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

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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: Switching devices, of IEC technical committee 17: High-voltage switchgear and controlgear.

This second edition cancels and replaces the first edition published in 2011. It constitutes a technical revision.

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

- document numbered to correspond to IEC 62271-1 2017.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
17A/1296/FDIS	17A/1301/RVD

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

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

This standard is to be read in conjunction with IEC 62271-1:2017. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses is used as in IEC 62271-1. Modifications to these clauses and subclauses are given under the same numbering, whilst additional subclauses are numbered from 101.

A 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 document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

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

1 Scope

This part of IEC 62271 applies to AC 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 kV and up to and including 24 kV. This document also includes additional requirements for outdoor installations where the equipment is housed in an additional protective enclosure.

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 document typically do not have adequate short-circuit interruption capability. In this context, this document gives requirements for:

– 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 document.

This document 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 document 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 document 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 60255-149.

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 62271-103.

The object of this document is to state:

a) the characteristics of contactors and starters and associated equipment;
b) the conditions with which contactors or starters 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.

2 Normative references

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

IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60068-2-1:2007, *Environmental testing – Part 2-1: Tests – Test A: Cold*

IEC 60068-2-2:2007, *Environmental testing – Part 2-2: Tests – Test B: Dry heat*

IEC 60068-2-30:2005, *Environmental testing – Part 2-30: Tests – Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60076-2, *Power transformers – Part 2: Temperature rise for liquid-immersed transformers*

IEC 60076-11:2018, *Power transformers – Part 11: Dry-type transformers*

IEC 60255-21-1:1988, *Electrical relays – Part 21: Vibration, shock, bump and seismic tests on measuring relays and protection equipment – Section One: Vibration tests (sinusoidal)*

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

IEC 60417, *Graphical symbols for use on equipment* (available at http://www.graphical-symbols.info/equipment)

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

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

IEC 61000-4-18:2019, *Electromagnetic compatibility (EMC) – Part 4-18: Testing and measurement techniques – Damped oscillatory wave immunity test*

IEC 61230, *Live working – Portable equipment for earthing or earthing and short-circuiting*

IEC 61812-1, *Time relays for industrial use and residential use – Part 1: Requirements and tests*

IEC 62271-1:2017, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and controlgear*

IEC 62271-100:2021, *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*

IEC 62271-102:2018, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

IEC 62271-110:2017, *High-voltage switchgear and controlgear – Part 110: Inductive load switching*

IEC 62271-200:2021, *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*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in Clause 3 of IEC 62271-1:2017, as well as the following, apply.

3.1 General terms and definitions

Subclause 3.1 of IEC 62271-1: 2017 applies with the following additions:

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

[SOURCE: IEC 60050-441:2000, 441-11-03]

3.1.102
overcurrent
current exceeding the rated current

[SOURCE: IEC 60050-441:2000, 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

[SOURCE: IEC 60050-441:2000, 441-11-07]

3.1.104
overload
operating conditions in an electrically undamaged circuit, which cause an over-current

[SOURCE: IEC 60050-441:2000, 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

[SOURCE: IEC 60050-441:2000, 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 1 to entry: For switching devices or fuses installed inside an enclosure, it is the temperature of the air outside the enclosure.

[SOURCE: IEC 60050-441:2000, 441-11-13]

3.2 Assemblies of switchgear and controlgear

Subclause 3.2 of IEC 62271-1: 2017 applies.

3.3 Parts of assemblies

Subclause 3.3 of IEC 62271-1: 2017 applies.

3.4 Switching devices

Subclause 3.4 of IEC 62271-1: 2017 applies with the following modifications.

3.4.101
switching device
device designed to make or break the current in one or more electric circuits

[SOURCE: IEC 60050-441:2000, 441-14-01]

3.4.102
mechanical switching device
switching device (such as a contactor or a disconnector) designed to close and open one or more electric circuits by means of separable contacts

[SOURCE: IEC 60050-441:2000, 441-14-02, modified: Note 1 to entry deleted.]

3.4.103
disconnector
mechanical switching device which provides, in the open position, an isolating distance in accordance with specified requirements

Note 1 to entry: A disconnector 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 disconnector 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 to entry: A withdrawable contactor assembly may be used as a disconnector.

Note 3 to entry: In North America, this device is also called an isolating means or an isolating switch.

[SOURCE: IEC 60050-441:2000, 441-14-05, modified: Note 2 and 3 added.]

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 1 to entry: An earthing switch may have a short-circuit making capacity.

[SOURCE: IEC 60050-441:2000, 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 1 to entry: Contactors may be designated according to the method by which the force for closing the main contacts is provided.

[SOURCE: IEC 60050-441:2000, 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
SF_6 contactor
contactor in which the main contacts open and close within an SF_6 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 1 to entry: The latching, and the release of the latching, may be mechanical, electromagnetic, pneumatic, etc.

[SOURCE: IEC 60050-441:2000, 441-14-34, modified: Note 2 to entry deleted.]

3.4.110
starter
combination of all the switching means necessary to start and stop a motor in combination with suitable overload protection

[SOURCE: IEC 60050-441:2000, 441-14-38, modified: Note 1 to entry deleted.]

3.4.110.1
direct-on-line starter
starter which connects the line voltage across the motor terminals in one step

[SOURCE: IEC 60050-441:2000, 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 1 to entry: 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 1 to entry: 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.

[SOURCE: IEC 60050-441:2000, 441-14-42, modified: Note 1 to entry added.]

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

[SOURCE: IEC 60050-441:2000, 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 to entry: 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 to entry: 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 to entry: A three-step rheostatic starter has two sections of resistors used for starting.

[SOURCE: IEC 60050-441:2000, 441-14-41]

3.4.111
controller
combination starter
equipment consisting of a contactor, overload protection, a disconnector and a short-circuit protective device (SCPD), mounted and wired in one common enclosure

Note 1 to entry: A controller may be used for functions other than motor starting, for example transformer control and protection, or capacitor control.

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 1 to entry: 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

3.4.114
contactor class C2
contactor with a very low probability of restrike during capacitive current breaking as demonstrated by type tests

3.5 Parts of switchgear and controlgear

Subclause 3.5 of 62271-1:2017 applies with the following modifications:

3.5.101 Parts of contactors, starters and controllers

3.5.101.1
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 1 to entry: 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.

[SOURCE: IEC 60050-441:2000, 441-15-01]

3.5.101.2
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

[SOURCE: IEC 60050-441:2000, 441-15-02]

3.5.101.3
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

[SOURCE: IEC 60050-441:2000, 441-15-03]

3.5.101.4
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 1 to entry: 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.

[SOURCE: IEC 60050-441:2000, 441-15-04]

3.5.101.5
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

[SOURCE: IEC 60050-441:2000, 441-15-07]

3.5.101.6
control contact
contact included in a control circuit of a mechanical switching device and mechanically operated by this device

[SOURCE: IEC 60050-441:2000, 441-15-09]

3.5.101.7
auxiliary contact
contact included in an auxiliary circuit and mechanically operated by the switching device

[SOURCE: IEC 60050-441:2000, 441-15-10]

3.5.101.8
"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

[SOURCE: IEC 60050-441:2000, 441-15-12]

3.5.101.9
"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

[SOURCE: IEC 60050-441:2000, 441-15-13]

3.5.110 Fuses

3.5.110.1
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

Note 1 to entry: Fuses are commonly used as the SCPD in starts and controllers (3.4.112).

[SOURCE: IEC 60050-441:2000, 441-18-01]

3.5.110.2
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

[SOURCE: IEC 60050-441:2000, 441-18-18]

3.5.110.3
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

[SOURCE: IEC 60050-441:2000, 441-18-21]

3.5.110.4
operating time
total clearing time
sum of the pre-arcing time and the arcing time

[SOURCE: IEC 60050-441:2000, 441-18-22]

3.5.110.5
Joule integral
$\boldsymbol{I^2t}$
integral of the square of the current over a given time interval:

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

Note 1 to entry: The pre-arcing I^2t is the I^2t integral extended over the pre-arcing time of the fuse.

Note 2 to entry: The operating I^2t is the I^2t integral extended over the operating time of the fuse.

Note 3 to entry: 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 A^2s.

[SOURCE: IEC 60050-441:2000, 441-18-23]

3.5.112
extendable power bus
main power bus

that portion of the power bus that is capable of being extended to connect two or more vertical sections or controllers

3.6 Operational characteristics of switchgear and controlgear

Subclause 3.6 of IEC 62271-1: 2017 applies with the following modifications:

3.6.101
operation <of a mechanical switching device>
transfer of the moving contact(s) from one position to an adjacent position

Note 1 to entry: For a circuit-breaker, this can be a closing operation or an opening operation.

Note 2 to entry: 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.

[SOURCE: IEC 60050-441:2000, 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 to entry: This may be a closing operation followed by an opening operation.

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

[SOURCE: IEC 60050-441:2000, 441-16-02, modified: Notes 1 and 2 added.]

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

[SOURCE: IEC 60050-441:2000, 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

[SOURCE: IEC 60050-441:2000, 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

[SOURCE: IEC 60050-441:2000, 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

[SOURCE: IEC 60050-441:2000, 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

[SOURCE: IEC 60050-441:2000, 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 1 to entry: 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 1 to entry: 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 1 to entry: 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 1 to entry: 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

Subclause 3.7 of 62271-1: 2017 applies with the following additions:

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

[SOURCE: IEC 60050-441:2000, 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 to entry: The voltage to be stated and the conditions to be prescribed are dealt with in the relevant publications.

Note 2 to entry: 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.

[SOURCE: IEC 60050-441:2000, 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 1 to entry: The voltage to be stated and the conditions to be prescribed are dealt with in the relevant specifications.

[SOURCE: IEC 60050-441:2000, 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

[SOURCE: IEC 60050-441:2000, 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 1 to entry: 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.

[SOURCE: IEC 60050-441:2000, 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 to entry: 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 to entry: 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.

[SOURCE: IEC 60050-441:2000, 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 1 to entry: 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.

[SOURCE: IEC 60050-441:2000, 441-17-29]

3.7.108
power frequency recovery voltage
recovery voltage after the transient voltage phenomena have subsided

[SOURCE: IEC 60050-441:2000, 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

[SOURCE: IEC 60050-441:2000, 441-17-01, modified: Note 1 to entry deleted.]

3.7.110
prospective peak current
peak value of a prospective current during the transient period following initiation

Note 1 to entry: 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.

[SOURCE: IEC 60050-441:2000, 441-17-02]

3.7.111
maximum prospective peak current <of an AC circuit>
prospective peak current when initiation of the current takes place at the instant which leads to the highest possible value

Note 1 to entry: For a multiple device in a polyphase circuit, the maximum prospective peak current refers to a single pole only.

[SOURCE: IEC 60050-441:2000, 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 1 to entry: 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.

[SOURCE: IEC 60050-441:2000, 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

[SOURCE: IEC 60050-441:2000, 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

Note 1 to entry: 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.

[SOURCE: IEC 60050-441:2000, 441-17-12]

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

[SOURCE: IEC 60050-441:2000, 441-17-16, modified: “the time current characteristics of two over-current protective devices” was replaced by: “the release initiated opening time of the contactor and the time-current characteristic of the SCPD”.]

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 1 to entry: 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 1 to entry: 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

[SOURCE: IEC 60050-441:2000, 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

[SOURCE: IEC 60050-441:2000, 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

[SOURCE: IEC 60050-441:2000, 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 1 to entry: This term may be qualified by prefixing it with "minimum" or "maximum" depending upon the opening time and the arcing time used.

3.7.127
thermal current
current assigned for a specific time by the manufacturer on the basis of information gained from “temperature rise” tests and can be higher or lower than the continuous current ratings

3.7.128
operational current
current stated by the manufacturer and takes into account the rated voltage, the rated frequency, the rated duties, the utilization category and the type of protective enclosure

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4 Normal and special service conditions

4.1 Normal service conditions

4.1.1 General

Subclause 4.1.1 of IEC 62271-1:2017 applies.

4.1.2 Indoor switchgear and controlgear

Subclause 4.1.2 of IEC 62271-1:2017 applies.

4.1.3 Outdoor switchgear and controlgear

Subclause 4.1.3 of IEC 62271-1:2017 applies with the following modifications.

Starters and controllers are designed for indoor installation; typically, for outdoor installations this equipment is housed in an additional protective enclosure, refer to 9.102.6.

4.2 Special service conditions

4.2.1 General

Subclause 4.2.1 of IEC 62271-1:2017 applies.

4.2.2 Altitude

Subclause 4.2.2 of IEC 62271-1:2017 applies with the following addition:

Above 1 000 m and below sea level it is often necessary to make adjustments to the contactor. See 9.102.7.

4.2.3 Exposure to pollution

Subclause 4.2.3 of IEC 62271-1:2017 applies.

4.2.4 Temperature and humidity

Subclause 4.2.4 of IEC 62271-1:2017 applies.

4.2.5 Exposure to abnormal vibrations, shock or tilting

Subclause 4.2.5 of IEC 62271-1:2017 applies.

4.2.6 Wind speed

Subclause 4.2.6 of IEC 62271-1:2017 applies.

4.2.7 Other parameters

Subclause 4.2.7 of IEC 62271-1:2017 applies.

5 Ratings

5.1 General

Subclause 5.1 of IEC 62271-1: 2017 applies with the following additions and exceptions.

A contactor, starter or controller when installed, maintained and adjusted for normal service condition 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 can 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)	5.2	X	X	X
b) Rated insulation levels (U_d, U_p, U_s)	5.3	X	X	X
c) Rated frequency (f_r)	5.4	X	X	X
d) Rated continuous current (I_r)	5.5			X
e) Rated operational current (I_e) or rated operational power	5.101	X	X	
f) Rated short-time withstand current (I_k)	5.6	X	X	X
g) Rated peak withstand current (I_p)	5.7	X	X	X
h) Rated duration of short-circuit (t_k)	5.8	X	X	X
i) Rated short-circuit breaking current (I_{sc})	5.107			X
j) Rated short-circuit making current (I_{ma})	5.107			(X)
k) Rated duties	5.102	X	X	X
l) Rated load and overload characteristics, by utilization category	5.103, 5.104	X	X	X
m) Rated supply voltage of operating devices, and of auxiliary and control circuits (U_a)	5.9	X	X	X
n) Rated supply frequency of operating devices and of auxiliary circuits (f_a)	5.10	X	X	X
o) Rated pressure of compressed gas supply for insulation and/or operation	5.11	X	X	
(B) *Characteristics to be given on request*				
a) Thermal current (I_{th})	9.102.5	X	X	X
b) Electrical endurance	5.106	X		
c) Coordination with short-circuit protective devices	5.107	X	X	X
d) Damage classification	5.107.2.3	X	X	X
e) Short-circuit breaking capacity	5.107, 7.104	X	X	
f) Short-circuit making capacity	5.107, 7.104	X	X	
g) Motor switching characteristics	7.108	X		
h) Take-over current for release-operated controller	5.107.2.2			X
i) Rated capacitive switching current	5.112	X		X
(C) *Characteristics dependent on starter type*				
a) Automatic change-over devices and automatic acceleration control devices	5.108		X	X
b) Starting auto-transformer or reactor characteristics	5.109		X	X
c) Starting resistor characteristics	5.110		X	X
X: applicable for this configuration				
(X): applicable, but see 5.102.2 regarding intermittent duty				

5.2 Rated voltage (U_r)

Subclause 5.2 of IEC 62271-1: 2017 does not apply.

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.

Contactors or starters that are part of a controller or a switchgear or controlgear assembly shall have a rated voltage that is greater or equal to that of the assembly.

5.2.101 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 up to 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.

5.2.102 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.

5.2.103 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.

5.3 Rated insulation level (U_d, U_p, U_s)

Subclause 5.3 of IEC 62271-1:2017 applies with the following modifications.

a) The insulation levels for systems rated 2,5 kV are those defined for 3,6 kV rated voltage and for systems rated 5,0 kV are those defined for 7,2 kV rated voltage;

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

When the contactors or starters are part of a controller, switchgear or controlgear assembly, the rated insulation level is the one of the assembly.

5.3.101 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.

5.4 Rated frequency (f_r)

Subclause 5.4 of IEC 62271-1:2017 does not apply.

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.

5.5 Rated continuous current (I_r)

Subclause 5.5 of IEC 62271-1:2017 applies.

NOTE The term continuous current replaces the term thermal current which was used in the former editions.

A rated continuous current is normally not assigned to the contactor or starter, however maximum (operational) currents maybe assigned to them. See 5.101.

When contactors or starters are combined into larger assemblies, the rated continuous current of the connecting busbars shall be in accordance with IEC 62271-200. The connecting busbars are sometime referred to as "extendable bus".

See also thermal current (3.7.127).

5.6 Rated short-time withstand current (I_k)

Subclause 5.6 of IEC 62271-1:2017 applies with the following addition.

For a contactor, or starter, this is the RMS 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 RMS value of current.

5.7 Rated peak withstand current (I_p)

Subclause 5.7 of IEC 62271-1:2017 applies.

5.8 Rated duration of short-circuit (t_k)

Subclause 5.8 of IEC 62271-1:2017 applies 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.

5.9 Rated supply voltage of auxiliary and control circuits (U_a)

Subclause 5.9 of IEC 62271-1:2017 applies with the following additions.

5.9.1 General

Subclause 5.9.1 of IEC 62271-1 applies with the following addition.

The auxiliary and control circuits of contactors or starters that are part of a controller or a switchgear or controlgear assembly may have a rated voltage that is different from that of the assembly. The auxiliary circuits of contactors or starters are designed to operate at specific ranges and may not operate properly at higher or lower voltages (see 6.4). The manufacturer of the devices shall be consulted.

5.9.2 Rated supply voltage (U_a)

Subclause 5.9.2 of IEC 62271-1:2017 applies with the following additions.

A single-phase control supply voltage of 110 VAC is recognized in addition to those in Table 7 of IEC 62271-1:2017.

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

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

NOTE 1 Drop-out voltage is the voltage below which the contactor changes state.

NOTE 2 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 AC coils, the voltage limits apply at rated frequency.

5.10 Rated supply frequency of auxiliary and control circuits (f_a)

Subclause 5.10 of IEC 62271-1:2017 applies.

5.11 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 5.11 of IEC 62271-1:2017 applies.

5.101 Rated operational current or operational power

5.101.1 Rated operational current (I_e) or operational power

A rated operational current of a contactor or starter is stated by the manufacturer and takes into account the rated voltage (see 5.2), the rated frequency (see 5.4), the rated duties (see 5.102), the utilization category (see 5.104) 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.

5.101.2 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 5.2.101), the rotor thermal current, the rated frequency (see 5.4), the rated duty (see 5.102), the starting characteristics (see 5.111) 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.

5.102 Rated duties of a contactor or starter

5.102.1 Continuous duty

Duty in which the main contacts remain closed when carrying a continuous current without interruption for a period sufficient to reach thermal equilibrium without exceeding allowable temperature rise limits per 5.5.

5.102.2 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 temperature rise limits.

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.

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.

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

Special consideration should be given to autotransformer and reactor starters. See 5.109.

5.102.3 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 the temperature rise limits, 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.

5.103 Rated load and overload characteristics

5.103.1 Rated making and breaking capacities

5.103.1.1 General

A contactor or starter is defined by its making capacities and breaking capacities, as specified in Table 6, in accordance with utilization categories (see 5.104). For requirements when used in combination with short-circuit protective devices see 5.107.

5.103.1.2 Rated making capacity

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, and is expressed by the RMS value of the AC component of the current.

5.103.1.3 Rated breaking capacity

The rated breaking capacity is stated by reference to the rated voltage, rated operational current and to the utilization category, according to Table 6, and is expressed by the RMS value of the AC component of the current.

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

5.103.2 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 7.103.

5.104 Utilization category

The utilization categories as given in Table 2 are considered standard in this document. 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.

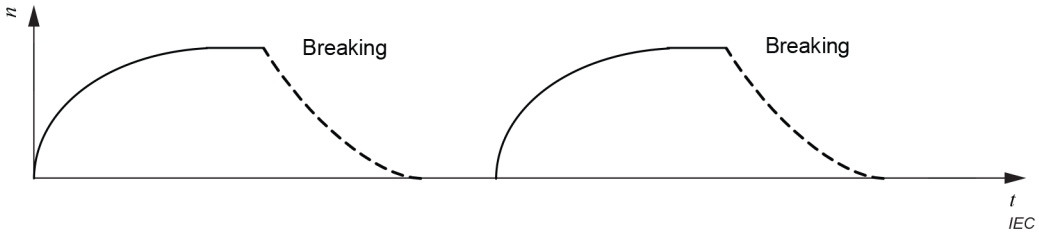
All two-step auto-transformer and reactor starters belong to utilization category AC-3.

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

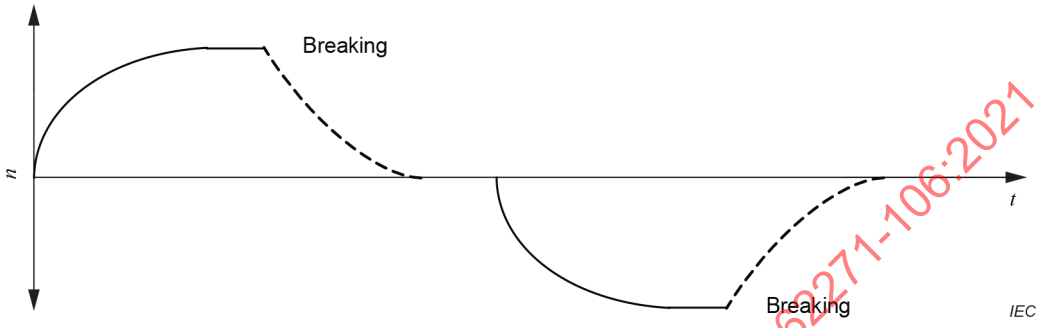
Table 2 – Utilization categories

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
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.	

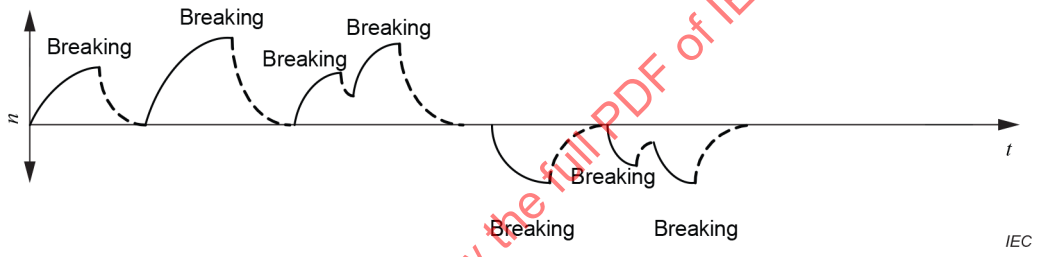
Typical service conditions for starters (see Figure 1) are:



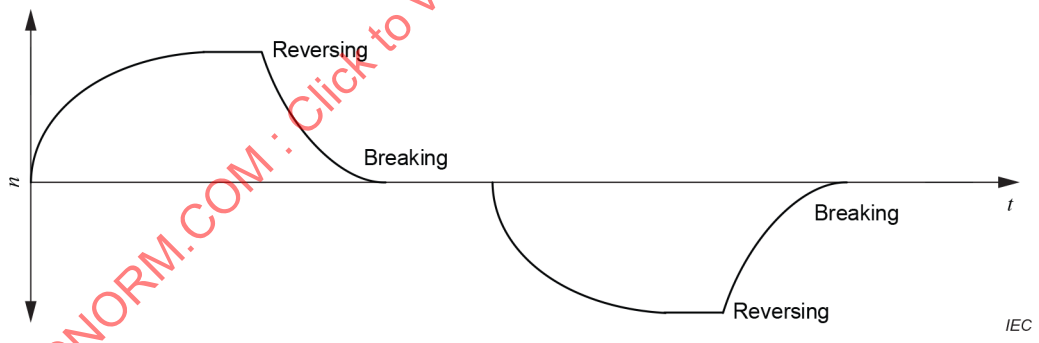
Case a)



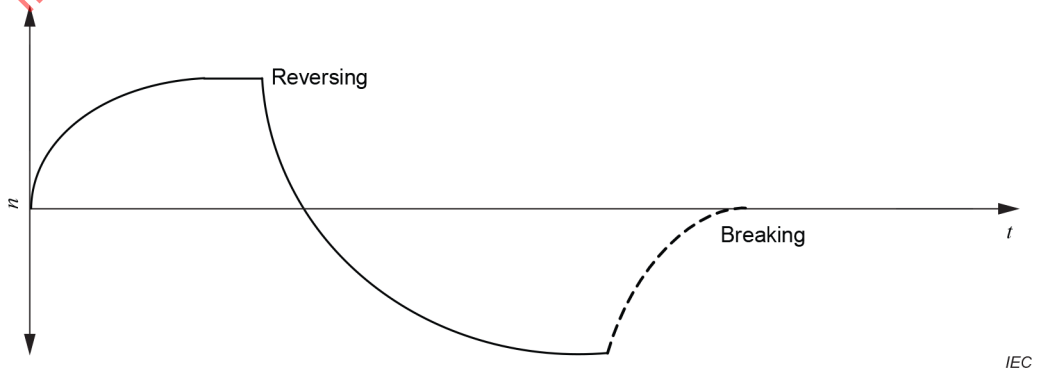
Case b)



Case c) and d)



Case e)



Case f)

Figure 1 – Examples of speed/time curves

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.

5.105 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.

In case of a controller, the mechanical endurance depends on the components of the controller; however, the minimum for major components are as stated here. A contactor of a controller shall operate in its intended manner without load for a minimum of 10 000 operations. The isolation means of a controller shall operate in its intended manner without load for a minimum of 1 000 operations.

5.106 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 7.107).

5.107 Rated short-circuit making and breaking currents – Coordination with short-circuit protective devices (SCPD)

5.107.1 General

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 7.6, 7.104 and 7.106.

5.107.2 Rated short-circuit of contactors or starters without SCPD

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;
– short time withstand current test and peak withstand current test 7.6 and short-circuit making and breaking tests 7.105 apply.

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

5.107.3 Rated short-circuit of contactors, starters, and controllers with SCPD

5.107.3.1 General

Controllers are required to have an SCPD.

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 5.107.2);
– rated short-circuit breaking current (I_{sc});
– rated short-circuit making current (I_{ma}).

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,
– the maximum voltage the SCPD can withstand during interruption.

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 document, 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 document, in a circuit having a power frequency voltage corresponding to the rated voltage of the controller.

The verification of coordination of SCPD is carried out according to 7.106.

NOTE 1 It is recognized that the series impedance of the combination or rapid operation of the fuses or switch can 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 can comply with more than one type of coordination for different values of the rated short-circuit current.

5.107.3.2 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 or AC-4 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.

5.107.3.3 Take-over current for release-operated controllers

The value of the three-phase symmetrical current used for test duty C (see 7.107.3.4). Figure 9 gives an example of calculating the take-over current.

5.107.3.4 Coordination and acceptable damage classification

For currents exceeding the maximum take-over current of the starter as defined in 7.107.3.4, 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 7.107.

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 document.

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.

5.108 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.

5.109 Reduced-voltage starting auto-transformers or reactors

5.109.1 Types and characteristics of starting auto-transformers or reactors

Account being taken of the starting characteristics (see 5.111), 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 5.102);
– 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.

5.109.2 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:

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;

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.

5.110 Types and characteristics of starting resistors for rheostatic rotor starters

Account being taken of the starting characteristics (see 5.111), 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 5.102);

– 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.

5.111 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	Locked rotor current	U_{tap} [c]
				Start time	No./h				T_{lr} [b]	I_{lr}	
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 5.101.2).

U_{ro} Rated rotor voltage (see 5.2.101).

U_{tap} Tap voltage (see 5.2.102 for auto-transformers and 5.2.103 for reactors).

[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 5.109.2, 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.

5.112 Rated capacitive switching currents

5.112.1 General

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 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 7.110.

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

NOTE 3 No rating or preferred values are defined. This is because inrush currents associated with single capacitor banks are not considered critical.

5.112.2 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 document. 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.

5.112.3 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 document.

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.

5.112.4 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.

6 Design and construction

6.1 Requirements for liquids in contactors, starters and controllers

Subclause 6.1 of IEC 62271-1:2017 applies.

6.2 Requirements for gases in contactors, starters and controllers

Subclause 6.2 of IEC 62271-1:2017 applies.

6.3 Earthing of contactors, starters and controllers

Subclause 6.3 of IEC 62271-1:2017 applies with the following additions.

6.3.101 Earthing of the main circuit

Subclause 6.3.101 of IEC 62271-200:2021 applies with the following additions:

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

6.3.102 Earthing of the enclosure

Subclause 6.3.102 of IEC 62271-200:2021 applies.

6.3.103 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 electrically 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).

6.4 Auxiliary and control equipment and circuits

Subclause 6.4 of IEC 62271-1:2017 applies with the following modification.

For the operating voltage of main, auxiliary and control devices, see 5.9.

6.5 Dependent power operation

Subclause 6.5 of IEC 62271-1: 2017 applies with the following modification.

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 5.9. If maximum closing and opening times are stated by the manufacturer, these shall not be exceeded.

As a result of loss of the energy supply or the re-application of the energy supply after a loss of energy the main contacts of a contactor or starter arranged for dependent power operation may open or close.

6.6 Stored energy operation

Subclause 6.6 of IEC 62271-1:2017 applies.

6.7 Independent unlatched operation (independent manual or power operation)

Subclause 6.7 of IEC 62271-1:2017 applies.

6.8 Manually operated actuators

Subclause 6.8 of IEC 62271-1:2017 applies.

6.9 Operation of releases

See 6.4 for the basis of operation limits with respect to supply voltage.

Subclauses 6.9.1 to 6.9.5 of IEC 62271-1:2017 apply with the following addition.

For types and characteristics of relays and releases, see 6.101.

NOTE In the remainder of this document, the term overload relay applies equally to an overload relay or an overload release as appropriate.

6.10 Pressure/level indication

Subclause 6.10 of IEC 62271-1:2017 applies.

6.11 Nameplates

Subclause 6.11 of IEC 62271-1:2017 applies 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.

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.

Rated operational currents or rated operational powers (see 5.101) 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.

For controllers

a) Manufacturer's name or trade mark and place of assembly;
b) Type designation;
c) Date of manufacture or serial number;
d) Altitude, if other than 0 m to 1 000 m;
e) Rated maximum voltage (U_r);
f) Rated power frequency (f_r), for example ~ 50 Hz
g) Rated continuous current (I_r);
h) Rated power frequency voltage (U_d);
i) Rated impulse withstand voltage (U_p);
j) Rated peak withstand current (I_p);

For starters and/or contactors

a) Manufacturer's name or trade mark and place of assembly;
b) Type designation;
c) Date of manufacture or serial number;
d) Altitude, if other than 0 m to 1 000 m;
e) Rated voltage (U_r);
f) Rated frequency (f_r), for example ~ 50 Hz;
g) Rated operational current (I_e) or power (see 5.101);

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

h) rated coil voltage;

i) either the indication "DC" (or the symbol ⎓) or value of the rated frequency, for example ~ 50 Hz;

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

j) rated capacitive switching current and class, if applicable.

6.12 Locking devices

Subclause 6.12 of IEC 62271-1: 2017 applies with the following addition.

Further requirements for interlocking of a controller are specified in 6.12 of IEC 62271-200:2021. 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.

6.13 Position indication

Where position indicators are required, 6.13 of IEC 62271-1:2017 applies.

6.14 Degrees of protection provided by enclosures

Subclause 6.14 of IEC 62271-1:2017 applies.

6.15 Creepage distances for outdoor insulators

Subclause 6.15 of IEC 62271-1:2017 does not apply.

6.16 Gas and vacuum tightness

Subclause 6.16 of IEC 62271-1:2017 applies.

6.17 Liquid tightness

Subclause 6.17 of IEC 62271-1:2017 applies.

6.18 Fire hazard (flammability)

Subclause 6.18 of IEC 62271-1:2017 applies.

6.19 Electromagnetic compatibility (EMC)

Subclause 6.19 of IEC 62271-1:2017 applies 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.

6.20 X-ray emission

Subclause 6.20 of IEC 62271-1:2017 applies.

6.21 Corrosion

Subclause 6.21 of IEC 62271-1:2017 applies.

6.22 Filling levels for insulation, switching and/or operation

Subclause 6.22 of IEC 62271-1:2017 applies.

6.101 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.

6.102 Enclosures

For metal-enclosed contactors, starters and controllers, subclause 6.102 of IEC 62271-200:2021 applies. This does not apply to contactors or starters that are not provided with enclosures.

6.103 Controllers

Controllers shall be designed to make and break any current up to and including the rated short circuit making and breaking current at the maximum rated voltage.

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

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.

6.105 Starters

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 capable of making the rated short-circuit making current at the rated voltage.

Starters shall be capable of breaking the rated breaking capacity of the contactor at the required recovery voltage.

For currents higher than the rated breaking capacity of the contactor, proper coordination with external overcurrent protective devices is provided.

7 Type tests

7.1 General

Clause 7 of IEC 62271-1:2017 applies with the following additions.

Annex E of IEC 62271-1: 2017 applies except for test tolerances, Table E.1 is replaced by Table E.101 of this document.

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

– mechanical endurance tests (see 7.102);
– making and breaking and reversibility tests (see 7.103);
– overload current withstand tests (see 7.104);
– short-circuit current making and breaking tests (see 7.105);
– verification of operating limits and characteristics of overload relays (see 7.106);
– change-over ability and reversibility, where applicable (see 7.103.6 and 7.103.7);
– tests of the striker mechanism (see 7.102.4).

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

– verification of coordination with SCPDs (see 7.107);
– electrical endurance tests (see 7.108);
– motor switching tests (see 7.109);
– capacitive switching tests (see 7.110).

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 document; 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 document;
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 ± 10 %, unless otherwise specified in the relevant subclauses.

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 AA.

Table 4 – Applicable type tests

Test	Contactor	Starter	Controller	Subclause
Dielectric tests	X	X	X	7.2
Resistance measurements	X	X	X	7.4
Continuous current test[a]	X	X	X	7.5
Short-time and peak withstand current test[ab]	X	X	X	7.6
Verification of the protection	–	X	X	7.7
Tightness tests	X	–	–	7.8
EMC tests	X	X	X	7.9
Additional test on auxiliary and control circuits	X	X	X	7.10
X-radiation test for vacuum interrupters	X	X	X	7.11
Verification of operating limits	X	X	X	7.102.1
Mechanical endurance test[ab]	X	X	X	7.102.2
Interlocking tests	–	X	X	7.102.3
Rated making and breaking capacity tests[ab]	X	–	–	7.103
Reversibility tests [ab]	–	X	X	7.103.6
Change-over ability tests [ab]	–	X	X	7.103.7
Overload current withstand tests[ab]	X	–	–	7.104
Short-circuit current making and breaking tests [ab]	X	–	–	7.105
Verification of operating limits of overload relays	–	X	X	7.106
Coordination with SCPD [ab]	–	–	X	7.107
Electrical endurance tests [ab]	X	–	–	7.108
Motor switching tests [ab]	X	–	–	7.109
Capacitive switching test [ab]	X	–	–	7.110
Tests on the striker mechanism	–	–	X	7.102.4

X: applicable to this configuration.

[a] These tests require resistance measurements before and after the test.

[b] These tests require power frequency test after the test.

7.2 Dielectric tests

Subclause 7.2 of IEC 62271-1:2017 applies with the following additions and modifications.

7.2.1 General

Subclause 7.2.1 of IEC 62271-1:2017 applies.

7.2.2 Ambient air conditions during tests

Subclause 7.2.2 of IEC 62271-1:2017 applies.

7.2.3 Wet test procedure

Subclause 7.2.3 of IEC 62271-1:2017 does not apply.

7.2.4 Arrangement of equipment (conditions of contactors, starters and controllers during dielectric tests)

Subclause 7.2.4 of IEC 62271-1:2017 applies with the following addition.

The dielectric tests shall be made with components giving the most onerous dielectric conditions. If an earthing switch is to be offered it shall be included in the test samples.

7.2.5 Criteria to pass the test

Subclause 7.2.5 of IEC 62271-1:2017 applies.

7.2.6 Application of the test voltage and test conditions

Subclause 7.2.6 of IEC 62271-1:2017 applies with the following addition.

Impulse tests across open contacts are not required for contactors.

7.2.6.1 General

Subclause 7.2.6.1 of IEC 62271-1:2017 applies.

7.2.6.2 General case

Subclause 7.2.6.2 of IEC 62271-1:2017 applies with the following additions: for impulse tests, only test conditions 1, 2, and 3 of Table 10 of IEC 62271-1:2017 are only applicable for the contactor.

7.2.6.3 Special case

Subclause 7.2.6.3 of IEC 62271-1:2017 does not apply.

7.2.7 Tests of contactors and starters of $U_r \leq 245$ kV

Subclause 7.2.7 of IEC 62271-1:2017 applies.

7.2.8 Tests of contactors and starters of $U_r > 245$ kV

Subclause 7.2.8 of IEC 62271-1:2017 does not apply.

7.2.9 Artificial pollution tests for outdoor insulators

Subclause 7.2.9 of IEC 62271-1:2017 does not apply.

7.2.10 Partial discharge tests

Subclause 7.2.10 of IEC 62271-1:2017 applies. Partial discharge test are not required.

7.2.11 Dielectric tests on auxiliary and control circuits

Subclause 7.2.11 of IEC 62271-1:2017 applies.

7.2.12 Voltage test as condition check

Subclause 7.2.12 of IEC 62271-1:2017 applies.

7.3 Radio interference voltage (RIV) test

Subclause 7.3 of IEC 62271-1:2017 does not apply.

7.4 Resistance measurement

Subclause 7.4 of IEC 62271-1:2017 applies with the following addition.

7.4.1 Measurement of the resistance of auxiliary circuits class 1 and class 2

Subclause 7.4.1 of IEC 62271-1:2017 does not apply.

7.4.2 Measurement of the resistance of auxiliary circuits class 3

Subclause 7.4.2 of IEC 62271-1:2017 does not apply.

7.4.3 Electrical continuity of earthed metallic part test

Subclause 7.4.3 of IEC 62271-1:2017 applies.

7.4.4 Resistance measurement of contacts and connections in the main circuit as a condition check

Subclause 7.4.4 of IEC 62271-1:2017 applies with the following addition.

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.

7.5 Continuous current tests

7.5.1 Conditions of the test object (contactors and starters)

Subclause 7.5.1 of IEC 62271-1:2017 applies.

7.5.2 Arrangement of the equipment

Subclause 7.5.2 of IEC 62271-1:2017 applies 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.

7.5.3 Test current and duration

Subclause 7.5.3.1 of IEC 62271-1:2017 applies. Subclause 7.5.3.2 of IEC 62271-1:2017 does not apply.

7.5.4 Temperature measurement during test

Subclause 7.5.4 of IEC 62271-1:2017 applies 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 14 of IEC 62271-1:2017:

– 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 62271-1:2017 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 7.4);

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.

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

7.5.5 Resistance of the main circuit

Subclause 7.5.5 of IEC 62271-1:2017 applies.

7.5.6 Criteria to pass test

Subclause 7.5.6 of IEC 62271-1:2017 applies with the following additions.

IEC 62271-1: 2017, Table 14 applies and, and for fuses, IEC 60282-1 applies.

The temperature rise of any part of the switchgear and controlgear at an ambient air temperature not exceeding 40 °C shall not exceed the temperature-rise limits specified in Table 14 under the conditions specified in the test clauses.

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 guide for selection (Clause 9).

A contactor or starter is also defined by its rated operational currents or rated operational power. See 5.101.

7.5.6.101 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 5.102.2)	One close-open operating cycle every s	Interval of time during which the supply of the control coil of electrically held contactors is maintained s
12	300	180
30	120	72
120	30	18
300	12	7,2

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

NOTE 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 5.102.2).

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 62271-1:2017.

7.5.6.102 Temperature-rise tests of auxiliary circuits

The temperature-rise tests of auxiliary circuits are made under the same conditions as those provided in 7.5.6.101.

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 can be of significance, these temperature-rise tests are made simultaneously.

7.5.6.103 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 5.102) and according to its characteristics dependent on starter type (see 5.111).

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 5.102 and 5.111); 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 62271-1:2017. 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.

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 document.

7.5.6.104 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 60076-11:2018), increased by 15 K (see 9.103.1), when the starter is operated at its rated duty (see 5.102). 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:

$$0{,}8 \times \frac{\text{starting voltage}}{U_e}$$ for a duration of 30 s (see 5.2.102).

The operating test cycle shall be per the duty cycles defined in 5.109.2.

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.

7.6 Short-time withstand current and peak withstand current tests

Subclause 7.6 of IEC 62271-1:2017 applies with the following modifications.

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 7.104.

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 5.107.3.4.

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

Tests shall be performed on the extendable (main) bus of controller assemblies. Subclause 7.6 of IEC 62271-200:2021 applies.

7.7 Verification of the protection

Subclause 7.7 of IEC 62271-1:2017 applies.

7.8 Tightness tests

Subclause 7.8 of IEC 62271-1:2017 applies.

7.9 Electromagnetic compatibility tests (EMC)

Subclause 7.9 of IEC 62271-1:2017 applies.

7.10 Additional tests on auxiliary and control circuits

Subclause 7.10 of IEC 62271-1:2017 applies.

7.11 X-radiation test for vacuum interrupters

Subclause 7.11 of IEC 62271-1: 2017 applies.

7.101 Additional tests required for contactors and contactor based equipment

Resistance measurements shall be made on the main circuit of the equipment under test and also on the main circuit of the contactor in the equipment under test in accordance with 7.4. This test shall be done before and after each test where indicated in the test subclauses. After each test the resistance of the main circuit of the equipment shall not increase by more than 20 %, and the resistance of the contactor shall not increase by more than 100 %, of the original resistance measured before the test.

If the resistance exceeds the allowable increase the contactor shall be subjected to a temperature rise test (see 7.5 for continuous current test of the main circuit). Temperatures measured during this test shall not exceed the temperature rise permitted by Table 14 of IEC 62271-1:2017 by more than 15°.

The voltage test as condition check in 7.2.12 shall be done after each test where indicated in the test subclauses.

The results shall be used as condition assessments for acceptance.

7.102 Mechanical tests

7.102.1 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 5.9 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 starter destined for installation at high altitude, it may be necessary to make adjustments to the mechanism to achieve correct operation. Refer to 9.102.7.

7.102.2 Mechanical endurance tests (contactor, starter or controller)

7.102.2.1 Condition for tests

The contactor, starter, or controller 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.

7.102.2.2 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.

7.102.2.3 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 5.105.

The maintenance programme prescribed by the manufacturer shall be followed.

This maintenance work shall not include any replacement of parts.

7.102.2.4 Results to be obtained

Following the tests of mechanical endurance, the equipment under test shall still be capable of complying with the operating conditions specified in 7.101 and 7.102.1.

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.

7.102.3 Interlocking tests (contactor, starter or controller)

Subclause 7.102 of IEC 62271-200:2021 applies to starters and controllers with the following modification to the first sentence of 7.102.2.

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.

7.102.4 Test of the striker mechanism (fuses)

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.

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.

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

7.103 Verification of rated making and breaking capacity and reversibility

7.103.1 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.

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 ensure 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]	cosφ [b]	I_c/I_e	cosφ [b]	I_c/I_e	cosφ [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 5.101).

I_m Making current.

I_c Breaking current.

[a] The conditions for making are expressed in RMS values; 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.

[b] Tolerance for cosφ: ± 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, oscillograms, or equivalent, records shall be taken of the first and last operation (see 5.103.1.1 and 5.103.1.2).

Throughout the tests, there shall be no permanent arcing, no flashover between poles, no blowing of the fuse in the earth circuit (see 7.103.2) 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 document and shall be the subject of a special agreement.

7.103.2 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 mm^2 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 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.

7.103.3 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 7.103.2.2 of IEC 62271-100:2021.

The supply side TRV requirements shall be in accordance with the requirements of 7.105.5 of IEC 62271-100:2021 for class S1. The load side shall be arranged to provide an amplitude factor and frequency of the TRV, on breaking, given by:

Amplitude factor: k_{af} = 1,5 (± 5 %)

Frequency: $f \geq 2\,000 \times I_c^{0,2} \times U_r^{-0,8}$ (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 can be adjustable to satisfy the specified test conditions. The reactors can be air-cored and can be connected in series with the resistors, and their value can be obtained by series coupling of individual reactors. Parallel connecting of reactors is allowed only when these reactors have practically the same time-constant. A shunt resistor can 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.

7.103.4 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:

– 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;
– 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 closing operations shall be recorded in the test report.

7.103.5 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.

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

7.103.6 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 7.103.3 and 7.103.4. A new starter may be used for the verification of reversibility.

The test circuit shall be in accordance with 7.103.3, 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:

1st cycle: close A – open A/close B – open B – 10 s to 30 s rest;

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.

7.103.7 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 7.103.3 and 7.103.4. A new starter may be used for the verification of change-over ability.

The test circuit shall be in accordance with 7.103.3 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.

7.103.8 Behaviour during making and 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 7.103.2) and no welding of the contacts.

7.103.9 Condition following making and breaking tests

The equipment under test shall be capable of operating satisfactorily and shall comply with 7.101 after performing the number of operations for rated making and breaking capacity (7.103.4 and 7.103.5), after the reversibility tests (7.103.6) and after change-over ability test (7.103.7).

The equipment under test shall be inspected after any test-duty. Its mechanical parts and insulators shall be in essentially the same condition as before the test-duty.

7.104 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.

Subclause 7.101 applies to the equipment and of the contactor under test.

Table 8 – Overload current withstand requirements

Test current	Duration of the test
	s
15 × I_e	1
6 × I_e	30

7.105 Short-circuit current making and breaking tests

7.105.1 General

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

7.105.2 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 mm^2 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 %.

It shall be shown that the device will operate satisfactorily under the above conditions at no-load. The travel of the switching contacts shall be recorded, if practicable.

See also the relevant conditions of 7.102 of IEC 62271-100:2021.

7.105.3 Test circuit

Earthing of test circuit shall be in accordance with the requirements of 7.103.3 of IEC 62271-100: 2021.

The TRV requirements shall be in accordance with the requirements of 7.104.5 of IEC 62271-100: 2021 for circuit-breaker used in cable systems (class S1).

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

7.105.4 Short-circuit making and breaking tests

At least one making and breaking operation (CO) shall be performed.

If three making and breaking operations (CO) are successfully performed at a value equal to or higher than the maximum take-over current of 7.107.4.4, then it is not necessary to perform test duty C in 7.107.4.4.

The test requirements shall be in accordance with the relevant requirements of 7.105 and 7.106.4 of IEC 62271-100: 2021.

Where appropriate, an SCPD shall be replaced by solid links of negligible impedance.

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

7.105.5 Behaviour during short-circuit making and breaking tests

During the tests there shall be no permanent arcing, no flash-over between poles, no blowing of the fuse in the earth circuit (see 7.105.2) and no welding of the contacts.

7.105.6 Condition after short-circuit making and breaking tests

After the test, the equipment under test shall be capable of operating satisfactorily and comply with 7.101.

The equipment shall be inspected after the test. Its mechanical parts and insulators shall be in essentially the same condition as before the test.

7.106 Verification of operating limits and characteristics of overload relays

When a 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. In the case of tests at −5 °C on overload relays compensated for ambient air temperature, the tests may be carried out on a starter without enclosure. The details of type and installation shall form part of the test report.

The starter shall be connected as in service, using cables the cross-sections of which shall be chosen, depending on the current setting of the overload relay, in accordance with the relation given in Table 5 between cross-sections and the value of the rated operational current.

Operating characteristics of the thermal overload shall be verified and need only be carried out at one specified value of ambient temperature.

7.107 Verification of coordination with SCPDs

7.107.1 General

The verification of the general condition of coordination under 5.107 shall be performed as follows:

– short-circuit breaking capacity of the SCPD: by reference to the results of breaking capacity tests carried out on the SCPD according to the relevant specification;

– overload current withstand of the SCPD: by reference to the results of overload tests carried out separately on the SCPD according to the relevant specification;

– the coordination and the type of damage classification shall be verified by the tests specified in 7.107.1 to 7.107.3. Such tests are special type tests.

7.107.2 Test conditions

7.107.2.1 Condition of the controller before test

The controller under test shall be mounted complete on its own support or on an equivalent support, and connected as in normal operation. The starter shall be operated in the manner specified and, in particular, it shall be operated at 85 % of the rated control circuit quantities.

It shall be shown that the starter will operate satisfactorily under the above conditions on no-load. The travel of the switching contacts shall be recorded, if practicable.

The tests shall be performed on the starter in association with an SCPD having the highest rated current declared by the manufacturer as suitable for use with the starter. The overload relay or release shall be of the lowest rated operational current rating associated with that SCPD, and of the shortest time setting, if adjustable. The tests shall be carried out at the ambient temperature and without previous loading.

7.107.2.2 Frequency

The controller shall be tested at rated frequency with a tolerance of ±10 %.

However, for convenience of testing, some deviations from the above tolerance are allowable; for example, when controllers rated at 50 Hz are tested at 60 Hz and vice versa, care should be exercised in the interpretation of results, taking into account all significant facts such as the type of the contactor and the type of test performed.

7.107.2.3 Power factor

The power factor of the test circuit shall be determined by calculation from the circuit constants or by measurement and shall be taken as the average of the power factors of all phases.

7.107.2.4 Arrangement of test circuits

For test duties A and B, the starter in association with the SCPD shall preferably be connected in a circuit having the neutral point of the supply not earthed and the three-phase short circuit earthed, as shown in Figure 5. Alternatively, a circuit as indicated in Figure 6 may be used.

The TRV requirements shall be in accordance with the requirements of Table 9.

For test duty C, the preferred circuit shall be as indicated in Figure 7. Alternatively, a circuit as indicated in Figure 8 may be used. The impedance necessary to set the test current to the value required for test duty C shall be added on the source side of the starter.

For a starter producing an emission of flame or metallic particles, the tests shall be made with metallic screens placed in the vicinity of the live parts and separated from them by a clearance distance which the manufacturer shall specify. The screens, frame and other normally earthed parts shall be insulated from earth, but connected thereto by a suitable device to indicate leakage current to earth.

7.107.3 Test quantities

7.107.3.1 General

Where a tolerance is not specified, tests shall be carried out at values not less severe than the specified values; the upper limits are subject to the consent of the manufacturer.

7.107.3.2 Applied voltage before short-circuit making tests

The average value of the applied voltage between phases shall be equal to the rated operational voltage. The difference between this average and the applied voltage between each pair of phases shall not exceed 5 %.

7.107.3.3 Prospective current

The RMS value of the AC component of the prospective short-circuit current shall be measured one half-cycle after the initiation of the short circuit in the prospective current test.

The RMS value of the AC component in any phase shall not vary from the average by more than 10 % of the average.

7.107.3.4 Breaking current

The breaking current shall be the RMS value of the AC component measured at the instant of initiation of the interruption process.

7.107.3.5 Transient recovery voltage (TRV)

The prospective TRV of the test circuit shall be determined by such a method as will produce and measure the oscillation without materially influencing it, and shall be measured at the terminals to which the apparatus under test will be connected, with all necessary test measuring devices, such as voltage dividers, included.

For three-phase circuits, the TRV refers to the first pole to clear, i.e. the voltage across one open pole with the other two poles closed, with the appropriate test circuit arranged in accordance with 7.107.2.4.

The prospective TRV curve of a test circuit is represented by its envelope drawn as shown in (Figure 2) and by its initial portion.

The prospective TRV wave of the test circuit shall comply with the following two requirements:

a) Its envelope shall at no time be below the specified reference line;

It is stressed that the extent by which the envelope may exceed the specified reference line requires the consent of the manufacturer.

b) Its initial portion shall not cross the delay line where specified.

When the prospective test TRV is not a single-frequency wave, it shall be evaluated by the two parameter method (Figure 2). The straight lines 0BAC obtained in this way shall be above the area bounded by the time axis and the reference line of the specified TRV (Figure 3).

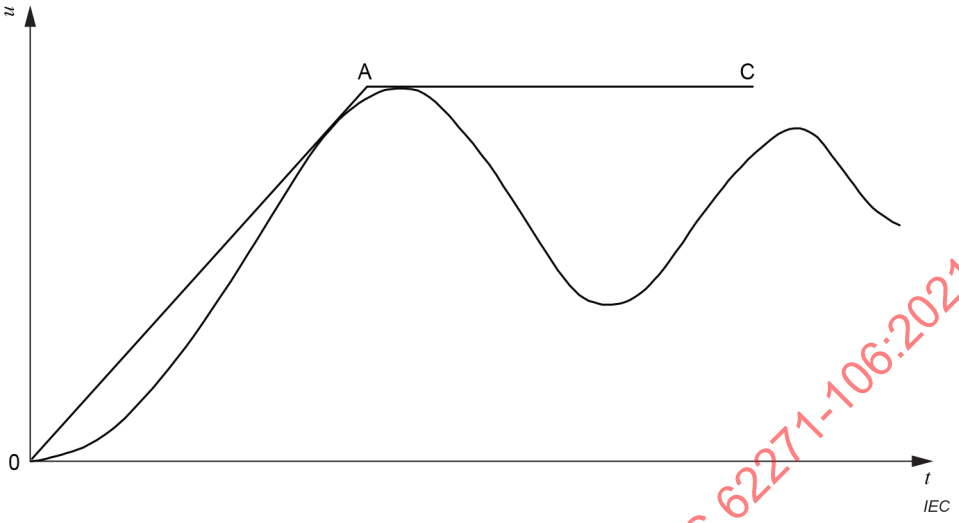


Figure 2 – Representation by two parameters of a prospective TRV of a circuit

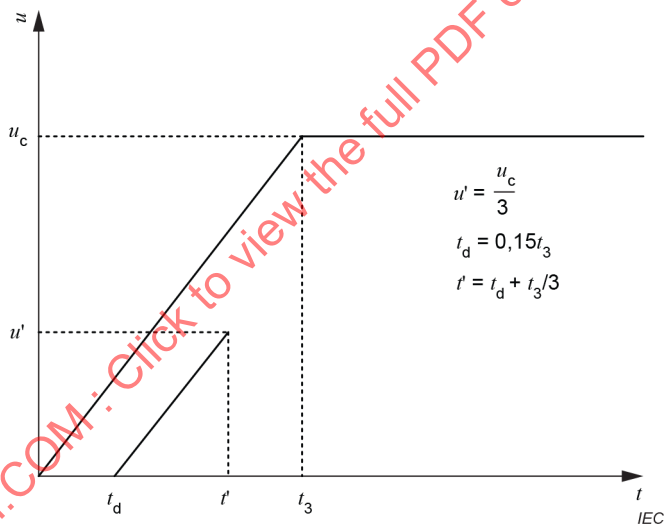


Figure 3 – Representation of the specified TRV by a two-parameter reference line and a delay line

7.107.3.6 Power frequency recovery voltage

The power frequency recovery voltage shall be maintained across the terminals of the controller for at least 0,3 s after interruption.

The power frequency recovery voltage of a three-phase test circuit shall be the average value of the power frequency recovery voltage in all phases measured after interruption. It shall be determined in accordance with 7.107.3.7.

7.107.3.7 Power frequency recovery voltage measurements

The power frequency recovery voltages of the test circuit shall be measured between the terminals of each pole of the controller in each phase of the test circuit.

Oscillograms of the power frequency recovery voltage shall be measured one cycle after interruption in accordance with Figure 4.

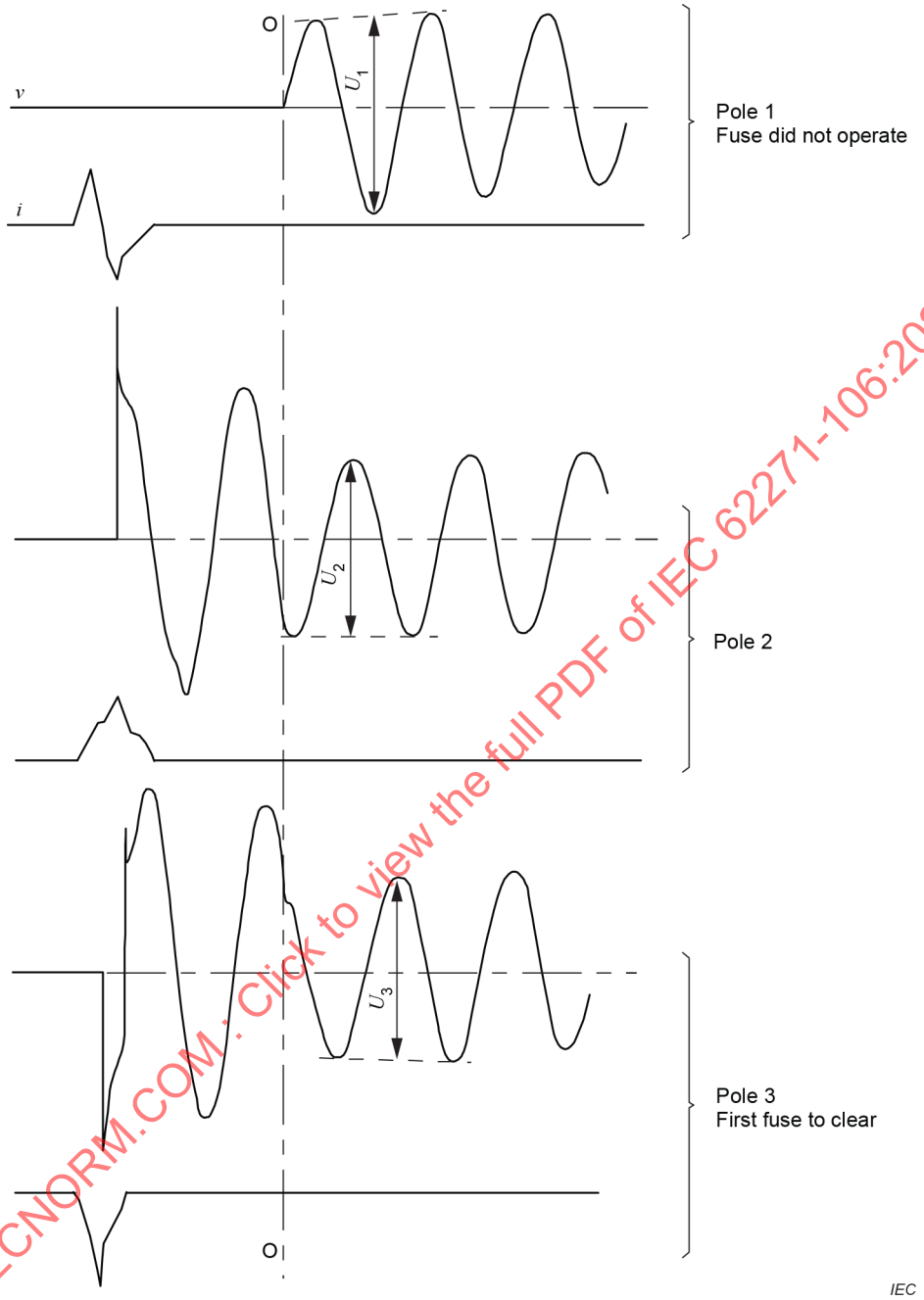


Figure 4 – Determination of power-frequency recovery voltage

7.107.4 Test duties

7.107.4.1 General

The controller under test shall be arranged as specified in 7.107.2. The test quantities shall be in accordance with 7.107.3, except that 7.106 does not apply to test duties A and B.

7.107.4.2 Test duty A – 100 % break test

One break test shall be made with the controller connected to a supply capable of delivering maximum prospective current equal to the rated short-circuit current of the controller, with a tolerance of $^{+5}_{0}$ %.

The power factor shall not exceed 0,15 inductive load.

The power frequency recovery voltage shall be equal to the rated voltage divided by √3.

For this test, the controller is closed as in normal service and the short circuit will be applied by external means (see 7.107.1 for control circuit parameters).

7.107.4.3 Test duty B – 100 % make test

One make test shall be made with the controller connected to a supply capable of delivering maximum prospective current equal to the rated short-circuit current of the controller, with a tolerance of $^{+5}_{0}$ %.

The power factor shall not exceed 0,15 inductive load.

For this test, the mechanical switching device will close on the fault (for control circuit parameters, see 7.107.1).

NOTE The variability of the closing time of the contactor prevents accurate control of contact touch therefore control of the making instant on the voltage wave cannot be applied.

7.107.4.4 Test duty C – Breaking tests near the take-over point

Three breaking tests shall be made to prove the protection coordination offered by the controller. The interval between tests shall not exceed 3 min, or such minimum longer time as is necessary to change fuse-links.

For this test duty, the value of the breaking current shall be equal to, or greater than, the maximum take-over current as determined by the coordination curves of maximum rated SCPD and overload relay characteristics for a given controller with a minimum of seven times the rated operational current (I_e) of the controller (see Figure 9).

These tests shall be made with the SCPD replaced by solid links of negligible impedance and shall be made in a three-phase circuit. The tolerance on the specified breaking current is $^{+5}_{0}$ % and the DC component of any phase at contact separation shall not exceed 20 %.

The power factor of the circuit, determined in accordance with 7.107.2.3, shall be 0,2 to 0,3 inductive load if the breaking current exceeds 400 A, or 0,3 to 0,4 inductive load if the breaking current is equal to or less than 400 A.

The power frequency recovery voltage shall be equal to the rated operational voltage divided by √3 whilst the prospective transient recovery voltage shall be in accordance with Table 9 and 7.107.3.6.

The test can be performed with a new controller.

Table 9 – Transient recovery voltage characteristics

Rated voltage U_r	TRV peak value u_c	Time coordinate t_3	Rate of rise u_c/t_3
kV	kV	µs	kV/µs
2,5	4,3	70	0,061
3,6	6,2	80	0,077
5,0	8,6	90	0,096
7,2	12,4	104	0,119
12,0	20,6	120	0,172
15,0	25,7	132	0,195
17,5	30,0	143	0,210
24,0	41,2	175	0,235

When a controller is installed for instance in the vicinity of a large transformer bank, and conditions can occur in which there are no parallel loads, the TRV can be more severe than the values of Table 9 for currents lower than the specified breaking current. Such conditions of application should be referred to the manufacturer.

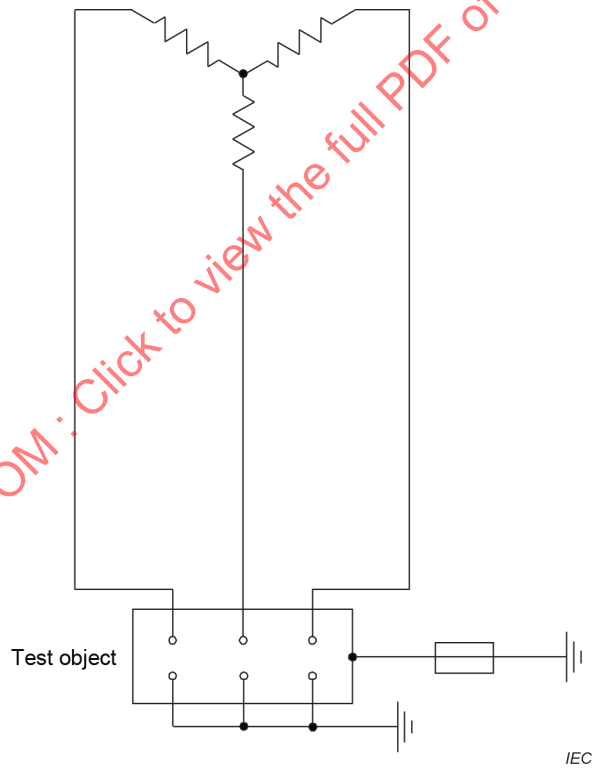


Figure 5 – Test duties A and B – preferred earth point

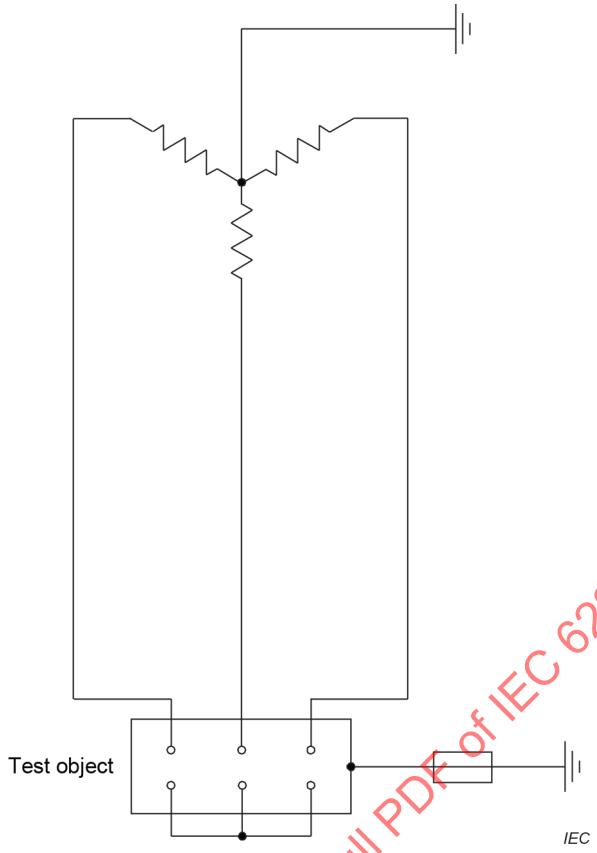


Figure 6 – Test duties A and B – alternative earth point

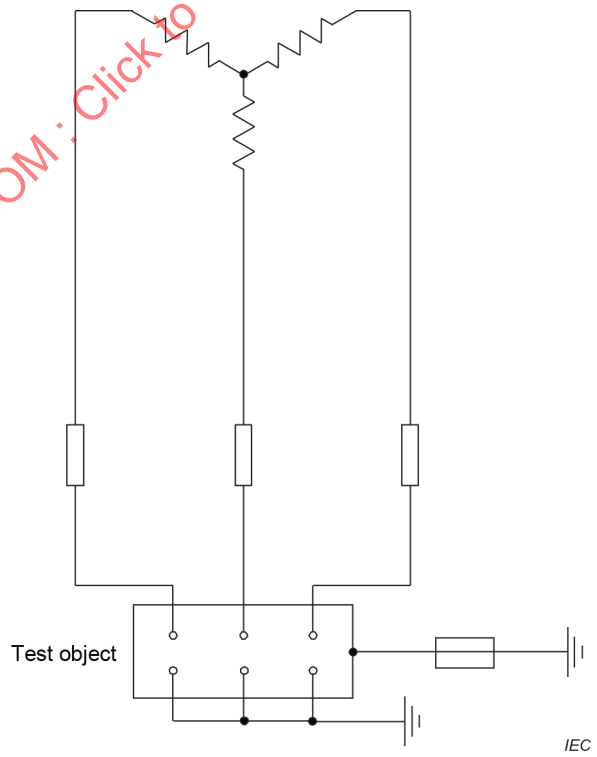


Figure 7 – Test duty C – preferred earth point

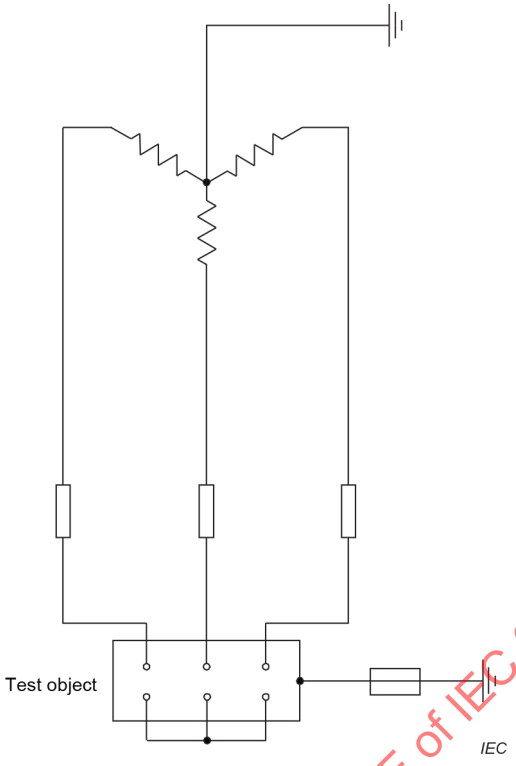


Figure 8 – Test duty C – alternative earth point

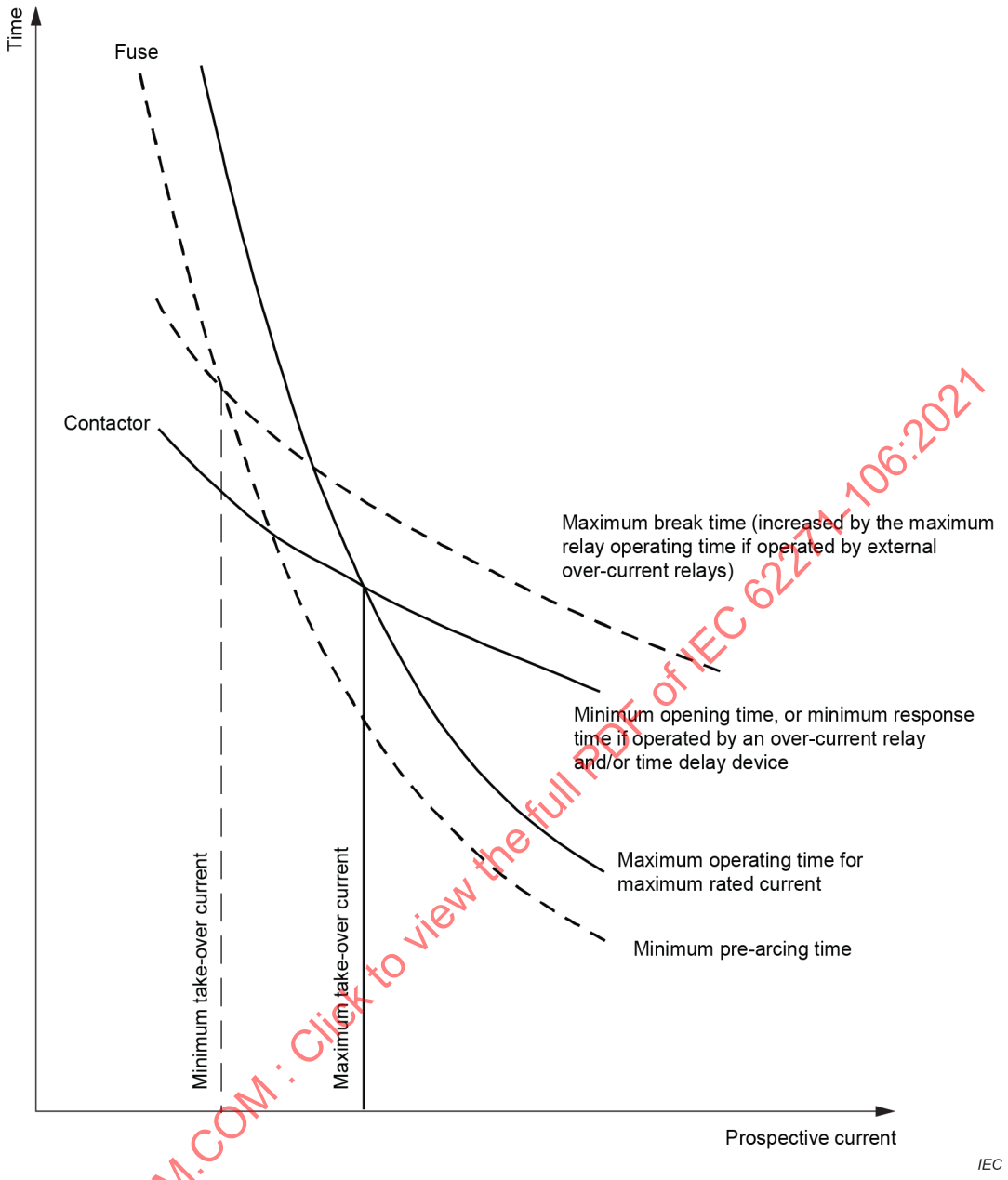


Figure 9 – Characteristics for determining take-over current

The tolerance on the specified breaking current is $^{+5}_{0}$ % and the DC component of any phase at contact separation shall not exceed 20 %.

7.107.4.5 Alternative method to test duty A, B and C

Instead of test duty A (7.107.4.2) a peak current withstand test shall be performed with the fuses replaced by solid links.

Instead of test duty B (7.107.4.3) a making test shall be performed using the same test circuit.

In both tests the test current shall be switched off after one cycle and the value of the peak current shall be not less than the value of the maximum of the peak let through current of the largest fuse with which the contactor is to be and the applied voltage shall be equal to the rated voltage.

If three making and breaking operations are successfully performed per 7.105 with a current equal to or higher than the maximum take-over current test duty C (7.107.4.4) is not required.

7.107.5 Behaviour of starter during tests

During the tests, there shall be no earth faults or excessive emission of flame or gases from enclosed starters which could endanger an operator.

For a starter that is intended for open mounting or to be mounted with other apparatus in an enclosure having large dimensions with respect to the volume of the starter, arc and flames shall not extend beyond the safety area stated by the manufacturer.

Any replacements during test duties A or B shall only be those permitted by classification type a, b or c as stated in 5.107.2.3.

7.107.6 Condition of starter after test

The condition of the starter after test duties A and B will be the basis for assigning the classification of the starter into type a, b or c as described in 5.107.2.3.

After test duty C, there shall be no material damage as described in 5.107.2.3.

7.108 Electrical endurance tests

Electrical endurance tests are included as special type tests and sufficient tests need only be carried out to provide a wear curve that can be reliably extrapolated, since the power requirements and time for a complete test are prohibitive.

The making and breaking currents and the test voltages are those given in Table 10.

The majority of the electrical endurance tests may, however, be carried out at any convenient voltage above the arc voltage with the device switching at the current and power factor given in Table 10. At this reduced voltage, it shall be shown that the arc duration is consistent with that measured during the corresponding full voltage test. A minimum of five tests shall be made at full voltage at the end of the test series to confirm that the performance is substantially unchanged. Oscillography or equivalent records, in accordance with Annex AA, shall be made of these final tests and included in the test report. The number of operations performed to determine the ware curve shall be noted in the test report.

Subclause 7.101 applies.

Table 10 – Verification of the number of on-load operating cycles – Conditions for making and breaking corresponding to the several utilization categories

Category	Make			Break		
	I_m/I_e [a]	U_r	cosφ [b]	I_c/I_e	U_{rec}/U_r	cosφ [b]
AC-1	1	1	0,95	1	1	0,95
AC-2	2,5	1	0,65	2,5	1	0,65
AC-3	6	1	0,35	1	0,17	0,35
AC-4 [c]	6	1	0,35	6	1	0,35

I_e Rated operational current (see 5.101)

I_m Making current

I_c Breaking current

U_r Rated voltage (see 5.2)

U_{rec} Recovery voltage

[a] The conditions for making are expressed in RMS values, but it is understood that the peak value of asymmetrical current, corresponding to the power factor of the circuit, can be a higher value than the peak of the RMS current (see 5.103.1).

[b] Tolerance for cosφ: ± 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.

7.109 High-voltage motor current switching tests

Subclause 3.3 of IEC 62271-110:2017 applies.

7.110 Capacitive current switching tests

Subclause 7.111 of IEC 62271-100 2021: applies with the following additions and changes to subclauses.

NOTE References to circuit-breakers will apply to contactors for this document.

7.110.1 Applicability

Only capacitor bank (single or back-to-back) current switching tests are applicable.

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

7.110.2 General

Tests for capacitor switching shall be performed according to 7.111.9.1 of IEC 62271-100:2021. The equipment is classified according to its restrike performance during this test.

Reignitions during the capacitive current switching tests are permitted. Two classes are defined according to their restrike performances (see 3.4.113, and 3.4.114).

7.110.3 Characteristics of supply circuits

Subclause 7.111.3 of IEC 62271-100:2021 applies.

7.110.4 Earthing of the test circuit

Subclause 7.111.4 of IEC 62271-100:2021 applies.

7.110.5 Characteristics of the capacitive circuit to be switched

Subclause 7.111.5 of IEC 62271-100:2021 applies.

7.110.6 Waveform of the current

Subclause 7.111.6 of IEC 62271-100:2021 applies.

7.110.7 Test voltage

Subclause 7.111.7 of IEC 62271-100:2021 applies.

7.110.8 Test current

Subclause 7.111.8 of IEC 62271-100:2021 applies with the following addition.

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

7.110.9 Test-duties

7.110.9.1 General

Subclause 7.111.9 of IEC 62271-100:2021applies with the following change.

Only test-duties BC1 and BC2 and test conditions for classes C1 or C2 are applicable for this document.

7.110.9.2 Test conditions

7.110.9.2.1 Common test conditions for classes C1 and C2 performances

Subclauses 7.111.9.1, 7.111.9.2 and 7.111.9.4.1 of IEC 62271-100:2021 apply with the following additions.

No preconditioning test is necessary.

It is not required to reverse terminal connections between test-duty 1 (BC1) and test-duty 2 (BC2).

7.110.9.2.2 Three-phase capacitor bank (single or back-to-back) current switching tests

Subclause 7.111.9.4.4 of IEC 62271-100:2021 applies with following addition.

If the opening time of the contactor prevents accurate control of contact separation, the requirement for either the closing angle or/and the minimum arcing times can be ignored.

7.110.9.2.3 Single-phase capacitor bank (single or back-to-back) current switching tests

Subclause 7.111.9.4.5 of IEC 62271-100:2021 applies with following addition.

If the opening time of the contactor prevents accurate control of contact separation, the requirement for either the closing angle or/and the minimum arcing times can be ignored.

7.110.10 Criteria for classification

7.110.10.1 General

The equipment under test shall be capable of operating satisfactorily and shall comply with 7.101 after performing the tests for BC2 and BC1.

The equipment under test shall be inspected after tests. Its mechanical parts and insulators shall be in essentially the same condition as before the test-duty.

7.110.10.2 Class C1

The contactor shall have successfully passed the tests if no more than five restrikes occurred during test-duties 1 (BC1) and 2 (BC2).

7.110.10.3 Class C2

The contactor shall have successfully passed the tests if no restrike occurred during test-duties 1 (BC1) and 2 (BC2).

If one restrike occurred during the complete test-duties 1 (BC1) and 2 (BC2), then both test-duties shall be repeated on the same apparatus without any maintenance. If no additional restrike happens during this extended series of tests, the contactor shall have successfully passed the tests. External flashover and phase-to-ground flashover shall not take place.

8 Routine tests

Clause 8 of IEC 62271-1: 2017 applies with the following addition.

The routine tests also comprise operating tests in accordance with 8.101 and tests dependent on starter type in accordance with 7.102.

8.1 General

Subclause 8.1 of IEC 62271-1: 2017 applies.

8.2 Dielectric test on the main circuit

Subclause 8.2 of IEC 62271-1: 2017 applies.

8.3 Tests on auxiliary and control circuits

Subclause 8.3 of IEC 62271-1: 2017 applies.

8.4 Measurement of the resistance of the main circuit

Subclause 8.4 of IEC 62271-1: 2017 applies.

8.5 Tightness test

Subclause 8.5 of IEC 62271-1: 2017 applies.

8.6 Design and visual checks

Subclause 8.6 of IEC 62271-1: 2017 applies.

8.101 Operating tests

Tests are carried out to verify operation within the limits specified in 5.9.

During these tests, it shall be verified, in particular, that the contactors open and close correctly when their operating devices are energized. It shall also be verified that operation will not cause any damage.

For all controllers, the following test shall be carried out where applicable:

a) with the action of one fuse striker of minimum energy simulated: one or more operations to test the reliability of the fuse-blown indicator;

b) at the specified maximum control supply voltage: one or more close and open operations;

c) at the specified minimum control supply voltage: one or more close and open operations;

d) for release-operated controllers only, at rated control supply voltage: one or more operations of each type of release.

Tests may be made without current passing through the main circuit.

During test d), for controllers fitted with overcurrent releases, the releases shall be set at the minimum calibration mark on the overcurrent scale, and it shall be shown that the overcurrent releases operate correctly at no more than 110 % of the setting value on the over-current scale.

NOTE This current can be supplied from a suitable low-voltage source or injected at the secondary of the current transformers.

During all the foregoing routine tests, no adjustments shall be made and the operation shall be faultless. The proper contactor position(s) shall be attained during each operating cycle of these tests.

After the tests, the controller shall be examined to determine that no parts have sustained damage and that all parts are in a satisfactory condition.

Tests shall be made to verify the operation of overload relays if supplied.

8.102 Tests dependent on starter type

8.102.1 For rheostatic rotor starters

Tests shall be performed to verify the proper operation of time-delay relays and the calibration of any other devices used for controlling the rate of starting.

The value of the starting resistors shall be verified for each step, with a tolerance of ± 10 %.

It shall also be verified that the rotor switching devices cut out the steps of resistors in the correct sequence.

8.102.2 For two-step auto-transformer starters

It shall be verified that the open-circuit voltages on the tapping terminals of the auto-transformer are in accordance with the design figures and that the phase sequence at the motor terminals is correct in both STARTING and RUN positions of the starter.

8.102.3 For two-step reactor starters

It shall be verified that the impedance of the tapping terminals of the reactor is in accordance with the design figures and that the phase sequence at the motor terminals is correct in both the STARTING and RUN positions of the starter.

9 Guide to the selection of contactors and motor-starters for service (informative)

9.1 General

Subclause 9.1 of IEC 62271-1: 2017 applies.

9.2 Selection of rated values

Subclause 9.2 of IEC 62271-1: 2017 applies.

9.3 Cable-interface considerations

Subclause 9.3 of IEC 62271-1: 2017 applies.

9.4 Continuous or temporary overload due to changed service conditions

Subclause 9.4 of IEC 62271-1: 2017 applies.

9.5 Environmental aspects

Subclause 9.5 of IEC 62271-1: 2017 applies.

9.101 General

A contactor or starter, including a controller, suitable for a given duty in service, is best selected by considering the individual rated values required by load conditions and fault conditions.

The complete list of rated characteristics is given in Clause 5. The following individual ratings are dealt with in this subclause:

- rated voltage (U_r) 9.102.1
- rated insulation level (U_d and U_p) 9.102.2
- rated frequency (f_r) 9.102.3
- rated short-circuit breaking current (I_{sc}) 9.102.4

For rated characteristics not dealt with in this subclause reference should, if applicable, be made to Clause 5 as follows.

Rated characteristics for all contactors and starters

- rated short-time withstand current (I_k) 5.6
- rated peak withstand current (I_p) 5.7
- rated duration of short circuit (t_k) 5.8
- rated supply voltage of operating devices, and of auxiliary and control circuits (U_a) 5.9
- rated supply frequency of operating devices and of auxiliary circuits 5.10
- rated operational current (I_e) or rated operational power 5.101
- rated duties 5.102
- rated load and overload characteristics 5.103
- utilization category 5.104
- mechanical endurance 5.105

Characteristics given on request

– thermal current (I_{th})	9.102.5
– electrical endurance	5.106
– coordination with short-circuit protective devices (SCPD)	5.107
– motor switching characteristics	7.108

Characteristics dependent on starter type

– automatic change-over devices and automatic acceleration control devices	5.108
– starting auto-transformer characteristics	5.109
– starting reactor characteristics	5.109
– starting resistor characteristics for rheostatic rotor starters	5.110

Other parameters to be considered when selecting contactors or starters are, for example:

– local atmospheric and climatic conditions	9.102.6
– use at altitudes other than sea level	9.102.7
– coordination with current-limiting fuses such as the SCPD	9.102.8
– degree of protection for the enclosure and partitions	IEC 62271-200
– type of metal-enclosed controlgear	IEC 62271-200

9.102 Selection of ratings and characteristics for service conditions

9.102.1 Selection of rated voltage

The rated voltage of the equipment should be chosen so as to be at least equal to the highest voltage of the system at the point where it is to be installed.

The rated voltage should be selected from the standard values given in 5.2.

In selecting the rated voltage, the corresponding insulation levels specified in 5.3 should also be taken into account (see also 9.102.2).

9.102.2 Insulation coordination

The rated insulation level should be selected according to 5.3. The values in these tables apply to both indoor and outdoor equipment.

9.102.3 Rated frequency

The manufacturer should be consulted if a contactor, or starter, is to be used at any frequency other than rated frequency (see 5.4).

9.102.4 Rated short-circuit breaking current

As stated in 5.107, 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 document in a circuit having a power-frequency recovery voltage corresponding to the rated voltage of the controller.

The rated short-circuit breaking current of a controller is largely determined by that of the SCPD and shall be equal to or greater than the maximum expected fault current level of the point in the distribution system at which the controller is to be located. When forming a switchboard incorporating both circuit-breakers and starters, the rated short-circuit breaking current of the complete board should have one value, namely that of the lowest rated circuit. This rating then forms the basis for type testing of the short-circuit withstand capability of the main circuit conductors of the controller, i.e. the busbars and connections upstream of the SCPD.

9.102.5 Thermal current (I_{th})

Reference should be made to IEC 60282-1 where comment is made on the rated normal current of fuses and its selection, and on how it may be affected by the mounting of the fuses in an enclosure.

The thermal current of a switch-fuse combination is assigned by the controller manufacturer on the basis of information gained from temperature-rise tests and will depend on the type and ratings of the contactor and the fuses. It may have to be reduced where the ambient temperature in service exceeds the prescribed ambient temperature (see 4.1 and 4.2 of IEC 62271-1: 2017).

The thermal current of a controller is generally less than, but should not be in excess of, the rated current of the fuses as assigned by the fuse manufacturer.

9.102.6 Local atmospheric and climatic conditions

It should be specified in the enquiry whether the equipment is to be of indoor or outdoor type. For outdoor installation, it is assumed that the equipment will be mounted in a suitable enclosure. Inside the enclosure, normal indoor conditions are considered to prevail. If necessary, appropriate measures shall be taken, such as space heaters or air-conditioning, so that common indoor components may be used. This does not apply to gas-filled compartments.

9.102.7 Use at altitudes other than sea level

The normal service conditions specified in Clause 4 of IEC 62271-1: 2017 provide for controlgear intended for use at altitudes not exceeding 1 000 m.

Installation at altitudes above 1 000 m or below sea level is also recognized in this document (4.2.2), but it may be necessary for the manufacturer and end user to take account of variations in the design for these altitudes, for example temperature rise, insulation level and mechanical parameters.

Above 1 000 m, or below sea level, it is often necessary to make adjustments to the spring force in the drive mechanism of the contactor vacuum interrupters to compensate for the different atmospheric pressure.

9.102.8 Coordination with current-limiting fuses such as the SCPD

9.102.8.1 General

The object of this part of the guide, taken in conjunction with that for fuses (IEC 60282-1), is to specify criteria for the selection of a combination of contactor and SCPD which will assure safe operation, using the parameter values established by tests in accordance with IEC 60282-1, IEC 60644 and this document.

IEC 60644 applies primarily to fuse-links, complying with the requirements of IEC 60282-1, used with motors started direct-on-line and intended to withstand normal service conditions, and to the selection of fuse-links with particular reference to the K factor under repetitive starting conditions.

The test duties specified in this document, together with the associated guidance as to the application of these tests to other combinations, cover most users' requirements. However, some cases, for example to support the use of a back-up fuse by type tests done on the controller using so-called full-range fuses from another manufacturer, may require additional testing. Such testing should be subject to agreement between the manufacturer and user.

9.102.8.2 Take-over current

The value of the take-over current of a controller is dependent upon both the release initiated opening time of the contactor and the time-current characteristic of the fuse. As its name implies, it is the value of overcurrent above which the fuses take over the function of current interruption from the release and contactor.

From a practical standpoint, the maximum take-over current for a given application is determined as follows.

Superimpose upon the maximum pre-arcing time-current characteristic (based on a current tolerance of ± 6,5 %) of the fuse (see Figure 9) a time equal to the minimum opening time, or minimum response time if operated by an overcurrent relay and/or time delay device. The associated current is the value of the take-over current, and shall not be greater than the rated take-over current which is the current determined by the fuse manufacturer and used on test duty C (see 7.107.4.4).

NOTE In this subclause, a current tolerance ± 6,5 % is used (i.e. ± 2σ of ± 10 %). This is based on current practice.

9.102.8.3 Extension of the validity of making and breaking type tests

As it is recognized that it may well be impractical to test all combinations of contactor and fuses, and to carry out repeat tests on controllers whenever the fuse is altered, this document specifies conditions whereby the validity of the making and breaking type tests may be extended to cover combinations of contactor and fuses other than that (those) tested.

The fuse manufacturer or the user can, on his own responsibility, avail himself of this extension and decide which other types of fuses can validly be used in the controller.

The principles on which the conditions for extending the validity of the making and breaking type tests are based are as follows:

– any fuse or modified fuse used in a controller shall have been certified to its relevant standard. This is necessary not only to prove the fuse but also to provide cut-off current and operating I^2t data;

– the cut-off current and operating I^2t of the fuse shall be no greater than those of the fuse tested in the controller in order to ensure that the contactor contacts cannot be subjected to unproven conditions;

– the same type of fuse striker (energy output) as that fitted to the fuse tested in the controller shall be used in order to give assurance that the contactor will be released without damage (see also 5.104).

9.102.8.4 Fuse operation

The three fuses fitted in a given controller shall be all of the same type and current rating, otherwise the breaking performance of the controller could be adversely affected.

It is vital, for the correct operation of the controller, that the fuses are inserted with the strikers correctly located.

When a controller has operated as a result of a three-phase fault, it is possible that:

a) only two out of the three fuses have operated;

b) all three fuses have operated, but only one out of the three strikers have ejected.

Such partial operation of one fuse can occur under three-phase service conditions and is not unusual;

c) where a controller has opened without any obvious signs of a fault on the system, examination of the operated fuse or fuses may give an indication as to the type of fault current and its approximate value. Such an investigation is best carried out by the fuse manufacturer who is usually prepared to offer such a service to users;

d) it is most strongly advisable to discard and replace all three fuses when the fuse(s) in one or two poles of a controller has(have) operated If one or more fuse elements have melted open within the fuse, this will lower the minimum breaking current so that it may fail at operational currents and burn out of the side of the fuse insulating tube destroying the controller. A resistance check in the micro ohm range can verify the serviceability of the fuse;

e) before removing or replacing fuses, the operator should satisfy himself that the fuse-mount is electrically disconnected from all parts of the controller which could still be electrically energized. This is especially important when the fuse-mount is not visibly isolated;

f) it is considered good practice, especially for lower damage classification categories, to check that the contactor has not been subjected to contact welding.

9.103 Additional information useful for application

9.103.1 Thermal current (I_{th})

For 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 60076-11:2018) is permissible for the windings of the transformer or reactor when the starter is operated according to the requirements of 5.102 and 5.111.

9.103.2 Stator thermal current (I_{ths})

For 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 Table 14 of IEC 62271-1 when tested in accordance with 7.5.4.

9.103.3 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 Table 14 of IEC 62271-1:2017 when tested in accordance with 7.5.4.

10 Information to be given with enquiries, tenders and orders (informative)

10.1 General

Subclause 10.1 of IEC 62271-1:2017 applies.

10.2 Information with enquiries and orders

Subclause 10.2 of IEC 62271-1:2017 applies. with the following additions.

10.2.101 Information to be given with enquiries and orders

When enquiring for or ordering a contactor, starter, or controller, the following particulars should be supplied by the enquirer.

a) Particulars of systems, i.e. nominal and highest voltages, frequency, number of phases, and details of neutral earthing.

   If the equipment is to be used in installations exposed to lightning and/or switching over-voltages.

b) Service conditions, including minimum and maximum ambient temperatures,; altitude of the intended installation; and any special conditions likely to exist or arise, for example unusual exposure to water vapour, moisture, fumes, explosive gases, excessive dust or salt air (see 9.102.6 and 9.102.7). If intended for installation in areas subject to seismic considerations, this shall also be indicated.

   If the equipment may be fitted to a moving device, if its support may be capable of assuming a sloping position either permanently or temporarily (for example devices fitted aboard ships), or if the equipment may be exposed in service to abnormal shocks or vibrations.

   The enquirer should provide information of the type and dimensions of any special electrical connections with other apparatus, in order to enable enclosures and terminals meeting the conditions of installation and temperature rise prescribed by this document to be provided. Attention should be drawn to any special need for silent operation.

   If the equipment will be used for applications not clearly within the scope of this document, for example the switching of transformers, this shall be noted.

c) Characteristics, as appropriate and listed in Table 1, should be given.

10.2.102 Information to be given for coordination with current-limiting fuse SCPDs

The controller manufacturer should give, apart from the rated quantities, the following information:

a) maximum acceptable power dissipation of the equipment (see 7.5.4);

b) maximum cut-off current that the equipment has been proven to be able to deal with as demonstrated during short-circuit testing.

c) maximum I^2t of fuses for protection of the equipment.;

d) opening time of the contactor when actuated by a fuse striker, and also, where applicable, the minimum release-initiated opening time of the contactor;

e) types and dimensions of the fuses which can be used in the controller;

f) type of fuse striker (medium or heavy);

g) filling medium (type and amount), where applicable.

Where a user wishes to use a fuse of a type different from those listed under 10.2.102 e) but of the same dimensions, he should, in addition to referring to the application guide (Clause 8), request the following information from the fuse manufacturer in accordance with IEC 60282-1.

h) I^2t characteristic (according to IEC 60282-1);

i) cut-off current characteristic;

j) rated short-circuit breaking current;

k) rated minimum breaking current;

l) power dissipation at rated current;

m) pre-arcing time-current characteristic;

n) type of fuse striker (medium or heavy).

10.3 Information with tenders

Subclause 10.3 of IEC 62271-1:2017 applies.

11 Transport, storage, installation, operating instructions and maintenance

Clause 11 of IEC 62271-1:2017 applies with the following addition.

High-voltage fuses, although robust in external appearance, may have fuse elements of relatively fragile construction. Fuses should, therefore, be kept in their protective packaging until ready for installation and should be handled with the same degree of care as a relay, meter or other similar item. Where fuses are already fitted in a controller, they should be temporarily removed while the unit is moved into position.

12 Safety

Clause 12 of IEC 62271-1:2017 applies.

13 Influence of the product on the environment

Clause 13 of IEC 62271-1:2017 applies.

Annex A
(normative)

Identification of test objects

Annex A of IEC 62271-1:2017 applies.

Annex B
(informative)

Determination of the equivalent RMS value of a short-time current during a short-circuit of a given duration

Annex B of IEC 62271-1:2017 applies.

Annex C
(normative)

Method for weatherproofing test for outdoor switchgear and controlgear

Annex C of IEC 62271-1:2017 applies.