching device (MPSD)

NOTE 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);
- extended functions as given in Annex H;
- load monitoring indicators as given in Annex O.

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:
 - substantially independent of previous load;
 - dependent on previous load;
 - dependent on previous load and also phase loss sensitive overload relay or release;
- d) relay or release integral to the starter or separately mounted;
- e) Instantaneous overload relay or release;
- f) Instantaneous short-circuit relays or releases;

NOTE A MPSD has a combination of relays or releases from c) and e) above. A IMPSD does not have any overload release.

- g) Stall relay or release;
- h) Relays with extended functions (see Annex T of IEC 60947-1:2020);
- i) Other relays or releases (e.g. control relay associated with devices for the thermal protection of the motor).

5.7.3 Characteristic values

- a) Release with shunt-coil, under-voltage (under-current), over-voltage (instantaneous over current), current or voltage imbalance and phase reversal opening relay or release:
 - rated voltage (current);
 - rated frequency;
 - operating time (when applicable);
 - inhibit time (when applicable).
- b) Motor overload relay and release of a starter (including the overload protection function of a MPSD):
 - designation and current settings (see 5.7.4);
 - associated current transformers when applicable;
 - 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 40 s;
 - nature of the relay: thermal, magnetic, electronic or electronic without thermal memory (electronic relay not fulfilling the thermal memory test verification according 8.2.1.5.1.2 shall be marked ~~Thm~~);
 - nature of the reset: in case of manual/automatic, the set position shall be indicated;
 - tripping time of overload relays class 10A if longer than 2 min at –5 °C or below (see 8.2.1.5.1.1, item c);
 - additional characteristics for a separately mounted overload relay
 - rated conditional short-circuit current (see 5.3.6.3);
 - type of co-ordination according to 8.2.5.1 for an electronic overload relay or co-ordination type 1 for a thermal overload relay;
 - Reference to possible associated SCPD type (e.g., IMPSD), current rating and characteristics;
 - Utilization category and rated operational currents at the rated operational voltages of the control circuit device according to IEC 60947-5-1;
 - Reference(s) to possible associated switching device(s) with suitable current rating including the rated making and breaking capacities for motor load according to Table 7.
- c) Release with residual current sensing relay:
 - rated current;
 - ground/earth fault current setting;
 - operating time or time-current characteristic according to Table T.1 of IEC 60947-1: 2020;
 - inhibit time (when applicable);
 - type designation (see T.4 of IEC 60947-1:2020).
- d) Short-circuit release of an MPSD:
 - rated operational currents (I_e) or rated operational powers;
 - rated frequency;
 - current setting (or range of settings) if applicable.

Table 2 – Trip classes of overload relays

Trip class	Tripping time T_p under the conditions specified in 8.2.1.5.1, Table 3, column D ^a	Tripping time T_p under the conditions specified in 8.2.1.5.1, Table 3, column D for tighter tolerances (tolerance band E) ^a
	s	s
2	–	$T_p \leq 2$
3	–	$2 < T_p \leq 3$
5	$0,5 < T_p \leq 5$	$3 < T_p \leq 5$
10A	$2 < T_p \leq 10$	–
10	$4 < T_p \leq 10$	$5 < T_p \leq 10$
20	$6 < T_p \leq 20$	$10 < T_p \leq 20$
30	$9 < T_p \leq 30$	$20 < T_p \leq 30$
40	–	$30 < T_p \leq 40$
NOTE 1 Depending on the nature of the relay, the tripping conditions are given in 8.2.1.5. NOTE 2 In the case of a rheostatic rotor starter, the overload relay is commonly inserted in the stator circuit. As a result, it cannot efficiently protect the rotor circuit and more particularly the resistors (generally more easily damageable than the rotor itself or the switching devices in case of a faulty start); protection of the rotor circuit is the subject of a specific agreement between manufacturer and user (see, inter alia, 8.2.1.1.3). NOTE 3 In the case of a two-step auto-transformer starter, the starting auto-transformer is normally designed for use during the starting period only: as a result, it cannot be efficiently protected by the overload relay in the event of faulty starting. Protection of the auto-transformer is the subject of specific agreement between manufacturer and user (see 8.2.1.1.4). NOTE 4 The lower limiting values of T_p are selected to allow for differing heater characteristics and manufacturing tolerances.		
^a The letter E shall be added to the trip classes to indicate compliance with the band E.		

5.7.4 Designation and current settings of overload relays

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

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

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

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

5.7.5 Time-current characteristics of overload relays

Typical time-current characteristics shall be given in the form of curves supplied with the overload relay. These curves shall indicate how the tripping time, starting from the cold state (see 5.7.6), varies with the current up to a value of at least eight times the full-load current of the motor with which it is intended that the relay be used. The product documentation shall indicate, by suitable means, the general tolerances applicable to these curves and the conductor cross-sections used for establishing these curves (see 9.3.3.2.2, item c)).

NOTE The current is plotted as abscissa and the time as ordinates, using logarithmic scales. The current is plotted as multiples of the setting current I_r and the time in seconds on the standard graph sheet detailed in 5.6.1 and Figure 1 of IEC 60269-1:2006 and in Figure 104, Figure 503 and Figure 504 of IEC 60269-2:2013.

5.7.6 Influence of ambient air temperature

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

The overload relays shall be able to operate within the ambient air temperature range of –5 °C to +40 °C, and the product documentation shall state the effect of variation in ambient air temperature on the characteristics of overload relays.

5.8 Co-ordination with short-circuit protective devices

The co-ordination of contactors and starters is characterized by the type, ratings and characteristics of the short-circuit protective devices (SCPD) that provide protection of the contactor and starter against short-circuit currents. Requirements are given in 8.2.5.1 and 8.2.5.2 of this document, and in 5.8 of IEC 60947-1:2020.

Requirements for AC-3e rated starters with type 2 co-ordination are given in 8.2.5.3. When a MPSD is used as a manual starter without associated contactor, this subclause does not apply.

5.9 Void

5.10 Types and characteristics of automatic change-over devices and automatic acceleration control devices

5.10.1 Types

- a) Time-delay devices, e.g. time-delay contactor relays according to IEC 60947-5-1 applicable to control-circuit devices or specified-time all-or-nothing relays according to IEC 61810-1.
- b) Undercurrent devices (undercurrent relays).
- c) Other devices for automatic acceleration control:
 - devices dependent on voltage;
 - devices dependent on power;
 - devices dependent on speed.

5.10.2 Characteristics

- a) The characteristics of time-delay devices are:
 - the rated time-delay or its range, if adjustable;
 - for time-delay devices fitted with a coil, the rated voltage, when it differs from the starter line voltage.

- b) The characteristics of the undercurrent devices are:
- the rated current (thermal current and/or rated short-time withstand current, according to the indications given in the product documentation);
 - the current setting or its range, if adjustable.
- c) The characteristics of the other devices shall be determined by agreement between manufacturer and user.

5.11 Types and characteristics of auto-transformers for two-step auto-transformer starters

Account being taken of the starting characteristics (see 5.3.5.5.4), starting auto-transformers shall be characterized by:

- the rated voltage of the auto-transformer;
- the number of taps available for adjusting the starting torque and current;
- the starting voltage, i.e. the voltage at the tapping terminals, as a percentage of the rated voltage of the auto-transformer;
- the current they can carry for a specified duration;
- the rated duty (see 5.3.4);
- the method of cooling

{	air-cooling;
	oil-cooling.

The auto-transformer can be:

- either built-in into the starter, in which case the resulting temperature-rise shall be taken into account in determining the ratings of the starter;
- or provided separately, in which case the nature and dimensions of the connecting links shall be specified by agreement between the manufacturer of the transformer and the manufacturer of the starter.

5.12 Types and characteristics of starting resistors for rheostatic rotor starters

Account being taken of the starting characteristics (see 5.3.5.5.2), the starting resistors shall be characterized by:

- the rated rotor insulation voltage (U_{ir});
- their resistance value;
- the mean thermal current, defined by the value of steady current they can carry for a specified duration;
- the rated duty (see 5.3.4);
- the method of cooling

{	free air;
	forced air;
	oil-immersion.

They can be:

- either built-in into the starter, in which case the resulting temperature-rise shall be limited in order not to cause any damage to the other parts of the starter;
- or provided separately, in which case the nature and dimensions of the connecting links shall be specified by agreement between the manufacturer of the resistor and the manufacturer of the starter.