

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**High-voltage switchgear and controlgear –
Part 106: Alternating current contactors, contactor-based controllers and motor-
starters**

**Appareillage à haute tension –
Partie 106: Contacteurs, combinés de démarrage à contacteurs et démarreurs de
moteurs, pour courant alternatif**

WILLOW



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

**Part 106: Alternating current contactors,
contactor-based controllers and motor-starters**

FOREWORD

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International Standard IEC 62271-106 has been prepared by subcommittee 17A: High-voltage switchgear and controlgear, of IEC technical committee 17: Switchgear and controlgear.

This standard cancels and replaces the second edition of IEC 60470 published in 1999. It constitutes a technical revision.

This edition includes the following significant technical changes with respect to IEC 60470:1999:

- Scope and object: The voltage range covered by the standard was expanded from 12 kV to 24 kV. Overload relay calibration and testing is not covered by this standard.
- 3 Terms and definitions: Added definitions for capacitor switching classes.
- 4.1 Rated voltage: Added 15, 17,5 and 24 kV as standard voltage values.
- 4.109.2 Starting duty of reduced-voltage starters: Added ratings for autotransformer and reactor starters (was in the testing section).

- 4.112 Rated capacitive switching currents: Added capacitor switching current ratings.
- 5.101 Protective relays: Removed the requirements for overload relays. This section is obsolete since there are only a few MV starters fitted with thermal overload relays and electronic relays have their own standards.
- 6.2.5 Application of the test voltage and test conditions (former 6.2.2 b)): Changed wording of requirement for impulse across the open gap of vacuum contactors.
- 6.4.2 Auxiliary circuits: The requirement for resistance checks of auxiliary circuits was deleted.
- 6.5.5.104 Temperature rise of the auto-transformer or reactor for two-step auto-transformer or reactor starters: Reworded to transfer ratings to subclause 4.109.2.
- 6.102.9 Condition following making and breaking tests: Gave specific direction as to what the tolerance should be based on where the resistance was to be checked.
- 6.104 Short-circuit current making and breaking tests: Clarified test conditions for short-circuit testing.
- 6.109 Capacitive current switching tests: Added capacitive current switching tests.
- Annex B: Added Table B.1 – Tolerances on test quantities for type test.

This standard is to be read in conjunction with IEC 62271-1:2007, to which it refers and which is applicable unless otherwise specified in this standard. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses is used as in IEC 62271-1. Amendments to these clauses and subclauses are given under the same references whilst additional subclauses are numbered from 101.

The text of this standard is based on the following documents:

FDIS	Report on voting
17A/971/FDIS	17A/976/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The list of all parts of the IEC 62271 series under the general title, *High-voltage switchgear and controlgear*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The contents of the corrigendum of February 2014 have been included in this copy.

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 106: Alternating current contactors, contactor-based controllers and motor-starters

1 General

1.1 Scope and object

This part of IEC 62271 is applicable to a.c. contactors and/or contactor-based controllers and motor-starters designed for indoor installation and operation at frequencies up to and including 60 Hz on systems having voltages above 1 000 V but not exceeding 24 000 V.

It is applicable only to three-pole devices for use in three-phase systems, and single-pole devices for use in single-phase systems. Two-pole contactors and starters for use in single-phase systems are subject to agreement between manufacturer and user.

Contactors and/or starters dealt with in this standard typically do not have adequate short-circuit interruption capability. In this context, this standard gives requirements for

- motor starters associated with separate short-circuit protective devices;
- controllers - contactors combined with short-circuit protective devices (SCPD).

Contactors intended for closing and opening electric circuits and, if combined with suitable relays, for protecting these circuits against operating overloads are covered in this standard.

This standard is also applicable to the operating devices of contactors and to their auxiliary equipment.

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 are dealt with.

Motor-starter types included are

- direct-on-line starters;
- reversing starters;
- two-direction starters;
- reduced kVA (voltage) starters;
 - auto-transformer starters;
 - rheostatic starters;
 - reactor starters.

This standard does not apply to

- circuit-breaker-based motor-starters;
- single-pole operation of multi-pole contactors or starters;
- two-step auto-transformer starters 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.

This standard does not deal with components contained in contactors and contactor-based motor-starters, for which individual specifications exist.

NOTE 1 Thermal electrical relays are covered by IEC 60255-8.

NOTE 2 High-voltage current-limiting fuses are covered by IEC 60282-1 and IEC 60644.

NOTE 3 Metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV are covered by IEC 62271-200.

NOTE 4 Disconnectors and earthing switches are covered by IEC 62271-102.

NOTE 5 High-voltage switches above 1 kV and less than 52 kV are covered by IEC 62271-103¹.

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,
 - 5) for controllers, interactions between the various components, for example SCPD co-ordination;
- 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.

1.2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60282-1, *High-voltage fuses – Part 1: Current-limiting fuses*

IEC 60417, *Graphical symbols for use on equipment*

IEC 60644, *Specification for high-voltage fuse-links for motor circuit applications*

IEC 62271-1:2007, *High-voltage switchgear and controlgear – Part 1: Common specifications*

IEC 62271-100:2008, *High-voltage switchgear and controlgear – Part 100: Alternating-current circuit-breakers*

¹ To be published

IEC 62271-102, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

IEC 62271-200:2003, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

2 Normal and special service conditions

2.1 Normal service conditions

Subclause 2.1 of IEC 62271-1 is applicable with the following addition:

For outdoor installations, refer to 8.102.6.

2.2 Special service conditions

Subclause 2.2 of IEC 62271-1 is applicable with the following exception:

2.2.1 Altitude

Subclause 2.2.1 of IEC 62271-1 is applicable with the following addition:

NOTE Above 1 000 m it is often necessary to make adjustments. See 8.102.7.

3 Terms and definitions

For the purposes of this standard, the terms and definitions given in Clause 3 of IEC 62271-1, as well as the following, apply.

3.1 General terms and definitions

3.1.101

controlgear

general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for the control of electric energy consuming equipment

[IEC 60050-441:1984, 441-11-03]

3.1.102

over-current

current exceeding the rated current

[IEC 60050-441:1984, 441-11-06]

3.1.103

short-circuit current

over-current resulting from a short circuit due to a fault or an incorrect connection in an electric circuit

[IEC 60050-441:1984, 441-11-07]

3.1.104

overload

operating conditions in an electrically undamaged circuit, which cause an over-current

[IEC 60050-441:1984, 441-11-08]

3.1.105

conductive part

part which is capable of conducting current although it may not necessarily be used for carrying service current

[IEC 60050-441:1984, 441-11-09]

3.1.106

ambient air temperature

temperature, determined under prescribed conditions, of the air surrounding the complete switching device or fuse

NOTE For switching devices or fuses installed inside an enclosure, it is the temperature of the air outside the enclosure.

[IEC 60050-441:1984, 441-11-13]

3.2 Assemblies of switchgear and controlgear

Clause 3.2 of IEC 62271-1 applies

3.3 Parts of assemblies

Clause 3.3 of IEC 62271-1 applies.

3.4 Switching devices

3.4.101

switching device

device designed to make or break the current in one or more electric circuits

[IEC 60050-441:1984, 441-14-01]

3.4.102

mechanical switching device

switching device (such as a contactor or a disconnecter) designed to close and open one or more electric circuits by means of separable contacts

[IEC 60050-441:1984, 441-14-02, modified]

3.4.103

disconnecter

mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements

NOTE 1 A disconnecter is capable of opening and closing a circuit either when negligible current is broken or made, or when no significant change in the voltage across the terminals of each of the poles of the disconnecter occurs. It is also capable of carrying currents under normal circuit conditions and carrying for a specified time currents under abnormal conditions such as those of short circuit.

NOTE 2 A withdrawable contactor assembly may be used as a disconnecter.

NOTE 3 In North America, this device is also called an isolating means or an isolating switch.

[IEC 60050-441:1984, 441-14-05, modified]

3.4.104**earthing switch**

mechanical switching device for earthing parts of a circuit, capable of withstanding for a specified time currents under abnormal conditions such as those of short circuit, but not required to carry current under normal conditions of the circuit

NOTE An earthing switch may have a short-circuit making capacity.

[IEC 60050-441:1984, 441-14-11]

3.4.105**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.

[IEC 60050-441:1984, 441-14-33]

3.4.106**electromagnetic contactor**

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

3.4.107**vacuum contactor**

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

3.4.108**SF₆ contactor**

contactor in which the main contacts open and close within an SF₆ gas-filled compartment

3.4.109**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 The latching, and the release of the latching, may be mechanical, electromagnetic, pneumatic, etc.

[IEC 60050-441:1984, 441-14-34, modified]

3.4.110**starter**

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

[IEC 60050-441:1984, 441-14-38, modified]

3.4.110.1**direct-on-line starter**

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

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

3.4.110.2**reversing starter**

starter intended to cause the motor to reverse the direction of rotation by reversing the motor primary connections even when the motor is running

3.4.110.3

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

3.4.110.4

reduced kVA (voltage) starter

starter which reduces the starting kVA of the motor

NOTE Reduced kVA starters may include auto-transformer, reactor, rheostatic starters.

3.4.110.5

auto-transformer starter

starter which uses one or more reduced voltages derived from an auto-transformer

3.4.110.6

rheostatic starter

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

NOTE 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 rotor circuit;
- the mechanical switching devices for cutting out the resistor(s) successively.

[IEC 60050-441:1984, 441-14-42, modified]

3.4.110.7

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

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

3.4.110.8

reactor starter

primary reactor starter

starter that includes a reactor connected in series with the stator winding of an alternating current motor to furnish reduced voltage for starting

3.4.110.9

electromagnetic starter

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

3.4.110.10

***n*-step starter**

starter in which there are ($n - 1$) intermediate accelerating positions between the off and full on positions

NOTE 1 A starter in which there is no intermediate accelerating position between the OFF and ON positions is a single step or direct-on-line starter (see 3.4.110.1).

NOTE 2 A starter in which there is only one intermediate accelerating position between the OFF and ON positions is known as a two-step starter.

NOTE 3 A three-step rheostatic starter has two sections of resistors used for starting.

[IEC 60050-441:1984, 441-14-41, modified]

3.4.111 **controller** **combination starter**

equipment consisting of a contactor, overload protection, a manual externally operated disconnecter and a short-circuit protective device (SCPD), mounted and wired in a dedicated enclosure

NOTE 1 A dedicated enclosure is an enclosure specifically designed and dimensioned for its application, in which all tests are conducted, and which may also include an earthing function.

NOTE 2 A controller may be used for functions other than motor starting, for example transformer control and protection.

3.4.111.1 **transformer controller**

combination of all the switching means necessary to energize and de-energize a transformer in combination with suitable overload protection

3.4.111.2 **capacitor controller**

combination of all the switching means necessary to energize and de-energize a capacitor or capacitor bank in combination with suitable protection

3.4.112 **short-circuit protective device** **SCPD**

device intended to protect a circuit or parts of a circuit against short-circuit currents by interrupting them

NOTE Usually this function is provided by fuses.

3.4.113 **contactor class C1**

contactor with a low probability of restrike during capacitive current breaking as demonstrated by the type tests (see 4.112)

3.4.114 **contactor class C2**

contactor with a very low probability of restrike during capacitive current breaking as demonstrated by type tests (see 4.112)

3.5 Parts of contactors and motor starters

3.5.101 **pole of a switching device**

portion of a switching device associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together

NOTE A switching device is called single-pole if it has only one pole. If it has more than one pole, it may be called multipole (two-pole, three-pole, etc.) provided the poles are or can be coupled in such a manner as to operate together.

[IEC 60050-441:1984, 441-15-01]

3.5.102 **main circuit** (of a switching device)

all the conductive parts of a switching device included in the circuit which it is designed to close or open

[IEC 60050-441:1984, 441-15-02]

3.5.103

control circuit (of a switching device)

all the conductive parts (other than the main circuit) of a switching device which are included in a circuit used for the closing operation or opening operation, or both, of the device

[IEC 60050-441:1984, 441-15-03]

3.5.104

auxiliary circuit (of a switching device)

all the conductive parts of a switching device which are intended to be included in a circuit other than the main circuit and the control circuits of the device

NOTE Some auxiliary circuits fulfil supplementary functions such as signalling, interlocking, etc., and, as such, they may be part of the control circuit of another switching device.

[IEC 60050-441:1984, 441-15-04]

3.5.105

main contact

contact included in the main circuit of a mechanical switching device, intended to carry, in the closed position, the current of the main circuit

[IEC 60050-441:1984, 441-15-07]

3.5.106

control contact

contact included in a control circuit of a mechanical switching device and mechanically operated by this device

[IEC 60050-441:1984, 441-15-09]

3.5.107

auxiliary contact

contact included in an auxiliary circuit and mechanically operated by the switching device

[IEC 60050-441:1984, 441-15-10]

3.5.108

"a" contact

make contact

control or auxiliary contact which is closed when the main contacts of the mechanical switching device are closed and open when they are open

[IEC 60050-441:1984, 441-15-12]

3.5.109

"b" contact

break contact

control or auxiliary contact which is open when the main contacts of a mechanical switching device are closed and closed when they are open

[IEC 60050-441:1984, 441-15-13]

3.6 Operation

3.6.101

operation (of a mechanical switching device)

transfer of the moving contact(s) from one position to an adjacent position

NOTE 1 For a circuit-breaker, this may be a closing operation or an opening operation.

NOTE 2 If distinction is necessary, an operation in the electrical sense, e.g. make or break, is referred to as a switching operation, and an operation in the mechanical sense, e.g. close or open, is referred to as a mechanical operation.

[IEC 60050-441:1984, 441-16-01]

3.6.102

operating cycle (of a mechanical switching device)

succession of operations from one position to another and back to the first position through all other positions, if any

NOTE 1 This may be a closing operation followed by an opening operation.

NOTE 2 A succession of operations not forming an operating cycle is referred to as an operating series.

[IEC 60050-441:1984, 441-16-02, modified]

3.6.103

closing operation (of a mechanical switching device)

operation by which the device is brought from the open position to the closed position

[IEC 60050-441:1984, 441-16-08]

3.6.104

opening operation (of a mechanical switching device)

operation by which the device is brought from the closed position to the open position

[IEC 60050-441:1984, 441-16-09]

3.6.105

closed position (of a mechanical switching device)

position in which the predetermined continuity of the main circuit of the device is secured

[IEC 60050-441:1984, 441-16-22]

3.6.106

open position (of a mechanical switching device)

position in which the predetermined clearance between open contacts in the main circuit of the device is secured

[IEC 60050-441:1984, 441-16-23]

3.6.107

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

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

3.6.108

overload relay or release

over-current relay or release intended for protection against overloads (including, where applicable, operating transformer(s) and interconnections)

3.6.109

thermal overload relay or release

inverse time-delay overload relay or release depending for its operation (including its time delay) on the thermal action of the current flowing in the relay or release

3.6.110

current setting of an overload relay or release

value of current for which the relay or release is adjusted and in accordance with which its operating conditions are defined

3.6.111

current setting range of an overload relay or release

range between the minimum and maximum values over which the current setting of the relay or release can be adjusted

3.6.112

phase failure sensitive overload relay or release

multi-pole overload relay or release which, in accordance with specified requirements, operates at a current value lower than its current setting in the case of current unbalance

3.6.113

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

3.6.114

starting time (of a rheostatic starter)

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

NOTE 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.

3.6.115

starting time (of an auto-transformer starter)

period of time during which the auto-transformer carries current

NOTE 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.

3.6.116

open transition (with an auto-transformer starter)

circuit arrangement so 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.

3.6.117

closed transition (with an auto-transformer starter)

circuit arrangement so 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.

3.6.118

inching

jogging

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

3.6.119

plugging

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

3.7 Characteristic quantities

3.7.101

breaking current (of a switching device or a fuse)

current in a pole of a switching device or in a fuse at the instant of initiation of the arc during a breaking process

[IEC 60050-441:1984, 441-17-07]

3.7.102

breaking capacity (of a switching device or a fuse)

value of prospective current that a switching device or a fuse is capable of breaking at a stated voltage under prescribed conditions of use and behaviour

NOTE 1 The voltage to be stated and the conditions to be prescribed are dealt with in the relevant publications.

NOTE 2 For switching devices, the breaking capacity may be termed according to the kind of current included in the prescribed conditions, e.g. line charging breaking capacity, cable charging breaking capacity, single capacitor bank breaking capacity, etc.

[IEC 60050-441:1984, 441-17-08]

3.7.103

making capacity (of a switching device)

value of prospective making current that a switching device is capable of making at a stated voltage under prescribed conditions of use and behaviour

NOTE The voltage to be stated and the conditions to be prescribed are dealt with in the relevant specifications.

[IEC 60050-441:1984, 441-17-09]

3.7.104

short-time withstand current

current that a circuit or a switching device in the closed position can carry during a specified short time under prescribed conditions of use and behaviour

[IEC 60050-441:1984, 441-17-17]

3.7.105

recovery voltage

voltage which appears across the terminals of a pole of a switching device or a fuse after the breaking of the current

NOTE This voltage may be considered in two successive intervals of time, one during which a transient voltage exists, followed by a second one during which the power frequency or the steady-state recovery voltage alone exists.

[IEC 60050-441:1984, 441-17-25]

3.7.106

transient recovery voltage**TRV**

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

NOTE 1 The transient recovery voltage may be oscillatory or non-oscillatory, or a combination of these, depending on the characteristics of the circuit and the switching device. It includes the voltage shift of the neutral of a polyphase circuit.

NOTE 2 The transient recovery voltage in three-phase circuits is, unless otherwise stated, that across the first pole to clear, because this voltage is generally higher than that which appears across each of the other two poles.

[IEC 60050-441:1984, 441-17-26]

3.7.107

prospective transient recovery voltage (of a circuit)

transient recovery voltage following the breaking of the prospective symmetrical current by an ideal switching device

NOTE The definition assumes that the switching device or the fuse, for which the prospective transient recovery voltage is sought, is replaced by an ideal switching device, i.e. having instantaneous transition from zero to infinite impedance at the very instant of zero current, i.e. at the "natural" zero. For circuits where the current can follow several different paths, e.g. a polyphase circuit, the definition further assumes that the breaking of the current by the ideal switching device takes place only in the pole considered.

[IEC 60050-441:1984, 441-17-29]

3.7.108

power frequency recovery voltage

recovery voltage after the transient voltage phenomena have subsided

[IEC 60050-441:1984, 441-17-27]

3.7.109

prospective current (of a circuit and with respect to a controller situated therein)

current that would flow in the circuit if each pole of the controller were replaced by a conductor of negligible impedance

[IEC 60050-441:1984, 441-17-01, modified]

3.7.110

prospective peak current

peak value of a prospective current during the transient period following initiation

NOTE The definition assumes that the current is made by an ideal switching device, i.e. with instantaneous transition from infinite to zero impedance. For circuits where the current can follow several different paths, e.g. polyphase circuits, it further assumes that the current is made simultaneously in all poles, even if only the current in one pole is considered.

[IEC 60050-441:1984, 441-17-02]

3.7.111

maximum prospective peak current (of an a.c. circuit)

prospective peak current when initiation of the current takes place at the instant which leads to the highest possible value

NOTE For a multiple device in a polyphase circuit, the maximum prospective peak current refers to a single pole only.

[IEC 60050-441:1984, 441-17-04]

3.7.112

prospective breaking current (for a pole of a switching device or a fuse)

prospective current evaluated at a time corresponding to the instant of the initiation of the breaking process

NOTE Specifications concerning the instant of the initiation of the breaking process are to be found in the relevant publications. For mechanical switching devices or fuses, it is usually defined as the moment of initiation of the arc during the breaking process.

[IEC 60050-441:1984, 441-17-06]

3.7.113

minimum breaking current

minimum value of prospective current that a fuse-link is capable of breaking at a stated voltage under prescribed conditions of use and behaviour

[IEC 60050-441:1984, 441-18-29]

3.7.114**cut-off current****let-through current**

maximum instantaneous value of current attained during the breaking operation of a switching device or a fuse

[IEC 60050-441:1984, 441-17-12]

NOTE This concept is of particular importance when the switching device or the fuse operates in such a manner that the prospective peak current of the circuit is not reached.

3.7.115**take-over current**

current coordinate of the intersection between the release initiated opening time of the contactor and the time-current characteristic of the SCPD

[IEC 60050-441:1984, 441-17-16 modified]

3.7.116**minimum take-over current**

current determined by the point of intersection of the time-current characteristics of the SCPD and the contactor corresponding to

- a) the maximum break time plus, where applicable, the maximum operating time of an external over-current or earth-fault relay;
- b) the minimum pre-arcing time of the SCPD

NOTE See also Figure 9.

3.7.117**maximum take-over current**

current determined by the point of intersection of the time-current characteristics of the SCPD and the contactor corresponding to

- a) the minimum opening time of the contactor, or minimum response time if operated by an overcurrent relay and/or time delay devices;
- b) the maximum operating time of the SCPD of highest rated current

NOTE See also Figure 9.

3.7.118**maximum acceptable power dissipation**

power which is dissipated by the controller when fitted with fuses of maximum power dissipation as determined by the temperature-rise tests

3.7.119**fused short-circuit current**

conditional short-circuit current when the current limiting device is a fuse

[IEC 60050-441:1984, 441-17-21]

3.7.120**applied voltage** (for a switching device)

voltage which exists across the terminals of a pole of a switching device just before the making of the current

[IEC 60050-441:1984, 441-17-24]

3.7.121

vacant

3.7.122

release-initiated opening time (of the contactor)

opening time defined according to the tripping method as stated below with any time-delay device forming an integral part of the contactor adjusted to a specified setting:

- a) for a contactor tripped by any form of auxiliary power, the interval of time between the instant of energizing the opening release, the contactor being in the closed position, and the instant when the arcing contacts have separated in all poles;
- b) for a contactor tripped (other than by the striker) by a current in the main circuit without the aid of any form of auxiliary power, the interval of time between the instant at which, the contactor being in the closed position, the current in the main circuit reaches the operating value of the over-current release and the instant when the arcing contacts have separated in all poles

3.7.123

minimum release-initiated opening time (of the contactor)

release-initiated opening time when the specified setting of any time-delay device forming an integral part of the contactor is its minimum setting

3.7.124

maximum release-initiated opening time (of the contactor)

release-initiated opening time when the specified setting of any time-delay device forming an integral part of the contactor is its maximum setting

3.7.125

arcing time (of a pole or a fuse)

interval of time between the instant of the initiation of the arc in a pole or a fuse and the instant of final arc extinction in that pole or that fuse

[IEC 60050-441:1984, 441-17-37]

3.7.126

break time (of the contactor in a release-operated controller)

interval of time between the beginning of the release-initiated opening time of the contactor and the instant of final arc extinction in all poles

NOTE This term may be qualified by prefixing it with "minimum" or "maximum" depending upon the opening time and the arcing time used.

3.101 Fuses

3.101.1

fuse

device that by the fusing of one or more of its specially designed and proportioned components opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device

[IEC 60050-441:1984, 441-18-01]

3.101.2

striker

mechanical device forming part of a fuse-link which, when the fuse operates, releases the energy required to cause operation of other apparatus or indicators, or to provide interlocking

[IEC 60050-441:1984, 441-18-18]

3.101.3

pre-arcing time

melting time

interval of time between the beginning of a current large enough to cause a break in the fuse element(s) and the instant when an arc is initiated

[IEC 60050-441:1984, 441-18-21]

3.101.4

operating time

total clearing time

sum of the pre-arcing time and the arcing time

[IEC 60050-441:1984, 441-18-22]

3.101.5

Joule integral

I^2t

integral of the square of the current over a given time interval:

$$I^2t = \int_{t_0}^{t_1} i^2 dt$$

NOTE 1 The pre-arcing I^2t is the I^2t integral extended over the pre-arcing time of the fuse.

NOTE 2 The operating I^2t is the I^2t integral extended over the operating time of the fuse.

NOTE 3 The energy in joules liberated in one ohm of resistance in a circuit protected by a fuse is equal to the value of the operating I^2t expressed in A²s.

[IEC 60050-441:1984, 441-18-23]

4 Ratings

Clause 4 of IEC 62271-1 is applicable with the additions and exceptions indicated below.

A contactor, starter or controller in the correct condition of maintenance and adjustment shall be able to withstand all the stresses that occur in service, provided that these do not exceed its rated characteristics.

The characteristics of a contactor, starter or controller, including its operating devices and auxiliary equipment that shall be used to determine the ratings, are given in Table 1.

Under this heading, consideration is also given to the characteristics which are not necessarily ratings but need to be taken into consideration in the specification and design stages.

The use of an SCPD other than that utilized in the type tests may change the ratings of the combination. In this case, the new ratings shall be assigned by the manufacturer.

NOTE Ratings may differ between the table columns.

Table 1 – Ratings and characteristics

Rating/characteristic		Contactor 3.4.105	Starter 3.4.110	Controller 3.4.111
(A) Rated characteristics				
a) Rated voltage (U_r)	4.1	X	X	X
b) Rated insulation levels (U_d , U_p)	4.2	X	X	X
c) Rated frequency (f_r)	4.3	X	X	X
d) Rated operational current (I_e) or rated operational power	4.101	X	X	X
e) Rated short-time withstand current (I_k)	4.5	X	X	X
f) Rated peak withstand current (I_p)	4.6	X	X	X
g) Rated duration of short-circuit (t_k)	4.7	X	X	X
h) Rated short-circuit breaking current (I_{sc})	4.107			X
i) Rated short-circuit making current (I_{ma})	4.107			X
j) Rated duties	4.102	X	X	(X)
k) Rated load and overload characteristics, by utilization category	4.103, 4.104	X	X	X
l) Rated supply voltage of operating devices, and of auxiliary and control circuits (U_a)	4.8	X	X	X
m) Rated supply frequency of operating devices and of auxiliary circuits	4.9	X	X	X
n) Rated pressure of compressed gas supply for insulation and/or operation	4.10	X	X	X
(B) Characteristics to be given on request				
a) Thermal current (I_{th})	4.4.101	X	X	X
b) Electrical endurance	4.106	X		
c) Coordination with short-circuit protective devices	4.107	X	X	X
d) Damage classification	4.107.3	X	X	X
e) Short-circuit breaking capacity	4.107, 6.104	X	X	
f) Short-circuit making capacity	4.107, 6.104	X	X	
g) Motor switching characteristics	6.108	X		
h) Take-over current for release-operated controller	4.107.2			X
i) Rated capacitive switching current	4.112	X		X
(C) Characteristics dependent on starter type				
a) Automatic change-over devices and automatic acceleration control devices	4.108		X	X
b) Starting auto-transformer or reactor characteristics	4.109		X	X
c) Starting resistor characteristics	4.110		X	X
X: applicable for this configuration				
(X): applicable, but see NOTE 2 of 4.102.2 regarding intermittent duty				

4.1 Rated voltage (U_r)

The rated voltage indicates the upper limit of the highest voltage of the system for which the device is intended. Standard values of rated voltages are:

2,5 kV – 3,6 kV – 5,0 kV – 7,2 kV – 12 kV – 15 kV – 17,5 kV – 24 kV

For rheostatic rotor starters, the rated voltage refers to the stator.

4.1.101 Rated rotor voltage (U_{ro})

For rheostatic rotor starters, the value of the rated voltage is that of the voltage which, when combined with a rated rotor 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.

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

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

4.2 Rated insulation level (U_a , U_p)

Subclause 4.2 of IEC 62271-1 is applicable with the following additions.

For rheostatic rotor starters, the rated insulation level refers to the stator.

NOTE The insulation levels for 2,5 kV and 5,0 kV systems are 3,6 kV and 7,2 kV respectively.

4.2.101 Rated rotor insulation level

For rheostatic rotor starters, the rated rotor insulation level is that which is assigned 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.

4.2.102 Rated starting voltage (U_{tap}) 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 (U_{tap}) are 50 %, 65 % or 80 % of the rated voltage.

4.2.103 Rated starting voltage (U_{tap}) of a reactor starter

The rated starting voltage of a reactor starter is the reduced voltage derived from the impedance of the reactor and the motor current before rotation.

Preferred values of rated starting voltage (U_{tap}) are 50 %, 65 % or 80 % of the rated voltage.

4.3 Rated frequency (f_r)

The rated frequency is the supply frequency for which the device is designed and to which the other characteristic values correspond. The standard values of the rated frequency are 50 Hz and 60 Hz.

4.4 Rated normal current and temperature rise

4.4.1 Rated normal current (I_r)

A rated normal current is normally not assigned to the contactor or motor starter. When contactors or motor starters are combined into larger assemblies, the rated normal current of the connecting busbars shall be in accordance with IEC 62271-200.

See also thermal current (4.4.101).

4.4.2 Temperature rise

IEC 62271-1 applies and, and for fuses, IEC 60282-1 applies.

Subclause 4.4.2 of IEC 62271-1 is applicable with the following addition.

It is recognized that a controller may be fitted with types and ratings of fuses other than those utilized in the temperature-rise tests and this may change the thermal current of the controller. For any particular case, the thermal current of the controller shall be assigned by the manufacturer. For further information, see the application guide (Clause 8).

A contactor or starter is also defined by its rated operational currents or powers. See 4.101.

4.4.101 Thermal current (I_{th})

The thermal current is the maximum current carried on continuous duty (see 4.102.1) without the temperature rise of the various parts exceeding the limits specified in 6.5. Selection from the R10 series is not applicable.

Because, in an auto-transformer or reactor starter, the auto-transformer or reactor is energized only intermittently, a maximum temperature rise 15 K greater than the limits stated in the appropriate component standard (for example IEC 60076-2 or IEC 60076-11:2004) is permissible for the windings of the transformer or reactor when the starter is operated according to the requirements of 4.102 and 4.111.

4.4.101.1 Stator thermal current (I_{ths})

For motor starters, the stator thermal current is the maximum current it can carry on continuous duty without the temperature rise of its several parts exceeding the limits specified in 4.4.2 when tested in accordance with 6.5.3.

4.4.101.2 Rotor thermal current (I_{thr})

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, (after cutting out resistors) can carry continuously without their temperature rise exceeding the limits specified in 4.4.2 when tested in accordance with 6.5.3.

4.5 Rated short-time withstand current (I_k)

Subclause 4.5 of IEC 62271-1 is applicable with the following addition.

For a contactor, or starter, this is the r.m.s. value of the current which can be carried in a closed position for a time sufficient for an external SCPD to operate. Alternatively, the value of current may be assigned for use of a specified SCPD. In this case, the value of the current need not be selected from the R10 series. For a controller, this is the prospective r.m.s. value of current.

4.6 Rated peak withstand current (I_p)

Subclause 4.6 of IEC 62271-1 is applicable.

4.7 Rated duration of short circuit (t_k)

Subclause 4.7 of IEC 62271-1 is applicable with the following addition.

Alternatively, the interval of time for which a contactor, or starter, can carry its short-time withstand current may be that resulting from operation of the specified SCPD.

4.8 Rated supply voltage of closing and opening devices, and of auxiliary and control circuits (U_a)

Subclause 4.8 of IEC 62271-1 is applicable with the following addition.

A single-phase control supply voltage of 110 V a.c. is recognized in addition to those in Table 5 of IEC 62271-1.

NOTE 1 For starters with short-time rated coils such as closing and trip coils for latched contactors, operating limits should be agreed between manufacturer and user.

The drop-out voltage shall be not higher than 75 %, nor (with worn contacts) lower than 10 % of the rated control supply voltage U_a .

NOTE 2 Drop-out voltage is the voltage below which the contactor changes state.

NOTE 3 Close voltage is the voltage above which the contactor will fully close.

The close and drop-out values specified above are applicable after the coils have reached a stable temperature corresponding to indefinite application of 100 % U_a . In the case of a.c. coils, the voltage limits apply at rated frequency.

4.9 Rated supply frequency of closing and opening devices, and of auxiliary circuits (f_a)

Subclause 4.9 of IEC 62271-1 is applicable.

4.10 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 4.10 of IEC 62271-1 is applicable.

4.101 Rated operational current (I_e) or rated operational power

A rated operational current of a contactor or starter is stated by the manufacturer and takes into account the rated voltage (see 4.1), the rated frequency (see 4.3), the rated duties (see 4.102), the utilization category (see 4.104) and the type of protective enclosure, if appropriate.

In the case of contactors or starters for direct switching of individual motors, the indication of a rated operational current may be replaced or supplemented by the indication of the maximum rated power output, at the rated voltage considered, of the motor for which it is

intended. The manufacturer shall be prepared to state the relationship assumed between the operational current and the operational power, if any.

For rheostatic rotor starters, the rated operational current refers to the stator.

4.101.1 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 voltage (see 4.1.101), the rotor thermal current, the rated frequency (see 4.3), the rated duty (see 4.102), the starting characteristics (see 4.111) 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, 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 at the rated rotor voltage.

4.102 Rated duties

The rated duties considered as normal for a contactor, or starter, are as follows.

4.102.1 Continuous duty

Duty in which the main contacts remain closed when carrying a steady current without interruption for a period sufficient to reach thermal equilibrium without exceeding allowable temperature rise limits per 4.4.2.

4.102.2 Intermittent periodic duty or intermittent duty

Duty in which the main contacts remain closed for periods bearing a definite relation to the no-load periods, where the device does not reach thermal equilibrium, without exceeding allowable temperature rise limits per 4.4.2.

Intermittent duty is characterized by the value of the current, the duration of current flow and by the on-load factor, which is the ratio of the in-service period to the entire period, often expressed as a percentage. Standard values of on-load factor are 15 %, 25 %, 40 % and 60 %.

According to the number of operating cycles which they shall be capable of carrying out per hour, contactors or starters are divided into the following classes:

- class 1: up to one operating cycle per hour;
- class 3: up to three operating cycles per hour;
- class 12: up to 12 operating cycles per hour;
- class 30: up to 30 operating cycles per hour;
- class 120: up to 120 operating cycles per hour;
- class 300: up to 300 operating cycles per hour.

An operating cycle is defined under 3.6.102.

NOTE 1 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.

NOTE 2 Special consideration should be given to the thermal performance of SCPDs in controllers subject to intermittent duty.

NOTE 3 Special consideration should be given to autotransformer and reactor starters. See 4.109.

4.102.3 Temporary duty

Duty in which the main contacts remain closed for periods of time insufficient to allow the device to reach thermal equilibrium without exceeding allowable temperature rise limits per 4.4.2, the current-carrying periods being separated by no-load periods of sufficient duration to restore equality of temperature with the cooling medium.

Standard values of temporary duty are 10 min, 30 min, 60 min and 90 min with contacts closed.

4.103 Rated load and overload characteristics

4.103.1 Rated making and breaking capacities

A contactor or starter is defined by its making capacities and breaking capacities, as specified in Table 6, in accordance with utilization categories (see 4.104). For requirements when used in combination with short-circuit protective devices see 4.107.

4.103.1.1 Rated making capacity

The rated making capacity of a contactor or starter is a value of current determined under steady-state conditions which the device can make without welding or undue erosion of the contacts or excessive display of flame, under specified making conditions.

The rated making capacity is stated by reference to the rated operational voltage and rated operational current, and to the utilization category, according to Table 6.

The rated making capacity is expressed by the r.m.s. value of the a.c. component of the current.

NOTE The peak value of the current during the first half-cycle following closing of the contactor or starter may be appreciably greater than the peak value of the current under steady-state conditions, depending on the power factor of the circuit and the instant on the voltage wave when closing occurs.

A contactor or starter shall be capable of closing on a current corresponding to the a.c. component of the current that defines its making capacity within the limits that result from power factors indicated in Table 6, regardless of the value of the d.c. component.

The rated making capacity is based on the contactor or starter being operated in accordance with the requirements of 4.8.

4.103.1.2 Rated breaking capacity

The rated breaking capacity of a contactor or starter is a value of current which the device can break without undue erosion of the contacts or excessive display of flame, under specified breaking conditions at the rated voltage.

The rated breaking capacity is stated by reference to the rated voltage and rated operational current, and to the utilization category, according to Table 6.

A contactor or starter shall be capable of breaking any value of the load current up to its highest rated breaking capacity, according to 4.104.

If the contactor or starter exhibits a minimum breaking current, the magnitude and the power factor shall be declared by the manufacturer.

If the contactor or starter exhibits a extended arc time at lower than rated operational current, the magnitude and the power factor shall be declared by the manufacturer.

The rated breaking capacity is expressed by the r.m.s. value of the a.c. component of the current.

4.103.2 Ability to withstand overload currents

Contactors or starters with utilization categories AC-3 or AC-4 shall withstand the overload currents given in Table 8 as specified in 6.103.

4.104 Utilization category

The utilization categories as given in Table 2 are considered standard in this publication. Any other type of utilization category shall be based on agreement between manufacturer and user.

Each utilization category is characterized by the values of the currents and voltages, expressed as multiples of the rated operational current and of the rated voltage, and by the power factors as shown in Table 6 and other test conditions used in the definitions of the rated making and breaking capacities.

For contactors or starters defined by their utilization category, it is therefore unnecessary to specify separately the rated making and breaking capacities, as those values depend directly on the utilization category as shown in Table 6.

The utilization categories of Table 6 correspond to the applications listed in Table 2.

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

All direct-on-line starters belong to utilization category AC-3 or AC-4.

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

The stator contactor of rheostatic rotor starters belong to utilization category AC-2.

Table 2 – Utilization categories

Category	Typical application
AC-1	Non-inductive or slightly inductive loads, resistance furnaces
AC-2	Starting and plugging – slip-ring motors
AC-3	Starting and switching off motors during running – squirrel-cage motors
AC-4	Starting, plugging and inching – squirrel-cage motors
NOTE The application of contactors or starters to the switching of rotor circuits, capacitors or transformers shall be subject to special agreement between manufacturer and user.	

Typical service conditions for starters (see Figure 1) 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 (see Table 3) compatible with the making capacities of Table 6. When the starting current of a motor, with stalled rotor, exceeds these values, the rated operational current should be decreased accordingly.

4.105 Mechanical endurance

With respect to its endurance against mechanical wear, a contactor or starter is characterized by the number of no-load operating cycles (i.e. without current on the main contacts) which can be made before it becomes necessary to replace any parts.

The preferred numbers of no-load operating cycles, expressed in millions, are: 0,01 – 0,03 – 0,1 – 0,3 – 1 and 3.

If no mechanical endurance is stated by the manufacturer, a class of intermittent duty implies a minimum mechanical endurance corresponding to 8 000 h of operation at the highest corresponding frequency of operating cycles.

4.106 Electrical endurance

With respect to its endurance against electrical wear, a contactor or starter is characterized by the number of on-load operating cycles, corresponding to the service conditions given in Table 10, which can be made without repair or replacement. For category AC-3, the manufacturer shall state, on request, the number of on-load operating cycles which can be made without any repair or replacement for the corresponding service conditions of Table 10 (see 6.107).

4.107 Coordination with short-circuit protective devices (SCPD)

Contactors and starters are characterized by the type, ratings and characteristics of the short-circuit protective devices (SCPD), for example current-limiting fuses, to be used to provide over-current discrimination between starter and SCPD and adequate protection of the contactor and starter against short-circuit currents. Requirements are given in 6.6, 6.104 and 6.106 of this standard.

- a) For a contactor or starter not equipped with short-circuit protection, the following information shall be given by the manufacturer to enable design for coordination to be achieved:
- highest cut-off current of the SCPD intended for use in the controller;
 - maximum short-circuit breaking capacity;
 - maximum prospective short-time withstand current and duration, or the Joule integral ($\int i^2 dt$) withstand capability of the contactor or starter;
 - maximum prospective peak withstand current.

See 6.6 and 6.104.

The short-circuit breaking capacity shall not be limited to the R10 series.

- b) The manufacturer of the SCPD shall state
- the maximum peak current and the maximum Joule integral let through by the SCPD as a function of the short-circuit current;
 - the time-current characteristics of the SCPD.
- c) For a contactor or starter equipped with an SCPD, the manufacturer shall state the following in order to achieve a given type of coordination:
- types and characteristics of the coordinated devices;
 - type of damage classification (see 4.107.3);
 - rated short-circuit breaking current (I_{sc});
 - rated short-circuit making current (I_{ma}).

The rated short-circuit breaking current is the highest prospective short-circuit current which the controller shall be capable of breaking, under the conditions of use and behaviour prescribed in this standard, in a circuit having a power frequency recovery voltage corresponding to the rated voltage of the controller. The rated short-circuit breaking current shall not be limited to the R10 series.

The rated short-circuit making current is the highest prospective peak current which the controller shall be capable of making, under the conditions of use and behaviour defined in this standard, in a circuit having a power frequency voltage corresponding to the rated voltage of the controller.

The verification of coordination is carried out according to 6.106.

NOTE 1 It is recognized that the series impedance of the combination or rapid operation of the fuses or switch may cause one or both of the following effects:

- a) a reduction of short-circuit current to a value appreciably below that which would otherwise be reached;
- b) such rapid operation that the short-circuit current wave is distorted from its normal form.

This is why the term "prospective current" is used when assessing breaking and making performances.

NOTE 2 A given combination of a contactor or starter and an SCPD may comply with more than one type of coordination for different values of the rated short-circuit current.

4.107.1 General requirements for coordination

The SCPD shall be located on the supply side of the contactor or starter, and have a short-circuit breaking capacity not less than the prospective short-circuit current at its location. This requirement shall be verified by reference to the results of breaking capacity tests carried out on the SCPD according to the relevant specification.

Overload relay setting will be such that the SCPD shall not operate in place of the switching device for currents up to the maximum overload levels in normal service (including stalled current of the motor). This requirement shall be verified by reference to the results of overload tests carried out separately on the SCPD according to the relevant specification.

For currents equal to the breaking currents of the contactor or starter indicated in Table 6 for AC-3 utilization category, it shall be verified from information supplied by the manufacturer of the SCPD that the latter is able to withstand those currents for times at least equal to the corresponding tripping time of the overload relays.

For all values of overcurrent for which the controller is suitable, the contactor or starter, including the SCPD, if integrally mounted, shall operate in such a manner that the external manifestations (such as emission of flames or hot gases) do not extend beyond a safety perimeter stated by the manufacturer of the starter. If the SCPD is remote from the starter, it shall operate according to its relevant specifications.

4.107.2 Take-over current for release-operated controllers

The value of the three-phase symmetrical current used for test duty C (see 6.106.3.3). Figure 9 gives an example of calculating the take-over current.

4.107.3 Coordination and acceptable damage classification

For currents exceeding the maximum take-over current of the starter as defined in 6.106.3.3, the flow of current in the contactor or starter during the breaking time may cause damage to the switching device. According to the amount of damage acceptable, several types are considered standard. The coordination and type of damage classification shall be verified by the tests specified in 6.106.

Type a – Any kind of damage is allowed (with the exclusion of external damage to the enclosure, if any) so as to make necessary the replacement of the device as a whole or the replacement of fundamental parts in addition to those listed in type b coordination.

Type b – The characteristics of the overload relay of the starter may be permanently altered. Other damage shall be confined to the main contacts and/or the arc chambers of the starter which may require replacement or attention.

Type c – Damage shall be confined to the main contacts of the starter (which may require replacement or the breaking of welds).

Cases where the applications call for a practically negligible risk of contact welding are subject to agreement between manufacturer and user, and are not covered by this standard.

For currents not exceeding the maximum take-over current, there shall be no material damage to the contactor or starter and it shall subsequently be capable of normal operation.

4.108 Types of automatic change-over devices and automatic acceleration control devices

Automatic change over devices and automatic acceleration control devices may be supplied including:

- a) Time-delay devices, for example time-delay contactor relays (see IEC 60947-5-1) applicable to control-circuit devices, or specified-time all-or-nothing relays (see IEC 61812-1);
- b) Undercurrent devices (undercurrent relays);
- c) Other devices for automatic acceleration control

- devices dependent on voltage;
- devices dependent on power;
- devices dependent on speed.

4.109 Reduced-voltage starting auto-transformers or reactors

4.109.1 Types and characteristics of starting auto-transformers or reactors

Account being taken of the starting characteristics (see 4.111), these shall be characterized by

- the rated voltage;
- 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;
- the current they can carry for a specified duration;
- the rated duty (see 4.102);
- the method of cooling (air-cooling, oil-cooling).

The auto-transformer or reactor can be

- either built-in into the starter, in which case the resulting temperature rise has to 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 have to be specified by agreement between the manufacturer of the transformer or reactor and the manufacturer of the starter.

4.109.2 Starting duty of reduced-voltage starters

The locked-rotor current at full voltage is assumed to be 6 times full load current. The peak temperature shall not rise more than 15 K above the insulation class of the auto-transformer or reactor. Ratings shall be determined as following duty cycles:

- a) medium duty: the starter shall be rated based on the following duty cycle: on 30 s, off 30 s, repeat two times for a total of three CO operations. Rest 1 h, and then repeat;
- b) heavy duty: The starter shall be rated based on the following duty cycle: on 1 min, off 1 min, repeat four times for a total of five CO operations. Rest 2 h, then repeat.

4.110 Types and characteristics of starting resistors for rheostatic rotor starters

Account being taken of the starting characteristics (see 4.111), the starting resistors shall be characterized by

- the rated rotor insulation level;
- their resistance value;
- the thermal current, defined by the value of steady current they can carry for a specified duration;
- the rated duty (see 4.102);
- the method of cooling (for example free air, forced air, oil immersion).

The starting resistors can be

- either built-in into the starter, in which case the resulting temperature rise has to 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 have to be specified by agreement between the manufacturer of the resistors and the manufacturer of the starter.

4.111 Characteristics dependent on starter type

Table 3 indicates characteristics of the various starter types. These should be considered as typical, but for some applications there may be very specific starting requirements.

Table 3 – Characteristics dependent on starter type

Type of starter	Utilization category	Number of steps	Power	Duty cycle		U_{ro}	I_{er}^a	Cooling	Locked rotor torque T_{lr}^b	Locked rotor current I_{lr}	U_{tap}^c
				Start time	No. /h						
1. Direct-on-line	AC-3, AC-4	1	x		x						
2. Reversing	AC-4	1	x		x						
3. Two-direction	AC-2, AC-3	1	x		x						
4. Reduced kVA											
a) Rheostatic	AC-2, AC-3	n^e	x	x	x	x	x	x	x		
b) Auto-transformer	AC-3	2	x	x	x ^d			x	x	x	x
c) Reactor	AC-3	2	x	x	x ^d			x	x	x	x
I_{er} Rated rotor operational current (see 4.101.1) U_{ro} Rated rotor voltage (see 4.1.101) U_{tap} Tap voltage (see 4.2.102 and 4.2.103)											
^a Information usually supplied by the motor manufacturer. ^b To be supplied to the starter manufacturer. Standard values are 70 %, 100 %, 150 % and 200 % of the rated torque T_e . ^c Standard values are 50 %, 65 % and 80 %. ^d Per duty cycle in 4.109.2, assumed unless otherwise specified. ^e For most applications, between two and six starting steps are adequate depending upon load torque, inertia and the severity of the start required.											

4.112 Rated capacitive switching currents

The rating of a contactor for capacitive current switching shall include, where applicable:

- rated single capacitor bank breaking current;
- rated back-to-back capacitor bank breaking current;
- rated single capacitor bank inrush making current;
- rated back-to-back capacitor bank inrush making current.

The values of rated capacitive switching currents shall be given by manufacturer.

Two classes of contactors are defined according to their restrike performances:

- class C1: low probability of restrike during capacitive current breaking allows up to 5 restrikes as demonstrated by the type tests;
- class C2: very low probability of restrike during capacitive current breaking with no restrikes allowed as demonstrated by type tests.

NOTE 1 The probability is related to the performance during the series of type tests stated in 6.109.

NOTE 2 The same contactor can have different classes depending on the application.

4.112.1 Rated single capacitor bank breaking current

The rated single capacitor bank breaking current is the maximum capacitor current that the contactor shall be capable of breaking at its rated voltage under the conditions of use and behaviour prescribed in this standard. This breaking current refers to the switching of a shunt capacitor bank where no shunt capacitors are connected to the source side of the contactor.

4.112.2 Rated back-to-back capacitor bank breaking current

The rated back-to-back capacitor bank breaking current is the maximum capacitor current that the contactor shall be capable of breaking at its rated voltage under the conditions of use and behaviour prescribed in this standard.

This breaking current refers to the switching of a shunt capacitor bank where one or several shunt capacitor banks are connected to the source side of the contactor giving an inrush making current equal to the rated back-to-back capacitor bank inrush making current.

4.112.3 Rated single capacitor bank inrush making current

No rating or preferred or values are defined. This is because inrush currents associated with single capacitor banks are not considered critical.

4.112.4 Rated back-to-back capacitor bank inrush making current and frequency

The rated back-to-back capacitor bank inrush making current is the peak value of the current that the contactor shall be capable of making at its rated voltage and with a frequency of the inrush current. The values for the inrush current and frequency shall be given by the manufacturer.

5 Design and construction

5.1 Requirements for liquids in contactors and motor starters

Subclause 5.1 of IEC 62271-1 is applicable.

5.2 Requirements for gases in contactors and motor starters

Subclause 5.2 of IEC 62271-1 is applicable.

5.3 Earthing of contactors and motor starters

Subclause 5.3 of IEC 62271-1 is applicable with the following additions.

5.3.101 Earthing of the main circuit

Subclause 5.3.1 of IEC 62271-200:2003 is applicable with the following additions:

- a) if an earthing switch is supplied, the requirements of IEC 62271-102 shall apply;
- b) earthing of the main circuit may be accomplished by internal connections to portable earthing equipment as described in IEC 61230.

5.3.102 Earthing of the enclosure

Subclause 5.3.2 of IEC 62271-200 is applicable.

5.3.103 Earthing of switching devices

The exposed conductive parts (for example chassis, framework and fixed parts of metal enclosures), other than those that cannot become energized, shall be earthed.

interconnected and connected to a protective earth terminal for connection to an earth electrode or to an external protective conductor. This requirement can be met by the normal structural parts providing adequate electrical continuity and applies whether the equipment is used on its own or incorporated in an assembly. Any connecting point shall be marked with the "protective earth" symbol, as indicated by symbol IEC 60417-5019 (2006-08).

5.4 Auxiliary and control equipment

Subclause 5.4 of IEC 62271-1 is applicable with the following modification.

For the operating range of main, auxiliary and control devices, see 4.8 of this standard.

5.5 Dependent power operation

Subclause 5.5 of IEC 62271-1 is applicable with the following addition.

A contactor or starter arranged for dependent power operation with external energy supply shall be capable of making and breaking its rated short-circuit current (if any) when the voltage of the power supply of the operating device is at the lower of the limits specified under 4.8. If maximum closing and opening times are stated by the manufacturer, these shall not be exceeded.

5.6 Stored energy operation

Subclause 5.6 of IEC 62271-1 does not apply.

5.7 Independent manual operation or power operation (independent unlatched operation)

Subclause 5.7 of IEC 62271-1 does not apply.

5.8 Operation of releases

Subclauses 5.8.2 to 5.8.4 of IEC 62271-1 are applicable with the following addition.

For types and characteristics of relays and releases, see 5.101 of this standard.

NOTE In the remainder of this standard, the term overload relay should be taken to apply equally to an overload relay or an overload release as appropriate.

5.9 Low- and high-pressure interlocking and monitoring devices

Subclause 5.9 of IEC 62271-1 is applicable.

5.10 Nameplates

Subclause 5.10 of IEC 62271-1 is applicable with the following addition.

Each contactor, controller or starter shall be provided with a nameplate carrying the following data, marked in a durable manner, and located in a place such that they are visible and legible when the contactor, controller or starter is in position.

Rated operational currents or rated operational powers (see 4.101) and other data required for application purposes shall be made available by the manufacturer, for which purpose the type designation or serial number is an essential part of the nameplate data.

If the available space on the nameplate is insufficient to carry all the data, the contactor or starter shall carry at least the information under a) and b). In this instance, the complete data shall be displayed elsewhere on the equipment.

NOTE In the case of contactors, controller or starters designed as withdrawable or removable units for building into factory assembled switchgear and controlgear, such nameplates need only be visible following such withdrawal or removal.

- a) the manufacturer's name or trade mark;
- b) type designation or serial number;
- c) rated frequency (f_r), for example ~ 50 Hz;
- d) rated voltage (U_r) (see 4.1);
- e) rated operational current (I_e) or power (see 4.101);
- f) altitude above 1 000 m (if applicable).

The following information concerning the operating coils of the contactor or starter shall be placed either on each coil or on the device:

- g) either the indication "d.c." (or the symbol ---) or value of the rated frequency, for example ~ 50 Hz;
- h) rated coil voltage.

Coils of operating devices shall have a reference mark permitting the complete data to be obtained from the manufacturer.

- i) rated capacitive switching current and class, if applicable.

5.11 Interlocking devices

Subclause 5.11 of IEC 62271-1 is applicable with the following addition.

Further requirements for interlocking of a controller are specified in 5.11 of IEC 62271-200. Reversing contactors, and any other arrangement of two or more contactors that would cause a line-to-line fault if they were in the closed position at the same time, shall be mechanically and electrically interlocked to preclude this condition.

5.12 Position indication

Where position indicators are required, subclause 5.12 of IEC 62271-1 is applicable.

5.13 Degrees of protection provided by enclosures

Subclause 5.13 of IEC 62271-1 is applicable.

5.14 Creepage distances for outdoor insulators

Subclause 5.14 of IEC 62271-1 does not apply.

5.15 Gas and vacuum tightness

Subclause 5.15 of IEC 62271-1 is applicable.

5.16 Liquid tightness

Subclause 5.16 of IEC 62271-1 is applicable.

5.17 Fire hazard (flammability)

Subclause 5.17 of IEC 62271-1 is applicable.

5.18 Electromagnetic compatibility (EMC)

Subclause 5.18 of IEC 62271-1 is applicable with the following addition.

Emission caused by switching operations is of short duration, of the order of milliseconds. The frequency, level and consequences of such emission are considered to be part of the normal electromagnetic environment of switchgear and controlgear. Such emission shall therefore not be taken to be electromagnetic disturbance.

5.19 X-ray emission

Subclause 5.19 of IEC 62271-1 is applicable.

5.101 Protective relays

Relays that provide protective functions such as overload, overcurrent, earth fault, and under/over voltage may be supplied by arrangement between manufacturer and user, for example to meet special requirements such as closer overload protection or abnormally long starting times.

It is the responsibility of the user to confirm that the characteristics of the protective devices provide adequate protection for the load circuit. The manufacturer shall provide details of the protective relays and SCPD on request.

5.102 Enclosures

For metal-enclosed contactors, starters and controllers, subclause 5.102 of IEC 62271-200 is applicable.

5.103 Controller

Controllers shall be designed so as to be capable of breaking, at the required recovery voltage, any current up to and including the rated short-circuit breaking current.

They shall also be designed so as to be capable of making, at the rated voltage, onto circuits to which the rated short-circuit making current applies.

5.104 Linkages between the fuse striker(s) and the indicator or contactor release

Any linkages between the fuse striker(s), fuse-blown indicator and/or contactor release, where fitted, shall be such that the contactor operates satisfactorily under both three-phase and single-phase conditions at the minimum and maximum requirements of a given type of striker (medium or heavy), irrespective of the method of striker operation (spring or explosive). The requirements for strikers are given in IEC 60282-1.

5.105 Starter

Starters shall be supplied with an overload current-sensing device. Overload current-sensing devices shall be arranged to open the contactor and may also energize a signal device.

Starters shall be designed so as to be capable of breaking, at the required recovery voltage, any current up to and including the rated short-circuit breaking current.

They shall also be designed so as to be capable of making, at the rated voltage, onto circuits to which the rated short-circuit making current applies.

6 Type tests

6.1 General

Clause 6 of IEC 62271-1 is applicable with the following additions.

The type tests also include (refer to Table 4 for applicability)

- mechanical endurance tests (see 6.101);
- making and breaking and reversibility tests (see 6.102);
- overload current withstand tests (see 6.103);
- short-circuit current making and breaking tests (see 6.104);
- verification of operating limits and characteristics of overload relays (see 6.105);
- change-over ability and reversibility, where applicable (see 6.102.6 and 6.102.7);
- tests of the striker mechanism (see 6.101.4).

The following special type tests are not mandatory but should be conducted to verify performance claims:

- verification of coordination with SCPDs (see 6.106);
- electrical endurance tests (see 6.107);
- motor switching tests (see 6.108);
- capacitive switching tests (see 6.109).

The individual tests shall be made on a contactor in a clean and as-new condition, and the various type tests may be made at different times and at different locations.

All tests listed in Table 4 for the contactor shall be performed either on the stand alone contactor or as part of the tests for the starter or controller. Tests carried out on the starter or controller apply to the stand alone contactor installed during those tests. Further, it is understood that the SCPD will have been tested to the requirements of the relevant standard.

Thus, for controllers, four groups of tests are involved:

- a) tests on the contactor in accordance with this standard; these tests may be done on a controller other than that used for tests according to c);
- b) tests on the SCPD in accordance with the relevant standard, for example IEC 60282-1 or IEC 60644;
- c) tests on the controller in accordance with this standard;
- d) tests of the enclosure in accordance with IEC 62271-200.

The controller submitted for test shall

- 1) conform in all essential details to drawings of its type;
- 2) be in a clean and as-new condition, and fitted with the appropriate SCPD;
- 3) when release-operated, be equipped with over-current relays or releases of the lowest normal current rating associated with the fuses.

The responsibility of the manufacturer is limited to the specified values and not to the values obtained during the type tests.

The tests shall be made at the rated frequency with a tolerance of $\pm 10\%$, unless otherwise specified in the relevant subclauses.

NOTE For convenience of testing, wider tolerances of the rated frequency may be necessary. If the deviations are appreciable, i.e. when controlgear is rated for 50 Hz and tested at 60 Hz and vice versa, care should be taken in the interpretation of results.

Details relating to records and reports of type tests for making, breaking and short-time current performance are given in Annex A.

Table 4 – Applicable type tests

Test	Contactors	Starter	Controller	Subclause
Dielectric tests	X	X	X	6.2
Measurement of circuit resistance	X	X	X	6.4
Temperature-rise tests	X	X	X	6.5
Short-time and peak withstand current tests	X	X	X	6.6
Verification of the protection	–	X	X	6.7
Tightness tests	X	–	–	6.8
EMC tests	X	X	X	6.9
Verification of operating limits	X	X	X	6.101.1
Mechanical endurance tests	X	X	X	6.101.2
Interlocking tests	–	X	X	6.101.3
Rated making and breaking capacity tests	X	–	–	6.102
Reversibility tests	–	X	X	6.102.6
Change-over ability tests	–	X	X	6.102.7
Overload current withstand tests	X	–	–	6.103
Short-circuit current making and breaking tests	X	–	–	6.104
Verification of operating limits of overload relays	–	X	X	6.105
Coordination with SCPDs	X	–	–	6.106
Electrical endurance tests	X	–	–	6.107
Motor switching tests	X	–	–	6.108
Capacitive switching test	–	–	X	6.109
Tests on the striker mechanism	–	–	–	6.101.4
X: applicable to this configuration.				

6.2 Dielectric tests

Subclause 6.2 of IEC 62271-1 is applicable with the following additions.

6.2.1 Ambient air conditions during tests

Subclause 6.2.1 of IEC 62271-1 is applicable.

6.2.2 Wet test procedure

Subclause 6.2.2 of IEC 62271-1 not applicable.

6.2.3 Conditions of contactors and motor starters during dielectric tests

Subclause 6.2.3 of IEC 62271-1 is applicable with the following addition.

The dielectric tests shall be made with components giving the most onerous dielectric conditions.

6.2.4 Criteria to pass the test

Subclause 6.2.4 of IEC 62271-1 is applicable.

6.2.5 Application of the test voltage and test conditions

Subclause 6.2.5 of IEC 62271-1 is applicable with the following addition.

Impulse tests across open contacts are not required for contactors.

6.2.5.1 General case

Subclause 6.2.5.1 of IEC 62271-1 is applicable with the following additions: for impulse tests, only test conditions 1, 2, and 3 of Table 9 of IEC 62271-1 are applicable for the contactor.

6.2.5.2 Special case

Subclause 6.2.5.2 of IEC 62271-1 is not applicable.

6.2.6 Tests of contactors and motor starters of $U_r \leq 245$ kV

Subclause 6.2.6 of IEC 62271-1 is applicable.

6.2.7 Tests of contactors and motor starters of $U_r > 245$ kV

Subclause 6.2.7 of IEC 62271-1 is not applicable.

6.2.8 Artificial pollution tests for outdoor insulators

Subclause 6.2.8 of IEC 62271-1 is not applicable.

6.2.9 Partial discharge tests

Subclause 6.2.9 of IEC 62271-1 is not applicable.

6.2.10 Dielectric tests on auxiliary and control circuits

Subclause 6.2.10 of IEC 62271-1 is applicable.

6.2.11 Voltage test as condition check

Subclause 6.2.11 of IEC 62271-1 is applicable.

6.3 Radio interference voltage (r.i.v.) test

Subclause 6.3 of IEC 62271-1 is not applicable.

6.4 Measurement of the resistance of circuits

Subclause 6.4 of IEC 62271-1 is applicable with the following addition.

6.4.1 Main circuit

The current during the test shall have any convenient value between 50 A and the rated operational current. If the rated operational current is less than 50 A, the measurement shall be made at the rated operational current.

NOTE Where fuses are used as the SCPD, solid links of negligible resistance may be used instead of fuses but the resistance of the links should be recorded.

6.4.2 Auxiliary circuits

Subclause 6.4.2 of IEC 62271-1 is not applicable.

6.5 Temperature-rise tests

6.5.1 Conditions of the contactors and motor starters to be tested

Subclause 6.5.1 of IEC 62271-1 is applicable.

6.5.2 Arrangement of the equipment

Subclause 6.5.2 of IEC 62271-1 is applicable with the following addition.

For values of thermal current I_{th} :

- a) the connections shall be in free air and spaced not less than the distance existing between the terminals;
- b) for single-phase or multi-phase tests, the minimum length of each temporary connection from an equipment terminal to another terminal or to the test supply or to a star point shall be 1,2 m;
- c) for three-pole contactors and starters, the tests may be made with all poles connected in series.

6.5.3 Measurement of the temperature and temperature rise

Subclause 6.5.3 of IEC 62271-1 is applicable with the following addition.

The main circuit of a contactor, including the over-current releases which may be associated with it, shall be capable of carrying, without the temperature rises exceeding the limits specified in Table 3 of IEC 62271-1:

- for a contactor intended for continuous duty: its thermal current;
- for a contactor or controller intended for intermittent periodic duty or temporary duty: its rated operational current for the appropriate duty;
- for a controller with current-limiting fuses as the SCPD.

The test shall be carried out at the thermal current of the controller when fitted with fuses of the highest current rating and/or power dissipation. The temperature rises of the various parts of the controller shall not exceed the values specified in IEC 60282-1 for the fuses and IEC 62271-1 for the other parts of the controller.

The following characteristics of the fuses used for the test shall be recorded:

- a) manufacturer and type;
- b) rated voltage and rated current;
- c) internal resistance (see 6.4);
- d) power dissipation (measured according to the prescriptions of IEC 60282-1).

If the fuses are in an enclosure, the power dissipation at the end of the temperature-rise test is the maximum acceptable power dissipation of the controller and shall be recorded.

NOTE It is not necessary to test the performance for intermittent duty provided that compliance can be determined by calculation.

6.5.4 Ambient air temperature

Subclause 6.5.4 of IEC 62271-1 is applicable.

6.5.5 Temperature-rise test of the auxiliary and control equipment

Subclause 6.5.5 of IEC 62271-1 is applicable with the following additions.

6.5.5.101 Temperature-rise tests on contactor coils

The contactor coils shall be tested according to the following conditions, with the specified kind of supply current and at their rated voltage.

With rated operational current flowing through the main circuit, the windings of coils shall withstand, under continuous load and at the rated frequency, if applicable, their rated voltage without the temperature rises exceeding the limits specified. Specially rated coils, for example trip coils of latched contactors, shall withstand without damage the most severe operating cycle for which they are intended.

With no current flowing through the main circuit, under the same conditions of supply and without the temperature-rise limits being exceeded, the coil windings of contactors for intermittent duty classes 12 to 300 shall also withstand the frequencies of operation given in Table 5.

Table 5 – Intermittent duty operating cycles

Intermittent duty class of the contactor (see 4.102.2)	One close-open operating cycle every	Interval of time during which the supply of the control coil of electrically held contactors is maintained
	s	s
12	300	180
30	120	72
120	30	18
300	12	7,2

NOTE 1 Intermittent duty classes 1 and 3 do not need to be tested since they are essentially the same as continuous duty.

NOTE 2 The interval of time during which the supply of the control coil of electrically held contactors is maintained represents a 60 % on-load factor (see 4.102.2).

The temperature shall be measured when thermal equilibrium is reached in the contactor coils. Contactor coils shall be tested for a sufficient time for the temperature rise to reach a steady-state value. In practice, this condition is reached when the variation does not exceed 1 K per hour. At the end of these tests, the temperature rise of the different parts of the contactor coils shall not exceed the values specified for the insulation class in Table 3 of IEC 62271-1.

6.5.5.102 Temperature-rise tests of auxiliary circuits

The temperature-rise tests of auxiliary circuits are made under the same conditions as those provided in 6.5.5.101.

At the end of these tests, the temperature rise of auxiliary circuits shall not exceed the values specified.

NOTE When the mutual heating effect between main circuit, control circuits and auxiliary circuits may be of significance, these temperature-rise tests are made simultaneously.

6.5.5.103 Temperature rise of starting resistors for rheostatic rotor starters

The temperature rise of resistors shall not exceed the limits specified by the resistor manufacturer, when the starter is operated at its rated duty (see 4.102) and according to its starting characteristics (see 4.111).

The current through each section of the resistors shall be thermally equivalent to the current during the starting time when the controlled motor is operating with the maximum starting

torque and the starting time for which the starter is rated (see 4.102 and 4.111); in practice, the average current for that resistor section can be used.

Starting operations shall be evenly spaced in time according to the number of starts per hour.

The temperature rise of the enclosures and the air issuing there from shall not exceed the limits specified in Table 3 of IEC 62271-1. Additionally, the exteriors of enclosures and the air issuing from ventilation openings of enclosures for resistors shall not exceed a temperature rise of 200 K. The manufacturer shall provide sufficient information in accordance with Clause 10.

NOTE It is not practical to test the performance of the starting resistors of every combination of motor output and rotor voltage and current; it is required only that a sufficient number of tests be made to prove, by interpolation or deduction, compliance with this standard.

6.5.5.104 Temperature rise of the auto-transformer or reactor for two-step auto-transformer or reactor starters

The temperature rise of the auto-transformer or reactor shall not exceed the limits specified in the appropriate component standard (for example IEC 60076-2 or IEC 60076-11:2004), increased by 15 K (see 4.4.101), when the starter is operated at its rated duty (see 4.102). No damage shall result to the auto-transformer or reactor.

The current through each winding of the auto-transformer or reactor shall be thermally equivalent to the current carried when the controlled motor is operating with six times the rated operational current I_e multiplied by:

$$0,8 \times \frac{\text{starting voltage}}{U_e} \text{ for a duration of 30 s (see 4.2.102).}$$

The operating test cycle shall be per the duty cycles defined in clause 4.109.2.

In the case of an auto-transformer or reactor with several sets of taps, the test shall be made with the taps giving the highest power loss in the transformer or reactor.

In order to facilitate this test, star-connected impedances may be used in place of a motor.

6.5.6 Interpretation of the temperature-rise tests

Subclause 6.5.6 of IEC 62271-1 is applicable.

6.6 Short-time withstand current and peak withstand current tests

Subclause 6.6 of IEC 62271-1 is applicable with the following addition to 6.6.3.

These tests shall be performed on contactors which are to be assigned a short-circuit capability for coordination with short-circuit protective devices. Refer also to 6.104.

Separation of the contacts of a contactor or starter does not constitute a failure for these devices. The acceptability of damage shall be according to the classification assigned in accordance with 4.107.3.

NOTE Where applicable, solid links of negligible resistance are used in place of the SCPD.

6.7 Verification of the protection

Subclause 6.7 of IEC 62271-1 is applicable.

6.8 Tightness tests

Subclause 6.8 of IEC 62271-1 is applicable.

6.9 Electromagnetic compatibility tests (EMC)

Subclause 6.9 of IEC 62271-1 is applicable.

6.10 Additional tests on auxiliary and control circuits

Subclause 6.10 of IEC 62271-1 is applicable.

6.11 X-radiation test procedure for vacuum interrupters

Subclause 6.11 of IEC 62271-1 is applicable.

6.101 Mechanical tests

6.101.1 Verification of operating limits

When a contactor or starter can be supplied in several forms, according to the conditions of use (open type, various types of enclosure, etc.), the tests should only be carried out on one form stated by the manufacturer. The details of type and installation shall form part of the test report.

It shall be verified that the contactor or starter completes one operating cycle satisfactorily at each voltage limit specified in 4.8 and within the temperature limits specified when the coil is energized and de-energized long enough to ensure that the contactor comes to its extreme positions. Tests shall be performed with no current flowing through the main circuit.

When tests are performed on a contactor or motor starter destined for installation at high altitude, it may be necessary to make adjustments to the mechanism to achieve correct operation. Refer to 8.102.7.

6.101.2 Mechanical endurance tests

6.101.2.1 Condition for tests

The contactor or starter shall be installed as for normal service; in particular, the conductors shall be connected in the same manner as for normal use.

During the test, there shall be no voltage or current in the main circuit. The device may be lubricated before the test if lubrication is prescribed in normal service.

6.101.2.2 Operating conditions

The coils of the control electro-magnets shall be supplied at their rated voltage and, if applicable, at their rated frequency.

If a resistance or impedance is provided in series with the coils, whether short-circuited or not during the movement, the tests shall be carried out with these elements connected as in normal operation.

6.101.2.3 Test procedure

The tests are carried out at the frequency of operations corresponding to the class of intermittent duty. However, if the manufacturer considers that the device can satisfy the required conditions when using a higher frequency of operations in order to reduce the duration of the tests.

The duration of energization of the control coil shall be greater than the time of operation of the device, and the time for which the coil is not energized shall be of such a duration that the device can come to rest at both extreme positions.

The number of operating cycles to be carried out shall be not less than the number of no-load operating cycles specified in 4.105.

The maintenance programme prescribed by the manufacturer shall be followed.

This maintenance work shall not include any replacement of parts.

6.101.2.4 Results to be obtained

Following the tests of mechanical endurance, the contactor or starter shall still be capable of complying with the operating conditions specified in 4.8 and 6.101.1. The integrity of the interrupting medium shall be confirmed by performing a condition test as specified in 6.2.11.

There shall be no loosening of the parts used for connecting the conductors.

The results of the interrupting medium integrity tests shall be included in the test report.

6.101.3 Interlocking tests

Subclause 6.102 of IEC 62271-200 is applicable to starters and controllers with the following modification to the first sentence of 6.102.2.

The interlock shall be set in the position intended to prevent the operation of the switching devices and the insertion or withdrawal of removable parts, or the simultaneous operation of two switching devices.

6.101.4 Test of the striker mechanism

- a) To test the mechanical reliability of the linkages between the fuse striker(s) and the indicator or release, a total of 100 operations shall be made with the appropriate type of striker, of which 90 shall be made (30 in each pole) with one striker of minimum energy and 10 with three strikers of maximum energy operating simultaneously.

After performing this test duty, the mechanical functioning of the linkages shall be practically the same as before the tests.

- b) Using a dummy fuse-link with an extended striker, set to the minimum actual travel within the tolerance specified in IEC 60282-1, for each pole in turn it shall be shown that the contactor either cannot be closed or cannot remain closed according to its design.

NOTE For the purpose of these tests, a device simulating fuse-striker operation may be used.

6.102 Verification of rated making and breaking capacity

6.102.1 General

The tests concerning the verification of the making and breaking capacities of a contactor are intended to verify that the device is capable of making and breaking the currents stated in Table 6.

Reversibility and change-over tests are applied to controllers, as appropriate.

NOTE Some interrupting technologies may have extended arcing times at currents of less than 0,2 of rated operational current. In such cases further investigation may be required to insure that the contactor will function satisfactorily for applications such as reversing and autotransformer controllers.

Table 6 – Verification of rated making and breaking capacities – Conditions for making and breaking corresponding to the several utilization categories at rated voltage U_r

Category	Make		Break			
			Minimum rated breaking current		Highest rated breaking current	
	I_m/I_e^a	$\cos\varphi^b$	I_c/I_e	$\cos\varphi^b$	I_c/I_e	$\cos\varphi^b$
AC-1	1,5	0,95	0,2	0,95	1,5	0,95
AC-2	4	0,65	0,2	0,65	4	0,65
AC-3	8	0,35	0,2	0,15	8	0,35
AC-4 ^c	10	0,35	0,2	0,15	8	0,35

I_e Rated operational current (see 4.101)
 I_m Making current
 I_c Breaking current

^a The conditions for making are expressed in r.m.s. values, but it is understood that the peak value of asymmetrical current, corresponding to the power factor of the circuit, may be a higher value than the peak of the rms current (see 4.103.1.1, Note).
^b Tolerance for $\cos\varphi$: $\pm 0,05$.
^c In the case of re-acceleration or plug braking, it should be noted that, at the instant of making, the voltage and current may be doubled.

The verifications of making and breaking capacity may be made as a combined test.

During each series of tests, oscillographic, or equivalent, records shall be taken of the first and last operation (see 4.103.1.1 and 4.103.1.2).

Throughout the tests, there shall be no permanent arcing, no flashover between poles, no blowing of the fuse in the earth circuit (see 6.102.2) and no welding of the contacts.

The tests are made solely with the current of the same kind as the service current specified. In particular, devices intended for use on three-phase loads shall be tested with three-phase current; single-phase tests of such devices are not covered by this standard and shall be the subject of a special agreement.

6.102.2 Condition for tests

The device under test shall be mounted complete on its own support or on an equivalent support. A device whose performance may be influenced by any enclosure in which it is mounted shall be tested in the same type of enclosure as that in which it will be installed.

Air-break contactors intended for open mounting or to be mounted with other apparatus in an enclosure having large dimensions with respect to the volume of the contactor shall, for the verification of the making and breaking capacities, be surrounded by an enclosure. This enclosure shall be fabricated from bare woven wire cloth or perforated mild steel sheet of a thickness to ensure reasonable rigidity. Individual apertures in the wire cloth or perforated steel sheet shall not exceed 100 mm² in area. The dimensions of the enveloping earthed enclosure shall be declared to indicate the proximity of earthed metal permitted in subsequent applications.

The connections to the main circuit and auxiliary control circuit shall be similar to those intended to be used when the device is in service.

For verification of the making and breaking capacities, all parts of the device normally earthed in service, including its enclosure, shall be connected to the neutral point of the supply or to a substantially inductive artificial neutral permitting a prospective fault current of at least 10 kA.

This connection shall include a reliable device (such as a fuse and current transformer combination) for the detection of the fault current and, if necessary, a resistor limiting the value of the prospective fault current to about 100 A.

6.102.3 Test circuit for the verification of rated making and breaking capacities

The power supply used for the verification of making and breaking capacities shall have sufficient power to permit the verification of the characteristics given in Table 6.

The test circuit is composed of the supply side and the load side. Earthing of the test circuit shall be in accordance with the requirements of 6.103.3 of IEC 62271-100: 2008.

The supply side TRV requirements shall be in accordance with the requirements of 6.104.5 of IEC 62271-100: 2008 for class S1. The load side shall be arranged to provide an amplitude factor and frequency of the TRV, on breaking, given by:

$$\text{Amplitude factor: } 1,4 \leq k_{af} \leq 1,6$$

$$\text{Frequency: } f \geq 2\,000 \times I_c^{0,2} \times U_r^{-0,8} \quad (\text{kHz})$$

where the values of I_c and U_r are in amperes and volts respectively (see Table 6).

The resistance and reactance of the test circuit shall be adjustable to satisfy the specified test conditions. The reactors shall be air-cored and shall be connected in series with the resistors, and their value shall be obtained by series coupling of individual reactors. Parallel connecting of reactors is permitted only when these reactors have practically the same time-constant. A shunt resistor may be connected across the terminals of the reactor arrangement.

The total impedance required to set the test current shall be distributed between the supply side and the load side of the device. However, the impedance on the supply side shall be not greater than 10 % of the total impedance of the test circuit. A load side amplitude factor in excess of 1,6, where required for test purposes, shall be subject to agreement by the manufacturer.

6.102.4 Verification of rated making capacity

The making current to be obtained during the test shall be as given in Table 6 for the appropriate utilization category.

The number of closing operations to be made is the following:

- a) for contactors or starters of utilization category AC-3 or AC-4, the number is 100, of which 50 operations are made at 85 % and 50 operations at 110 % of the rated coil voltage;
- b) for contactors or starters of any other utilization category than AC-3 or AC-4, the number is 20, of which 10 operations are made at 85 % and 10 operations at 110 % of the rated coil voltage.

The duration of the test current shall be not less than 50 ms (thereby exceeding the total bounce time, if any, of the contacts). The time interval between opening operations shall be recorded in the test report.

6.102.5 Verification of rated breaking capacity (minimum and maximum)

The breaking current to be obtained during the test shall be as given in Table 6 for the appropriate utilization category.

The total number of opening operations for each of the minimum and maximum break conditions shall be 25.

The duration of the test current shall be not less than 50 ms and the time interval between opening operations should be recorded in the test report.

The recovery voltage after each operation shall be maintained for at least 0,3 s

NOTE The duration of each current flow need not exceed 0,5 s.

6.102.6 Reversibility tests

In the case of a reversing starter, the following test shall be carried out in addition to the making and breaking capacity tests of 6.102.3 and 6.102.4. A new starter may be used for the verification of reversibility.

The test circuit shall be in accordance with 6.102.3, and the current to be obtained shall be as given in Table 6 for category AC-4.

The test comprises 10 operating sequences, each sequence comprising the two operating cycles described below:

- a) 1st cycle: close A – open A/close B – open B – 10 s to 30 s rest;
- b) 2nd cycle: close B – open B/close A – open A – 10 s to 30 s rest;

(where A and B are either the two mechanical switching devices of the starter or the two circuits of a single switching device).

These cycles are repeated alternately.

The use of a symbolic form such as "open A/close B" implies that the change-over operation concerned shall be made as fast as the normal control system will allow.

During the test, the starter shall be operated in the manner in which it is intended to be used in service, and any mechanical or electrical interlocking devices which are normally provided shall be in use.

6.102.7 Change-over ability tests

In the case of a two-step auto-transformer, the following test shall be carried out in addition to the making and breaking capacity tests of 6.102.3 and 6.102.4. A new starter may be used for the verification of change-over ability.

The test circuit shall be in accordance with 6.102.3 and the current to be obtained in the RUN position shall be as given in Table 6 for category AC-3. The current obtained in the STARTING position shall be as derived from the auto-transformer or reactor. When an auto-transformer or reactor has more than one output voltage or tap connection, it shall be connected to give the highest starting current.

The test comprises 10 operating sequences as follows:

- make the current in the STARTING position;
- transition to the RUN position;
- break the current in the RUN position;
- OFF time.

The ON time in the STARTING and RUN positions shall be not less than 0,05 s, and the OFF time shall not be greater than stated in Table 7.

The load circuit shall be connected to the starter as would be the windings of a motor. The RUN position is that in which the auto-transformer is not in effect, and the motor is connected directly to rated voltage (U_r). During the test, the starter shall be operated in the manner in which it is intended to be used in service, and any mechanical or electrical interlocking devices which are normally provided shall be in use.

Table 7 – Relationship between current broken I_c and OFF time

Current broken I_c A	OFF time s
$I_c \leq 100$	10
$100 < I_c \leq 200$	20
$200 < I_c \leq 300$	30
$300 < I_c \leq 400$	40
$400 < I_c \leq 600$	60
$600 < I_c \leq 800$	80

The OFF time values may be reduced if agreed by the manufacturer.

6.102.8 Behaviour during making, breaking, reversibility and change-over tests

During tests within the limits of specified making and breaking capacities, and with the specified number of operations, there shall be no permanent arcing, no flash-over between poles, no blowing of the fuse in the earth circuit (see 6.102.2) and no welding of the contacts.

6.102.9 Condition following making and breaking tests

The contactor shall, after performing the number of operations for rated making and breaking capacity (6.102.4 and 6.102.5), be capable of operating satisfactorily.

The contactor shall be inspected after any test-duty. Its mechanical parts and insulators shall be in essentially the same condition as before the test-duty. Visual inspection is usually sufficient for verification of the insulating properties. In case of doubt, the condition checking test according to subclause 6.2.11 of IEC 62271-1 is sufficient to prove the insulation properties.

In addition, the contactor shall be capable of carrying its normal current with a temperature rise not in excess of the temperature rise permitted by Table 3 of IEC 62271-1. If the condition of the contacts cannot be determined by visual inspection it will be necessary to perform an additional temperature-rise test.

For contactors with sealed for life interrupter units, the condition checking test is mandatory.

In the case of vacuum interrupters the condition check is by resistance. If the resistance across the terminals of the controller has changed by more than 20 % or if the resistance measurement is made across the terminals of the vacuum interrupters a 100 % increase of resistance is allowable.

Moderate wear of the parts of arc control devices exposed to the arc is permissible.

6.103 Overload current withstand tests

The overload current to be obtained during the tests shall be as given in Table 8, where I_e is selected for the appropriate utilization category.

The tests shall be performed, as three-phase tests, on a contactor or controller which has been closed by its normal means at the rated voltage of the closing device and held closed, or latched, for the duration of each test. The test voltage shall be sufficient to cause the required current to flow through all poles simultaneously for the specified duration.

Following these tests, the contactor or controller shall be capable of making and breaking its rated operational current at the rated voltage although its overload withstand performance may be impaired.

The main contacts shall be in such a condition, in particular with regard to burning, contact area, pressure and freedom of movement, that they are capable of carrying the rated operational current of the contactor or controller. The resistance of the main circuit shall be measured according to 6.4. If the resistance has increased by more than 20 %, and if it is not possible to confirm the condition of the contacts by visual inspection, it will be necessary to perform an additional temperature-rise test.

Table 8 – Overload current withstand requirements

Test current	Duration of the test s
$15 \times I_e$	1
$6 \times I_e$	30

6.104 Short-circuit current making and breaking tests

6.104.1 General

These tests shall be performed on contactors which are to be assigned a short-circuit capability for coordination with short-circuit protective devices.

6.104.2 Condition for test

The device under test shall be mounted complete on its own support or on an equivalent support. A device whose performance may be influenced by any enclosure in which it is mounted shall be tested in the same type of enclosure as that in which it will be installed.

Air-break contactors intended for open mounting or to be mounted with other apparatus in an enclosure having large dimensions with respect to the volume of the contactor shall, for the verification of the making and breaking capacities, be surrounded by an enclosure. This enclosure shall be fabricated from bare woven wire cloth or perforated mild steel sheet of a thickness to ensure reasonable rigidity. Individual apertures in the wire cloth or perforated steel sheet shall not exceed 100 mm² in area. The dimensions of the enveloping earthed enclosure shall be declared to indicate the proximity of earthed metal permitted in subsequent applications.

The connections to the main circuit and auxiliary control circuit shall be similar to those intended to be used when the device is in service.

For these tests, all parts of the device normally earthed in service, including its enclosure, shall be connected to the neutral point of the supply or to a substantially inductive artificial neutral permitting a prospective fault current of at least 100 A. This connection shall include a reliable device (such as a fuse and current transformer combination) for the detection of the fault current and, if necessary, a resistor limiting the value of the prospective fault current to about 100 A.

The operation voltage at the coil shall be 100 %.