IEC 61439-4

Edition 2.0 2023-10
EXTENDED VERSION

INTERNATIONAL STANDARD

colour inside

This extended version of IEC 61439-4:2023 includes the content of the references made to IEC 61439-1:2020

**Low-voltage switchgear and controlgear assemblies –
Part 4: Particular requirements for assemblies for construction sites (ACS)**

IEC 61439-4:2023-10 EXV(en)

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Low-voltage switchgear and controlgear assemblies –
Part 4: Particular requirements for assemblies for construction sites (ACS)

INTERNATIONAL
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COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES –

Part 1: General rules

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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This extended version (EXV) of the official IEC Standard provides the user with the comprehensive content of the Standard.

IEC 61439-4:2023 EXV includes the content of IEC 61439-4:2023, and the references made to IEC 61439-1:2020.

The specific content of IEC 61439-4:2023 is displayed on a blue background.

IEC 61439-4 has been prepared by subcommittee 121B: Low-voltage switchgear and controlgear assemblies, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low voltage. It is an International Standard.

This second edition of IEC 61439-4 cancels and replaces the first edition published in 2012. This edition constitutes a technical revision.

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

a) alignment with IEC 61439-1:2020 regarding the structure and technical content, as applicable.

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

Draft	Report on voting
121B/183/FDIS	121B/188/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

This document is to be read in conjunction with IEC 61439-1:2020. The provisions of the general rules dealt with in IEC 61439-1:2020 are only applicable to this document insofar as they are specifically cited. When this document states “addition”, “modification” or “replacement”, the relevant text in IEC 61439-1:2020 is to be adapted accordingly.

Subclauses that are numbered with a 101 (102, 103, etc.) suffix are additional to the same subclause in IEC 61439-1:2020.

Tables and figures in this document that are new are numbered starting with 101.

New annexes in this document are lettered AA, BB, etc.

In this document, terms written in small capitals are defined in Clause 3.

The reader’s attention is drawn to the fact that Annex N lists all of the “in-some-country” clauses on differing practices of a less permanent nature relating to the subject of this document.

A list of all parts of the IEC 61439 series, under the general title *Low-voltage switchgear and controlgear assemblies,* 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 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.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

The purpose of this document is to harmonize as far as practicable all rules and requirements of a general nature applicable to low-voltage switchgear and controlgear assemblies, in order to obtain uniformity of requirements and verification for assemblies and to avoid the need for verification in other standards. All those requirements for the various assembly standards which can be considered as general have therefore been gathered in this document together with specific subjects of wide interest and application, e.g. temperature-rise, dielectric properties, etc.

For each type of low-voltage switchgear and controlgear assembly, only two main standards are necessary to determine all requirements and the corresponding methods of verification:

– the basic standard, (this document) referred to as "IEC 61439-1" in the specific standards, covering the various types of low-voltage switchgear and controlgear assemblies;
– the specific assembly standard hereinafter also referred to as the relevant assembly standard.

For a general rule to apply to a specific assembly standard, it should be explicitly referred to by quoting this document followed by the relevant clause or subclause number e.g. "IEC 61439-1:2020, 9.1.3".

A specific assembly standard may not require, and hence need not call up, a general rule where it is not applicable, or it can add requirements if the general rule is deemed inadequate in the particular case, but it may not deviate from it unless there is substantial technical justification detailed in the specific assembly standard.

Where, in this document, a cross-reference is made to another clause, the reference is to be taken to apply to that clause as amended by the specific assembly standard, where applicable.

Requirements in this document that are subject to agreement between the assembly manufacturer and the user are summarized in Annex C (informative). This schedule also facilitates the supply of information on basic conditions and additional user specifications to enable proper design, application and utilization of the assembly.

For the IEC 61439 series, the following parts are published:

a) IEC 61439-1: General rules
b) IEC 61439-2: Power switchgear and controlgear assemblies (PSC-assemblies)[1]
c) IEC 61439-3: Distribution boards intended to be operated by ordinary persons (DBO)
d) IEC 61439-4: Particular requirements for assemblies for construction sites (ACS)
e) IEC 61439-5: Assemblies for power distribution in public networks
f) IEC 61439-6: Busbar trunking systems (busways)
g) IEC 61439-7: Assemblies for specific applications such as marinas, camping sites, market squares, electric vehicle charging stations
h) IEC TR 61439-0: Guidance to specifying assemblies.

This list is not exhaustive; additional parts can be developed as the need arises.

1 IEC 61439-2 includes requirements for assemblies for use in photovoltaic installations.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES –

Part 1: General rules

1 Scope

NOTE Throughout this document, the abbreviation ACS (assembly for construction site, see 3.1.101) is used for a low-voltage switchgear and controlgear assembly intended for use on construction and similar sites.

This document defines the specific requirements of ACS as follows:

– assemblies for which the rated voltage does not exceed 1 000 V in case of AC or 1 500 V in case of DC;
– assemblies where the nominal primary voltage and the nominal secondary voltage of transformers incorporated in ACS are within the limits specified above;
– assemblies intended for use on construction sites, both indoors and outdoors, i.e. temporary places of work to which the public do not generally have access and where building construction, installation, repairs, alteration or demolition of property (buildings) or civil engineering (public works) or excavation or any other similar operations are carried out;
– transportable (semi-fixed) or MOBILE assemblies with enclosure.

The manufacture and/or assembly can be carried out by an entity other than by the original manufacturer (see 3.10.1 of IEC 61439-1:2020).

This document does not apply to individual devices and self-contained components, such as motor starters, fuse switches, electronic equipment, etc. which will comply with the relevant product standards.

This document does not apply to assemblies for use in the administrative centres of construction sites (offices, cloakrooms, meeting rooms, canteens, restaurants, dormitories, toilets, etc.).

Requirements for electrical protection provided by equipment manufactured according to this document are given in IEC 60364-7-704.

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

IEC 60068-2-11:1981, *Basic environmental testing procedures – Part 2-11: Tests – Test Ka: Salt mist*

IEC 60068-2-27, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

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

IEC 60068-2-42, *Environmental testing – Part 2-42: Tests – Test Kc: Sulphur dioxide test for contacts and connections*

IEC 60073:2002, *Basic and safety principles for man-machine interface, marking and identification – Coding principles for indicators and actuators*

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

IEC 60364 (all parts), *Low-voltage electrical installations*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*
IEC 60364-4-41:2005/AMD1:2017

IEC 60364-5-51:2005, *Electrical installations of buildings – Part 5-51: Selection and erection of electrical equipment – Common rules*

IEC 60364-5-52:2009, *Low-voltage electrical installations – Part 5-52: Selection and erection of electrical equipment – Wiring systems*

IEC 60364-7-704:2017, *Low-voltage electrical installations – Part 7-704: Requirements for special installations or locations – Construction and demolition site installations*

IEC 60439 (all parts), *Low-voltage switchgear and controlgear assemblies*[2]

IEC 60445:2017, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals, conductor terminations and conductors*

IEC 60447:2004, *Basic and safety principles for man-machine interface, marking and identification – Actuating principles*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*[3]
IEC 60529:1989/AMD1:1999
IEC 60529:1989/AMD2:2013

IEC 60695-2-10:2013, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC 60695-2-11:2014, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products* (GWEPT)

IEC 60695-2-12, *Fire hazard testing – Part 2-12: Glowing/hot-wire based test methods – Glow-wire flammability index (GWFI) test method for materials*

IEC 60865-1:2011, *Short-circuit currents – Calculation of effects – Part 1: Definitions and calculation methods*

IEC TR 60890:2014, *A method of temperature-rise verification of low-voltage switchgear and controlgear assemblies by calculation*

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2 Withdrawn. The IEC 60439 series has been cancelled and replaced by the IEC 61439 series.

3 There is a consolidated document edition 2.2 (2013) that includes IEC 60529 (1989) and its Amendment 1 (1999) and Amendment 2 (2013).

IEC 60947-4-1:2018, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*

IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio frequency, electromagnetic field immunity test*[4]
IEC 61000-4-3:2006/AMD1:2007
IEC 61000-4-3:2006/AMD2:2010

IEC 61000-4-4:2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*[5]
IEC 61000-4-5:2014/AMD1:2017

IEC 61000-4-6:2013, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

IEC 61000-4-8:2009, *Electromagnetic compatibility (EMC) – Part 4-8: Testing and measurement techniques – Power frequency magnetic field immunity test*

IEC 61000-4-11:2004, *Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests*
IEC 61000-4-11:2004/AMD1:2017

IEC 61000-6-3:2006, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*
IEC 61000-6-3:2006/AMD1:2010

IEC 61000-6-4:2018, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61082-1:2014, *Preparation of documents used in electrotechnology – Part 1: Rule*s

IEC 61180:2016, *High-voltage test techniques for low-voltage equipment – Definitions, test and procedure requirements, test equipment*

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

IEC 61439-1:2020, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

IEC 61558-2-23, *Safety of transformers, reactors, power supply units and combinations thereof – Part 2-23: Particular requirements and tests for transformers and power supply units for construction sites*

[4] There is a consolidated edition 3.2 (2010) that includes IEC 61000-4-3 (2006) and Amendment 1 (2007) and Amendment 2 (2010).

[5] There is consolidated edition 3.1 (2017) that includes IEC 61000-4-5 (2014) and its Amendment 1 (2017).

IEC 61921:2017, *Power capacitors – Low-voltage power factor correction banks*

IEC 62208:2011, *Empty enclosures for low-voltage switchgear and controlgear assemblies – General requirements*

IEC 81346-1:2009, *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 1: Basic rules*

IEC 81346-2:2019, *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 2: Classification of objects and codes for classes*

CISPR 11:2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*
CISPR 11:2015/AMD1:2016
CISPR 11:2015/AMD2:2019

CISPR 32:2015, *Electromagnetic compatibility of multimedia equipment – Emission requirements*
CISPR 32:2015/AMD1:2019

ISO 178:2010, *Plastics – Determination of flexural properties*
ISO 178:2010/AMD1:2013

ISO 179-1:2010, *Plastics – Determination of Charpy impact properties – Part 1: Non-instrumented impact test*

ISO 179-2:1997, *Plastics – Determination of Charpy impact properties – Part 2: Instrumented impact test*
ISO 179-2:1997/AMD1:2011

ISO 2409:2013, *Paints and varnishes – Cross-cut test*

ISO 4628-3:2016, *Paints and varnishes – Evaluation of degradation of coatings – Designation of quantity and size of defects, and of intensity of uniform changes in appearance – Part 3: Assessment of degree of rusting*

ISO 4892-2:2013, *Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc lamps*

ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

3.1 General terms

3.1.1
low-voltage switchgear and controlgear assembly
assembly
combination of one or more low-voltage switching devices together with associated control, measuring, signalling, protective, regulating equipment, with all the internal electrical and mechanical interconnections and structural parts, as defined by the original manufacturer, which can be assembled in accordance with the original manufacturer's instructions

Note 1 to entry: Throughout this document, the term assembly(s) is used for a low-voltage switchgear and controlgear assembly(s)

Note 2 to entry: The term "switching device" includes mechanical switching devices and semiconductor switching devices, e.g. soft starters, semiconductor relays, frequency converters. The auxiliary circuits may also include electro-mechanical devices, e.g. control relays, terminal blocks, and electronic devices, e.g. electronic motor control devices, electronic measurement and protection devices, bus communication, programmable logic controller systems.

3.1.2
assembly system
full range of mechanical and electrical components (enclosures, busbars, functional units, auxiliary circuits and associated controls, etc.), as defined by the original manufacturer, which can be assembled in accordance with the original manufacturer's instructions in order to produce various assemblies

3.1.3
main circuit
all the conductive parts of an assembly included in a circuit which is intended to transmit electrical energy

[SOURCE: IEC 60050-441:2000, 441-13-02]

3.1.4
auxiliary circuit
all the conductive parts of an assembly included in a circuit (other than the main circuit) intended to control, measure, signal, regulate and process data, etc.

Note 1 to entry: The auxiliary circuits of an assembly include the control and the auxiliary circuits of the switching devices.

[SOURCE: IEC 60050-441:2000, 441-13-03, modified – In the definition, "assembly of switchgear and controlgear" has been replaced with "assembly", and at the end of the definition "and process data, etc." has been added.]

3.1.5
busbar
low-impedance conductor to which several electric circuits can be connected at separate points

Note 1 to entry: The term "busbar" is generic and does not presuppose the material, the geometrical shape, size or dimensions of the conductor(s).

[SOURCE: IEC 60050-151:2001, 151-12-30, modified – The text of the note has been replaced.]

3.1.6
main busbar
busbar to which one or several distribution busbars and/or incoming and outgoing units are connected

Note 1 to entry: Conductors that are connected between a functional unit and a main busbar are not considered as a part of the main busbar.

3.1.7
distribution busbar
busbar within one section which is connected to a main busbar and from which outgoing units are supplied

Note 1 to entry: Conductors that are connected between a functional unit and a distribution busbar are not considered as a part of the distribution busbars.

3.1.8
functional unit
part of an assembly comprising all the electrical and mechanical elements including switching devices that contribute to the fulfilment of the same function

Note 1 to entry: The conductors connecting a functional unit to the main or distribution busbars and to the terminals for external conductors are part of the functional unit. Other conductors which are connected to a functional unit, but which are external to its compartment or enclosed protected space (e.g. auxiliary cables connected in a common compartment) are not considered to form part of the functional unit.

3.1.9
incoming unit
functional unit through which electrical energy is normally fed into the assembly

3.1.10
outgoing unit
functional unit through which electrical energy is normally supplied to one or more external circuits

3.1.11
short-circuit protective device
SCPD
device intended to protect a circuit or parts of a circuit against short-circuit currents by interrupting them

[SOURCE: IEC 60947-1:2020, 3.4.21]

3.1.12
current-limiting device
SCPD that, within a specified range of current, prevents the let-through current from reaching the prospective peak value and which limits the let-through energy (I^2t)

Note 1 to entry: The let-through current is also referred to as the cut-off current (see IEC 60050-441:2000, 441-17-12).

Note 2 to entry: Examples of current-limiting devices are current-limiting circuit-breakers in accordance with IEC 60947-2 and fuses in accordance with IEC 60269-2.

3.1.13
non-current-limiting device
SCPD that, within a specified range of current, allows the let-through current to reach the prospective peak value and which can have a rated short-time withstand current (I_{cw}) enabling it to withstand the let-through energy for the duration of the short-time current

3.1.14
line conductor
L
DEPRECATED: phase conductor (in AC systems)
DEPRECATED: pole conductor (in DC systems)
conductor which is energized in normal operation and capable of contributing to the transmission or distribution of electric energy but which is not a neutral or mid-point conductor

[SOURCE: IEC 60050-195:1998, 195-02-08]

3.1.15
relevant assembly standard
standard within the IEC 61439 series, Part 2 onwards, covering a generic type of assembly

EXAMPLE Power switchgear and controlgear assemblies (PSC-assemblies).

3.1.101
low-voltage switchgear and controlgear assembly for construction sites
ACS
combination of one or several transforming or low voltage switching devices with associated control, measuring, signalling, protective and regulating equipment complete with all their internal electrical and mechanical connections and structural parts, designed and built for use on all construction sites, indoors and outdoors

3.2 Constructional units of assemblies

3.2.1
fixed part
part consisting of components assembled and wired on a common support and which is designed for fixed installation

3.2.2
removable part
part consisting of components assembled and wired on a common support which is intended to be removed entirely from the assembly and replaced whilst the main circuit to which it is connected may be live

3.2.3
connected position
position of a removable part when it is fully connected for its intended function

3.2.4
removed position
position of a removable part when it is outside the assembly, and mechanically and electrically separated from it

3.2.5
insertion interlock
device preventing the introduction of a removable part into a location not intended for that removable part

3.2.6
fixed connection
connection which can be connected with or without a tool and only disconnected by means of a tool

3.2.7
section
constructional unit of an assembly between two successive vertical delineations

3.2.8
sub-section
constructional unit of an assembly between two successive horizontal or vertical delineations within a section

3.2.9
compartment
section or sub-section enclosed except for openings necessary for interconnection, control or ventilation

3.2.10
transport unit
part of an assembly or a complete assembly suitable for transportation without being dismantled

3.2.11
shutter
part of an assembly which can be moved between:

– a position in which it permits engagement of the contacts of a removable part with fixed contacts, and
– a position in which it becomes a part of a cover or a partition shielding the fixed contacts

[SOURCE: IEC 60050-441:2000, 441-13-07, modified – The text has been editorially reformatted into two bullet points.]

3.2.101
metering unit
functional unit equipped with apparatus for metering electrical energy

3.2.102
transformer unit
functional unit consisting mainly of one or several transformers

3.3 External design of assemblies

3.3.1
open-type assembly
This term of IEC 61439-1:2020 does not apply.

3.3.2
dead-front assembly
This term of IEC 61439-1:2020 does not apply.

3.3.3
enclosed ACS
ACS which is enclosed on all sides with the possible exception of its mounting surface in such a manner as to provide a defined degree of protection

3.3.4
cubicle-type assembly
enclosed assembly of the floor-standing type, which may comprise several sections, sub-sections or compartments

3.3.5
multi-cubicle-type assembly
combination of a number of mechanically joined cubicle-type assemblies

3.3.6
desk-type assembly
enclosed assembly with a horizontal or inclined control panel, or a combination of both, that incorporates control, measuring, and signalling apparatus, etc.

3.3.7
box-type ACS
ENCLOSED ACS intended:

– either to be mounted on a vertical surface;
– or to stand on a horizontal surface supported by feet or legs (articulated or not) or by a mounting not forming part of the ACS (see 3.4.2 of IEC 61439-1:2020)

3.3.8
multi-box-type assembly
combination of box-type assemblies mechanically joined together, with or without a common supporting frame, the electrical connections passing between two adjacent boxes through openings in the adjoining faces

3.3.9
wall-mounted surface type assembly
assembly for installation on the surface of a wall

3.3.10
wall-mounted recessed type assembly
assembly for installation into a wall recess, where the enclosure does not support the portion of wall above

3.3.11
floor-standing assembly
assembly for installation on the floor

3.4 Structural parts of assemblies

3.4.1
supporting structure
structure forming part of an assembly designed to support various components of the assembly and any enclosure

3.4.2
mounting structure
structure not forming part of an assembly, designed to support an assembly

3.4.3
mounting plate
plate designed to support various components and suitable for installation in an assembly

3.4.4
mounting frame
framework designed to support various components and suitable for installation in an assembly

3.4.5
enclosure
housing affording the type and degree of protection suitable for the intended application

[SOURCE: IEC 60050-195:1998, 195-02-35]

3.4.6
cover
external part of the enclosure of an assembly

3.4.7
door
hinged or sliding cover

3.4.8
removable cover
cover which is designed for closing an opening in the external enclosure and which can be removed for carrying out certain operations and maintenance work

3.4.9
cover plate
part of an assembly which is used for closing an opening in the external enclosure and designed to be held in place by screws or similar means

Note 1 to entry: It is not normally removed after the equipment is put into service.

Note 2 to entry: The cover plate can be provided with cable entries.

3.4.10
partition
part of an assembly separating one compartment from other compartments

[SOURCE: IEC 60050-441:2000, 441-13-06]

3.4.11
barrier
part providing protection against direct contact from any usual direction of access

[SOURCE: IEC 60050-195:1998, 195-06-15, modified – "(electrically) protective" has been deleted from the term.]

3.4.12
obstacle
part preventing unintentional direct contact, but not preventing direct contact by deliberate action

Note 1 to entry: Obstacles are intended to prevent unintentional contact with live parts but not intentional contact by deliberate circumvention of the obstacle. They are intended to protect skilled, competent, authorised or instructed persons but are not intended to protect ordinary persons.

[SOURCE: IEC 60050-195:1998, 195-06-16, modified – "(electrically) protective" has been deleted from the term. Note 1 to entry has been added.]

3.4.13
terminal shield
part enclosing terminals and providing a defined degree of protection against access to live parts by persons or objects

3.4.14
cable entry
part with openings which permit the passage of cables into the assembly

3.4.15
protected space
part of an assembly intended to enclose electrical components, and which provides defined protection against external influences and contact with live parts

3.5 Conditions of installation of assemblies

3.5.1
assembly for indoor installation
This term of IEC 61439-1:2020 does not apply (see 3.1.101).

3.5.2
assembly for outdoor installation
This term of IEC 61439-1:2020 does not apply (see 3.1.101).

3.5.3
stationary assembly
This term of IEC 61439-1:2020 does not apply.

3.5.4
movable assembly
This term of IEC 61439-1:2020 does not apply.

3.5.101
transportable ACS
semi-fixed ACS
ACS intended for use in a place where it is not permanently fixed

Note 1 to entry: The location of a TRANSPORTABLE ACS can vary during work on the same site. When the equipment is moved to another place, it is first disconnected from the supply.

3.5.102
mobile ACS
ACS capable of being moved as work advances on the site, without being disconnected from the supply

3.6 Insulation characteristics

3.6.1
clearance
shortest distance in air between two conductive parts

Note 1 to entry: This distance can be measured along a string stretched the shortest way between these conductive parts.

[SOURCE: IEC 60050-581:2008, 581-27-76, modified – Note 1 to entry has been added.]

3.6.2
creepage distance
shortest distance along the surface of a solid insulating material between two conductive parts

Note 1 to entry: A joint between two pieces of solid insulating material is considered part of the surface.

[SOURCE: IEC 60050-151:2001, 151-15-50, modified – Note 1 to entry has been added.]

3.6.3
overvoltage
voltage having a peak value exceeding the corresponding peak value of maximum steady-state voltage at normal operating conditions

[SOURCE: IEC 60664-1:2007, 3.7]

3.6.4
temporary overvoltage
overvoltage at power frequency of several seconds duration

3.6.5
transient overvoltage
short duration overvoltage of a few milliseconds or less, oscillatory or non-oscillatory, usually highly damped

[SOURCE: IEC 60050-614:2016, 614-03-14, modified – In the definition, “short duration overvoltage” has replaced “overvoltage with a duration”. Note 1 to entry and Note 2 to entry have been deleted.]

3.6.6
power-frequency withstand voltage
RMS value of a power-frequency sinusoidal voltage which does not cause breakdown under specified conditions of test

[SOURCE: IEC 60947-1:2020, 3.7.55]

3.6.7
impulse withstand voltage
highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified conditions

[SOURCE: IEC 60050-442:2014, 442-09-18]

3.6.8
pollution
addition of foreign matter, solid, liquid, or gaseous that can result in a reduction of electric strength or surface resistivity of the insulation

[SOURCE: IEC 60050-442:1998, 442-01-28, modified – In the definition, “can produce a permanent reduction of dielectric strength” has been replaced with “can result in a reduction of electric strength” and Note 1 to entry was deleted.]

3.6.9
pollution degree
<of environmental conditions> conventional number based on the amount of conductive or hygroscopic dust, ionized gas or salt, and on the relative humidity and its frequency of occurrence resulting in hygroscopic absorption or condensation of moisture leading to reduction in dielectric strength and/or surface resistivity

Note 1 to entry: The pollution degree to which the insulating materials of devices and components are exposed may be different from that of the macro-environment where the assemblies are located because of protection offered by means such as an enclosure or internal heating to prevent absorption or condensation of moisture.

Note 2 to entry: For the purpose of this document, the pollution degree is of the micro-environment inside the assembly, unless otherwise stated in the applicable clause.

[SOURCE: IEC 60947-1:2020, 3.7.57, modified – Notes to entry have been adapted for the conditions associated with assemblies.]

3.6.10
environment

3.6.10.1
micro-environment
immediate environment of the insulation which particularly influences the dimensioning of the creepage distances

Note 1 to entry: It is the effect of the micro-environment on the creepage and/or clearance distance that determines the selection of the insulation within the assembly. The micro-environment may be better or worse than the macro-environment.

[SOURCE: IEC 60050-851:2008, 851-15-16, modified – Note 1 to entry has been added.]

3.6.10.2
macro-environment
environment of the room or other location in which the assembly is installed or used

[SOURCE: IEC 60050-442:2014, modified – In the definition, the term “equipment” has been replaced by “assembly”.]

3.6.11
overvoltage category
<of a circuit or within an electrical system> conventional number based on limiting (or controlling) the values of prospective transient overvoltages occurring in a circuit (or within an electrical system having different nominal voltages) and depending upon the means employed to influence the overvoltages

Note 1 to entry: In an electrical system, the transition from one overvoltage category to another of lower category is obtained through appropriate means complying with interface requirements, such as an overvoltage protective device or a series-shunt impedance arrangement capable of dissipating, absorbing, or diverting the energy in the associated surge current, to lower the transient overvoltage value to that of the desired lower overvoltage category.

[SOURCE: IEC 60947-1:2020, 3.7.59]

3.6.12
surge protective device
SPD
device designed to protect the electrical apparatus from high transient overvoltages and to limit the duration and frequently the amplitude of the follow-on current

[SOURCE: IEC 60947-1:2020, 3.4.22, modified – The term "surge arrester" was replaced with "surge protective device" and "SPD".]

3.6.13
insulation coordination
mutual correlation of insulating characteristics of electrical equipment taking into account the expected micro-environment and other influencing stresses

[SOURCE: IEC 60050-442:2014, modified – In the definition, ‘electrical’ has replaced ‘electric’.]

3.6.14
inhomogeneous field
electric field which has not an essentially constant voltage gradient between electrodes

[SOURCE: IEC 60947-1:2020, 3.7.62]

3.6.15
tracking
progressive formation of conducting paths which are produced on the surface of a solid insulating material, due to the combined effects of electric stress and electrolytic contamination on this surface

[SOURCE: IEC 60947-1:2020, 3.7.63]

3.6.16
comparative tracking index
CTI
numerical value of the maximum voltage in volts which a material can withstand without tracking and without a persistent flame occurring under specified test conditions

Note 1 to entry: The value of each test voltage and the CTI should be divisible by 25.

[SOURCE: IEC 60947-1:2020, 3.7.64, modified – Note 1 to entry has been added.]

3.6.17
disruptive discharge
phenomenon associated with the failure of insulation under electrical stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or nearly zero

Note 1 to entry: A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength; in a liquid or gaseous dielectric, the loss may be only temporary.

Note 2 to entry: The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid dielectric.

Note 3 to entry: The term "flashover" is used when a disruptive discharge occurs over the surface of a dielectric in a gaseous or liquid medium.

Note 4 to entry: The term "puncture" is used when a disruptive discharge occurs through a solid dielectric.

3.7 Protection against electric shock

3.7.1
live part
conductive part intended to be energized under normal conditions, including a neutral conductor or mid-point conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor

Note 1 to entry: This term does not necessarily imply a risk of electric shock. When the neutral conductor is effectively earthed it is not a hazardous live part and therefore not switched in TN-S or TN-C-S systems unless specifically required by other standards.

[SOURCE: IEC 61140:2016, 3.4, modified – Note 1 to entry has been replaced.]

3.7.2
hazardous live part
live part which, under certain conditions, can give a harmful electric shock

[SOURCE: IEC 61140:2016, 3.5, modified – Note 1 to entry was deleted.]

3.7.3
exposed-conductive-part
conductive part of the assembly, which can be touched and which is not normally live, but which can become live when basic insulation fails

Note 1 to entry: A conductive part of the assembly which can only become live through contact with an exposed-conductive-part which has become live, is not considered to be an exposed-conductive-part itself.

[SOURCE: IEC 60050-195:1998, 195-06-10, modified – In the definition, "equipment" has been replaced by "the assembly". Note 1 to entry has been added.]

3.7.4
protective conductor
PE
conductor provided for purposes of safety, for example protection against electric shock

Note 1 to entry: As an example, the protective conductor can electrically connect the following parts:

– exposed-conductive-parts;
– extraneous conductive parts;
– main earthing terminal;
– earth electrode;
– earthed point of the source or artificial neutral.

Note 2 to entry: A protective conductor is sometimes referred to a protective earthing conductor.

[SOURCE: IEC 60050-826:2004, 826-13-22, modified – The note 1 has been replaced and note 2 added.]

3.7.5
neutral conductor
N
conductor electrically connected to the neutral point and capable of contributing to the distribution of electrical energy

[SOURCE: IEC 60050-195:1998, 195-02-06, modified – The abbreviated term “N” has been added and "electric" was replaced with "electrical".]

3.7.6
PEN conductor
conductor combining the functions of both a protective earthing conductor and a neutral conductor

[SOURCE: IEC 60050-195:1998, 195-02-12]

3.7.7
fault current
current resulting from an insulation failure, the bridging of insulation or incorrect connection in an electrical circuit

3.7.8
basic protection
protection against electric shock under fault-free conditions

Note 1 to entry: Basic protection is intended to prevent contact with live parts and generally corresponds to protection against direct contact.

[SOURCE: IEC 60050-195:1998, 195-06-01 modified – Note 1 to entry has been added]

3.7.9
basic insulation
insulation of hazardous live parts, which provides basic protection

Note 1 to entry: This concept does not apply to insulation used exclusively for functional purposes.

[SOURCE: IEC 60050-826:2004, 826-12-14]

3.7.10
fault protection
protection against electric shock under single-fault conditions

Note 1 to entry: Failure of basic insulation (3.7.9) is an example of a single fault condition.

Note 2 to entry: Fault protection generally corresponds to protection against indirect contact, mainly regarding failure of basic insulation.

[SOURCE: IEC 60050-195:1998, 195-06-02, modified – The notes to entry have been added.]

3.7.11
PELV system
electric system in which the voltage cannot exceed the values given in IEC 60364-4-41:2005, Clause 414;

- under normal conditions and
- under single fault conditions, except earth faults in other electric circuits

Note 1 to entry: PELV is the abbreviation for protective extra low-voltage.

Note 2 to entry: The PELV circuits and/or exposed-conductive-parts of equipment supplied by the PELV circuits can be earthed.

[SOURCE: IEC 60050-826:2004, 826-12-32, modified – The IEC 60364-4-41:2005 reference has been added to the definition. Note 2 to entry has been added.]

3.7.12
SELV system
electric system in which the voltage cannot exceed the values given in IEC 60364-4-41:2005, Clause 414:

- under normal conditions and
- under single fault conditions, including earth faults in other electric circuits

Note 1 to entry: SELV is the abbreviation for safety extra low-voltage.

Note 2 to entry: SELV circuits have basic insulation between live parts and earth.

[SOURCE: IEC 60050-826:2004, 826-12-31, modified – The IEC 60364-4-41:2005 reference has been added to the definition. Note 2 to entry has been added.]

3.7.13
(electrically) skilled person
person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which electricity can create

[SOURCE: IEC 60050-826:2004, 826-18-01]

3.7.14
competent person
person who can judge the work assigned and recognize possible hazards on the basis of professional training, experience and knowledge of the relevant equipment

Note 1 to entry: Several years of practice in the relevant technical field may be taken into consideration in assessment of professional training.

[SOURCE: IEC 60050-851:2008, 851-11-10]

3.7.15
instructed person
person adequately advised or supervised by skilled persons to enable him or her to perceive risks and to avoid hazards electricity can create

[SOURCE: IEC 60050-826:2004, 826-18-02, modified – "(electrically)" was deleted from the main term.]

3.7.16
ordinary person
person who is neither a skilled person nor an instructed person

[SOURCE: IEC 60050-826:2004, 826-18-03]

3.7.17
authorized person
skilled or instructed person who is empowered to execute defined work

3.7.18
mid-point conductor
M
conductor electrically connected to the mid-point and capable of the transmission of electrical energy

Note 1 to entry: The term mid-point conductor is most frequently associated with DC applications.

[SOURCE: IEC 60050-195:1998, 195-02-07, modified – In the definition, "contributing to the distribution" has been replaced by "the transmission". Note 1 to entry has been added.]

3.7.19
PEM conductor
conductor combining the functions of both a protective earthing conductor and a mid-point conductor

[SOURCE: IEC 60050-195:1998, 195-02-13]

3.7.20
PEL conductor
conductor combining the functions of both a protective earthing conductor and a line conductor

[SOURCE: IEC 60050-195:1998, 195-02-14]

3.7.21
supplementary insulation
independent insulation applied in addition to basic insulation for fault protection

[SOURCE: IEC 60050-826:2004, 826-12-15]

3.7.22
double insulation
insulation comprising both basic insulation and supplementary insulation

[SOURCE: IEC 60050-826:2004, 826-12-16]

3.7.23
reinforced insulation
insulation of hazardous-live-parts which provides a degree of protection against electric shock equivalent to double insulation

Note 1 to entry: Reinforced insulation may comprise several layers which cannot be tested singly as basic insulation or supplementary insulation.

Note 2 to entry: Reinforced insulation complies with IEC 60664-1:2007.

[SOURCE: IEC 60050-826:2004, 826-12-17, modified – New Note 2 to entry.]

3.7.24
class I assembly
assembly with at least one provision for a basic protection and a connection to a protective conductor as provision for a fault protection

Note 1 to entry: See IEC 61140:2016, 7.3 for further details.

Note 2 to entry: A class I assembly can have an insulated enclosure for basic protection and a protective conductor to facilitate fault protection for external circuits supplied through the class I assembly.

3.7.25
class II assembly
assembly which is provided with the following;

– basic insulation as provision for basic protection, and
– supplementary insulation as provision for fault protection,

or in which;

– basic protection and fault protection are provided by reinforced insulation

Note 1 to entry: See IEC 61140:2016, 7.4

3.8 Characteristics

3.8.1
nominal value
value of a quantity used to designate and identify a component, device, equipment or system

Note 1 to entry: The nominal value is generally a rounded value.

[SOURCE: IEC 60050-151:2001, 151-16-09]

3.8.2
limiting value
in a specification of a component, device, equipment or system, the greatest or smallest admissible value of a quantity

[SOURCE: IEC 60050-151:2001, 151-16-10]

3.8.3
rated value
value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

[SOURCE: IEC 60050-151:2001, 151-16-08]

3.8.4
rating
set of rated values and operating conditions

[SOURCE: IEC 60050-151:2001, 151-16-11]

3.8.5
nominal voltage
approximate value of voltage used to designate or identify an electrical system

[SOURCE: IEC 60050-601:1985, 601-01-21, modified – Deletion of "(of a system)" from the term and addition of "electrical" in the definition.]

3.8.6
short-circuit current
I_c
overcurrent 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]

3.8.7
prospective short-circuit current
I_{cp}
current which would flow if the supply conductors to the circuit are short-circuited by a conductor of negligible impedance located as near as practicable to the supply terminals of the assembly

Note 1 to entry: For AC and DC applications, the current is the RMS value and the mean value in sustained conditions, respectively.

3.8.8
cut-off current
let-through current
I_{lt}
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]

3.8.9
voltage ratings

3.8.9.1
rated voltage
U_n
highest nominal voltage of the electrical system, declared by the assembly manufacturer, to which the main circuit(s) of the assembly is (are) designed to be connected

Note 1 to entry: In polyphase circuits, it is the voltage between lines.

Note 2 to entry: Transients are disregarded.

Note 3 to entry: The value of the supply voltage may exceed the rated voltage due to permissible system tolerances.

Note 4 to entry: The voltage is the RMS value and the mean value for AC and DC applications, respectively.

3.8.9.2
rated operational voltage
U_e
value of voltage, AC (RMS) or DC (mean value), declared by the assembly manufacturer for the assembly or a circuit of an assembly, which, combined with the rated current, determines its application

Note 1 to entry: In polyphase circuits, it is the voltage between lines.

3.8.9.3
rated insulation voltage
U_i
RMS withstand voltage value, assigned by the assembly manufacturer (3.10.2) to the assembly or to a circuit of an assembly, characterizing the specified (long-term) withstand capability of the insulation

Note 1 to entry: In polyphase circuits, it is the voltage between lines.

Note 2 to entry: The rated insulation voltage is not necessarily equal to the rated operational voltage of equipment, which is primarily related to functional performance.

[SOURCE: IEC 60664-1 2007, 3.9.1, modified – The symbol U_{i} has been added. In the definition, "manufacturer" has been replaced by "assembly manufacturer (3.10.2)" and 'equipment or to a part of it' has been replaced by 'assembly or to a circuit of an assembly'. Note 1 to entry has been added.]

3.8.9.4
rated impulse withstand voltage
U_{imp}
impulse withstand voltage value, assigned by the assembly manufacturer for an assembly or a circuit of an assembly, characterizing the specified withstand capability of the insulation against transient overvoltages

[SOURCE: IEC 60664-1 2007, 3.9.2, modified – "withstand" has been added to term; the symbol U_{imp} has been added. In the definition, 'to the equipment or to a part of it' has been replaced by 'for an assembly or a circuit of an assembly'.]

3.8.10
current ratings

3.8.10.1
rated current
value of uninterrupted current, declared by the assembly manufacturer which can be carried without the temperature-rise of various parts of the assembly exceeding specified limits under specified conditions

Note 1 to entry: For rated current of the assembly (I_{nA}) see 3.8.10.7 and 5.3.1; for rated current of a main circuit (I_{nc}) see 3.8.10.5 and 5.3.2; and for group rated current of a main circuit (I_{ng}) see 3.8.10.6 and 5.3.3.

Note 2 to entry: Normally it is not necessary to take into account the inrush currents for motors, transformers, etc. when determining the rated current of a circuit.

3.8.10.2
rated peak withstand current
I_{pk}
value of peak short-circuit current declared by the assembly manufacturer, that can be withstood under specified conditions

3.8.10.3
rated short-time withstand current
I_{cw}
RMS value of AC or mean value of DC short-time current, declared by the assembly manufacturer, that can be withstood under specified conditions, defined in terms of current and time

Note 1 to entry: Rated short-time withstand current is not the same as an internal arc fault rating as given in IEC TR 61641.

3.8.10.4
rated conditional short-circuit current
I_{cc}
value of the prospective short-circuit current, declared by the assembly manufacturer, that can be withstood for the total operating time (clearing time) of the SCPD under specified conditions

3.8.10.5
rated current of a main circuit
I_{nc}
rated current which a main circuit can carry when it is the only main circuit within a section of an assembly that is carrying current

Note 1 to entry: The rated current of a main circuit can be lower than the rated currents of the devices installed in the main circuit, according to the respective device standards.

Note 2 to entry: Due to the complex factors determining the rated currents, no standard values can be given.

Note 3 to entry: An assembly can comprise of only a single section.

3.8.10.6
group rated current of a main circuit
I_{ng}
rated current which a main circuit can carry considering the mutual thermal influences of the other circuits that are simultaneously loaded in the same section of the assembly

Note 1 to entry: I_{ng} can equal I_{nc} in some designs of assembly.

Note 2 to entry: An assembly can comprise only a single section.

3.8.10.7
rated current of an assembly
I_{nA}
rated current which can be distributed by an assembly without the temperature-rise of any of the parts exceeding specified limits

Note 1 to entry: The rated current of the assembly is not to be exceeded if further circuits are added in the future.

3.8.10.8
design current (of an electric circuit)
I_B
electric current intended to be carried by an electric circuit in normal operation

Note 1 to entry: I_B is normally provided by the user.

[SOURCE: IEC 60050-826:2004, 826-11-10, modified – Note 1 to entry has been added.]

3.8.11
rated diversity factor
RDF
value, calculated by dividing the group rated current of an outgoing main circuit I_{ng} by the rated current I_{nc} of the same outgoing main circuit, where I_{ng} and I_{nc} are derived by test

Note 1 to entry: RDF therefore represents the per unit value of I_{nc}, to which two or more outgoing circuits in the same section of an assembly can be continuously and simultaneously loaded taking into account the mutual thermal influences.

Note 2 to entry: For a group of circuits that are continuously and simultaneously loaded, the rated current of a circuit (I_{nc}) multiplied by the rated diversity factor (RDF) normally is not less than the design current (I_B) of the circuit normally provided by the user i.e. $I_{nc} \times \text{RDF} \geq I_B$.

3.8.12
rated frequency
f_n
value of frequency, declared by the assembly manufacturer, for which a circuit is designed and to which the operating conditions refer

Note 1 to entry: A circuit may be assigned a number or a range of rated frequencies or be rated for both AC and DC.

3.8.13
electromagnetic compatibility
EMC
ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

Note 1 to entry: For EMC related terms and definitions see Annex J.

[SOURCE: IEC 60050-161:2018, 161-01-07, modified – Note 1 to entry has been added.]

3.9 Verification

3.9.1
design verification
verification made on a sample of an assembly or on parts of assemblies to show that the design meets the requirements of the relevant assembly standard

Note 1 to entry: Design verification may comprise one or more equivalent methods. See 3.9.1.1, 3.9.1.2 and 3.9.1.3.

3.9.1.1
verification test
test conducted on a sample of an assembly or on parts of assemblies to verify that the design meets the requirements of the relevant assembly standard

Note 1 to entry: Verification tests are equivalent to type tests as in the IEC 60439 series of standards.

3.9.1.2
verification comparison
structured comparison of a proposed design for an assembly, or parts of an assembly, with a reference design(s) verified by test

3.9.1.3
verification assessment
design verification using strict design rules and/or calculations applied to an assembly or to parts of assemblies to show that the design meets the requirements of the relevant assembly standard

3.9.1.4
reference design
design of an assembly or parts of an assembly that has been verified by test

3.9.2
routine verification
verification of each assembly performed during and/or after manufacture to confirm whether it complies with the requirements of the relevant assembly standard

3.9.3
inspection
action comprising careful scrutiny, including visual scrutiny where conditions are obvious, of an item carried out either without dismantling, or with the addition of partial dismantling as required, supplemented by means such as measurement, in order to arrive at a reliable conclusion as to the condition of an item

[SOURCE: IEC 60050-426:2008, 426-14-02, modified – The definition has been modified.]

3.10 Manufacturer

3.10.1
original manufacturer
organization that has carried out the original design and the associated verification of an assembly in accordance with the relevant assembly standard

3.10.2
assembly manufacturer
organization taking the responsibility for the completed assembly

Note 1 to entry: The assembly manufacturer can be the same or a different organization to the original manufacturer.

3.11
user
party who will specify, purchase, use and/or operate the assembly, or someone acting on their behalf

3.101 Function of the ACS

3.101.1
incoming supply function
suitability for connection of the ACS either to electricity public supply network or to the transformer substation or to on site generator

3.101.2
metering function
suitability for the metering of electrical energy consumed on the site

3.101.3
distribution function
suitability to provide the distribution and protection of electrical supply on the construction site by means of terminal connection or socket-outlets

3.101.4
transformer function
suitability to provide means for transformer voltages or to provide measures of electrical protection

Note 1 to entry: Details for their requirements are given in 101.1.

4 Symbols and abbreviations

Alphabetical list of terms with symbols and abbreviations together with the subclause where they are first used:

Symbol/Abbreviation	Term	Term number
CTI	comparative tracking index	3.6.16
EMC	electromagnetic compatibility	3.8.13
f_n	rated frequency	3.8.12
I_c	short-circuit current	3.8.6
I_{cc}	rated conditional short-circuit current of an assembly or a circuit of an assembly	3.8.10.4
I_{lt}	cut-off current, let-through current	3.8.8
I_{cp}	prospective short-circuit current	3.8.7
I_{cw}	rated short-time withstand current	3.8.10.3
I_B	design current (of an electric circuit)	3.8.10.8
I_{nA}	rated current of an assembly	3.8.10.7
I_{nc}	rated current of a main circuit	3.8.10.5
I_{ng}	group rated current of a main circuit	3.8.10.6
I_{pk}	rated peak withstand current	3.8.10.2
L	line conductor	3.1.14
M	mid-point conductor	3.7.18
N	neutral conductor	3.7.5
PE	protective conductor	3.7.4
PEL	PEL conductor	3.7.20
PEM	PEM conductor	3.7.19
PELV	protective extra low-voltage	3.7.11
PEN	PEN conductor	3.7.6
RDF	rated diversity factor	3.8.11
SCPD	short-circuit protective device	3.1.11
SELV	safety extra low-voltage	3.7.12
SPD	surge protective device	3.6.12
U_e	rated operational voltage	3.8.9.2
U_i	rated insulation voltage	3.8.9.3
U_{imp}	rated impulse withstand voltage	3.8.9.4
U_n	rated voltage	3.8.9.1

5 Interface characteristics

5.1 General

The characteristics of the assembly shall ensure compatibility with the ratings of the circuits to which they are connected plus the installation conditions and shall be declared by the assembly manufacturer using the criteria identified in 5.2 to 5.6.

5.2 Voltage ratings

5.2.1 Rated voltage (U_n) (of the assembly)

The rated voltage shall be at least equal to the nominal voltage of the electrical system.

NOTE For further details on nominal system voltage see IEC 60038.

5.2.2 Rated operational voltage (U_e) (of a circuit of an assembly)

The rated operational voltage of any circuit shall not be less than the nominal voltage of the electrical system to which it is to be connected. If the nominal voltage is given for a three-phase system, the rated operational voltage of single-phase circuits shall not be less than the nominal voltage divided by √3.

If different from the rated voltage of the assembly, the appropriate rated operational voltage of the circuit shall be stated.

5.2.3 Rated insulation voltage (U_i) (of a circuit of an assembly)

The rated insulation voltage of a circuit of an assembly is the voltage value to which dielectric test voltages and creepage distances are referred.

The rated insulation voltage of a circuit shall be equal to or higher than the values stated for U_n and for U_e for the same circuit.

For single-phase circuits derived from IT systems (see IEC 60364-5-52:2009), the rated insulation voltage shall be at least equal to the voltage between the line conductors of the supply.

5.2.4 Rated impulse withstand voltage (U_{imp}) (of the assembly)

The rated impulse voltage of an assembly is the voltage value to which clearance distances and solid insulation withstand to transient overvoltage are referred.

The rated impulse withstand voltage shall be equal to or higher than the values stated for the transient overvoltages occurring in the electrical system(s) to which the circuit is designed to be connected.

The preferred values of rated impulse withstand voltage are those given in Table G.1.

5.3 Current ratings

5.3.1 Rated current of an ACS (I_{nA})

The rated current of an ACS is **group rated current I_{ng}** of its incoming circuit.

This current shall be carried without the temperature rise of the individual parts exceeding the limits specified in 9.2 of IEC 61439-1:2020.

5.3.2 Rated current of a main outgoing circuit (I_{nc})

The rated current of a main outgoing circuit is the current that can be carried by the outgoing circuit when all other outgoing main circuits in the same section are not carrying current (see 10.10). This current shall be carried without the temperature-rise of the various parts of the assembly exceeding the limits specified in 9.2.

Declaration of the rated current of a circuit I_{nc} is voluntary if the group rated current I_{ng} of the circuit is declared. If I_{nc} is stated, the maximum permissible continuous load current on an individual circuit in a lightly loaded section can be assessed and the load on the individual circuit possibly allowed to exceed I_{ng}, but it is never allowed to exceed I_{nc}

NOTE I_{ng} represents the maximum permissible continuous load current in a fully loaded section.

5.3.3 Group rated current of a main circuit (I_{ng})

The group rated current of a main circuit is the current that can be carried by this circuit when it is loaded continuously and simultaneously together with at least one other circuit in the same assembly or section of the assembly, in a specific arrangement as defined by the original manufacturer. It shall be carried without the temperature-rise of the various parts of the assembly exceeding the limits specified in 9.2.

NOTE 1 Where the RDF for a design of assembly has been established in accordance with previous edditons of IEC 61439 series, the I_{ng} can be calculated by I_{nc} × RDF.

If I_{ng} is declared, the original manufacturer shall state the specific arrangements which are covered by the group rated current in terms of:

- type(s), ratings and maximum number of circuits/functional units allowed to be installed in the same assembly or section, and
- arrangement(s) of functional units within the sections and/or assemblies.

NOTE 2 For a functional unit with a given I_{ng}, the specific arrangement of assembly or section of an assembly can also be stated in terms of power loss.

NOTE 3 In most cases the same type of section provided by an original manufacturer can be equipped with a varying number and different types of circuits (functional units), depending on the needs of a specific customer. Usually, not all circuits installed in a section are required to carry their rated currents continuously and simultaneously. Therefore, the specific arrangement defined by the original manufacturer clarifies which situations are covered by a declared value of I_{ng}.

The group rated current of the main circuits, which are continuously and simultaneously loaded, shall be equal to or higher than the assumed loading of the outgoing circuits (equal to the design current I_B according to IEC 60364-1). The group rated current of the main circuits, which are continuously and simultaneously loaded, shall be equal to or higher than the assumed loading of the outgoing circuits (equal to the design current of the circuit, I_B, according to IEC 60364-1).

The assumed loading of outgoing circuits shall be addressed by the relevant assembly standard.

NOTE 4 The assumed loading of the outgoing circuits can be a steady continuous current or the thermal equivalent of a varying current (see Annex I).

I_{ng} is obtained by a test according to 10.10.2.3.5 or 10.10.2.3.6 or 10.10.2.3.7, or by calculation according to 10.10.4. Using method 10.10.2.3.6 or 10.10.2.3.7, I_{ng} values are required to calculate the RDF.

An alternative to declaring I_{ng} for each type of main circuit is to declare I_{nc} for each type of main circuit and the appropriate RDF.

5.3.4 Rated peak withstand current (I_{pk})

The rated peak withstand current shall be equal to or higher than the values stated for the peak value of the prospective short-circuit current of the supply system(s) to which the circuit(s) is (are) designed to be connected (see also 9.3.3).

5.3.5 Rated short-time withstand current (I_{cw}) (of a main circuit of an assembly)

The rated short-time withstand current of a main circuit of an assembly shall be equal to or higher than the prospective value of the short-circuit current I_{cp} at each point of connection to the supply (see also 3.8.10.3).

Different values of I_{cw} for different durations (e.g. 0,2 s; 1 s; 3 s) may be assigned to an assembly. Maximum duration normally does not exceed 1 s.

For AC, the value of the current is the RMS value of the AC component. For DC, the value of the current is the arithmetic mean value.

5.3.6 Rated conditional short-circuit current (I_{cc}) (of an assembly or a circuit of an assembly)

The rated conditional short-circuit current of an assembly or a circuit of an assembly, declared by the assembly manufacturer, is the maximum short-circuit current which that circuit when protected by a SCPD, as specified by the manufacturer, can satisfactorily withstand for the operating time of the device under the test conditions specified in 10.11.

The rated conditional short-circuit current of an assembly or a circuit of an assembly shall be equal to or higher than the prospective value of the short-circuit current I_{cp} for a duration limited by the operation of the short-circuit protective device that protects the circuit or assembly. The assembly manufacturer shall declare the breaking capacity, current limitation characteristics, I^2t and I_{lt}, of the specified short-circuit protective device, taking into consideration the data given by the device manufacturer.

5.4 Rated diversity factor (RDF)

As an alternative to declaring the group rated currents I_{ng} of each main outgoing circuit, their current carrying capacity under conditions of simultaneous operation can be stated in terms of the rated currents I_{nc} and the rated diversity factor.

The rated diversity factor is the per unit value of I_{nc}, to which outgoing circuits can be continuously and simultaneously loaded in the same section of the assembly in the specific arrangement(s) as defined by the original manufacturer, taking into account the mutual thermal influences. For further details on the specific arrangements, see 5.3.3.

NOTE 1 More information on RDF is given in Annex E.

The rated diversity factor multiplied by the rated current I_{nc} of the circuits shall be equal to or higher than the assumed loading of the outgoing circuits, where the assumed load current is equal to the design current I_B for continuously and simultaneously loaded circuits. If the design current I_B is not provided then the assumed loading of outgoing circuits shall be as given in the relevant assembly standard of IEC 61439 and is subject to agreement between user and manufacturer.

NOTE 2 The assumed loading of the outgoing circuits can be a steady continuous current or the thermal equivalent of a varying current (see Annex I).

The assumed loading of the outgoing circuits of the ACS or group of outgoing circuits shall be declared by the assembly manufacturer and can be based on the values in Table 101.

When the manufacturer does not declare any RDF, the values of Table 101 apply.

5.5 Rated frequency (f_n)

The rated frequency of a circuit is the value of frequency to which the operating conditions are referred. Where the circuits of an assembly are designed for different values of frequency, the rated frequency of each circuit shall be given.

The frequency should be within the limits specified in the relevant IEC standards for the incorporated components. Unless otherwise stated by the assembly manufacturer, the limits are assumed to be 98 % and 102 % of the rated frequency.

5.6 Other characteristics

The following characteristics shall be declared:

a) the function(s) assigned by the manufacturer (see 3.101);
b) the external design (see 3.3);
c) the mobility (see 3.5.101 and 3.5.102);
d) the degree of protection (see 8.2);
e) the method of mounting, for example fixed or removable parts (see 8.5.1 and 8.5.2);
f) protection against electric shock (see 8.4);
g) the resistance to corrosion (see 10.2.2.101);
h) special service conditions, if applicable (see 7.2);
i) electromagnetic compatibility (EMC) classification (see Annex J of IEC 61439-1:2020).

6 Information

6.1 ACS designation marking

The assembly manufacturer shall provide each ACS with one or more labels, marked in a durable manner and located in a place such that they are visible and legible when the ACS is installed and in operation.

Compliance is checked according to the test of 10.2.7 and by inspection.

The following information regarding the ACS shall be provided on the label(s):

a) assembly manufacturer's name or trade mark (see 3.10.2);
b) type designation or identification number or any other means of identification, making it possible to obtain relevant information from the assembly manufacturer;
c) means of identifying date of manufacture;
d) IEC 61439-4;
e) type of current (and the frequency in the case of AC);
f) rated voltage (U_n) (of the ACS) (see 5.2.1);
g) rated current of the ACS (I_{nA}) (see 5.3.1);
h) degree of protection (see 8.2);
i) the weight where this exceeds 30 kg.

If the indication of the name or trademark of the manufacturer appears on the ACS, it shall not be given on the nameplate.

6.2 Documentation

6.2.1 Information relating to the ACS

The following additional information, where applicable, shall be provided in the assembly manufacturer’s technical documentation supplied with the ACS:

a) rated operational voltage (U_e) (of a circuit) (see 5.2.2);
b) rated impulse withstand voltage (U_{imp}) (see 5.2.4);
c) rated insulation voltage (U_i) (see 5.2.3);
d) rated current of each circuit (I_{nc}) (see 5.3.2);
e) rated peak withstand current (I_{pk}) (see 5.3.4);
f) rated short-time withstand current (I_{cw}) together with its duration (see 5.3.4);
g) rated conditional short-circuit current (I_{cc}) (see 5.3.5);
h) rated frequency (f_n) (see 5.5);

i) rated diversity factor(s) (RDF) (see 5.4);

j) functions (see 3.101);

k) all necessary information relating to the other declared classifications and characteristics (see 5.6);

l) the short-circuit withstand strength and characteristics of short-circuit protective device(s) (see 9.3.2);

m) overall dimensions (including projections e.g handles, covers, doors).

6.2.2 Instructions for handling, installation, operation and maintenance

The assembly manufacturer shall provide in documents or catalogues the conditions, if any, for the handling, installation, operation and maintenance of the assembly and the equipment contained therein. Where appropriate, instructions shall state that the assembly manufacturer is to be consulted when repair of an assembly is required.

If necessary, the instructions shall indicate the measures that are of particular importance for the safe, proper and correct transport, handling, installation and operation of the assembly. The provision of weight details is of particular importance in connection with the transport and handling of transport units. In addition, installation instructions shall provide sufficient details for the installer to adequately secure the assembly in service.

The correct location and installation of lifting means and the thread size of lifting attachments, if applicable, shall be given in the assembly manufacturer's documentation or the instructions on how the transport unit has to be handled.

The measures to be taken, if any, with regard to EMC associated with the installation, operation and maintenance of the assembly shall be specified (see Annex J).

If an assembly specifically intended for environment A is to be used in environment B, a warning shall be included in the operating instructions, in accordance with the following:

CAUTION
This product has been designed for environment A. Use of this product in environment B can cause unwanted electromagnetic disturbances, in which case the user may be required to take adequate mitigation measures.

Where necessary, the above-mentioned documents shall indicate the recommended extent and frequency of maintenance.

If the circuitry within the assembly is not obvious, for example, there are connections from several incoming power-supplies such as photovoltaic supplies, generators, batteries, information detailing the circuit arrangements shall be supplied.

When fuses are installed, the assembly manufacturer shall state the type and rating of the fuse-links to be used.

The manufacturer of the ACS should specify in its technical documentation supplied with the ACS the other types of assemblies which can be connected to it. This information should indicate whether the compatibility is based upon the type of system earthing employed and/or on the need for co-ordination of the electrical protection within the complete installation.

The manufacturer should furnish the appropriate documentation for the purpose to maintain the protective measures and the co-ordination of the protective devices within the complete installation.

6.3 Device and/or component identification

Inside the assembly, it shall be possible to identify individual circuits and their protective devices. Identification tags shall be legible, permanent and appropriate for the physical environment. Any designations used shall be in compliance with IEC 81346-1:2009 and IEC 81346-2:2019 and identical to those used in the wiring diagrams, which shall be in accordance with IEC 61082-1:2014.

7 Service conditions

7.1 Normal service conditions

7.1.1 Climatic conditions

Assemblies conforming to this document are intended for use under the normal service conditions detailed in Table 15.

If components, for example relays, electronic equipment, are used which are not designed for these conditions, the environment provided within the assembly shall be suitable for the components.

7.1.2 Pollution degree

The pollution degree referred to in Annex C is the macro-environmental condition for which the assembly is intended.

For switching devices and components inside an enclosure, the pollution degree of the environmental conditions inside the enclosure, the micro-environment, is applicable.

For the purpose of evaluating clearances and creepage distances, the following four degrees of pollution in the micro-environment are established.

- Pollution degree 1:

  No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.
- Pollution degree 2:

  Only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected.
- Pollution degree 3:

  Conductive pollution occurs, or dry, non-conductive pollution occurs which is expected to become conductive due to condensation.
- Pollution degree 4:

  Continuous conductivity occurs due to conductive dust, rain or other wet conditions.

Pollution degree 4 is not applicable to this document for a micro-environment inside the assembly.

Only pollution degrees 3 and 4 are applicable.

The microenvironment can be reduced to pollution degree 2 if the degree of protection of the enclosure is at least IP5X and care is taken to avoid condensation.

NOTE The pollution degree of the micro-environment for the equipment can be influenced by installation in an enclosure. When there is a need to open the assembly for normal service or operation the macro-environment of the installation can have an effect on the micro-environment.

7.2 Special service conditions

Where any special service conditions exist, the applicable particular requirements shall be complied with or special agreements shall be made between the assembly manufacturer and the user. The user shall inform the assembly manufacturer if such exceptional service conditions exist.

Special service conditions include, for example:

a) values of temperature, relative humidity and/or altitude differing from those specified in 7.1;

b) applications where variations in climatic conditions are likely to result in exceptional condensation inside the assembly;

c) heavy pollution of the air by dust, smoke, corrosive or radioactive particles, vapours or salt;

d) exposure to strong electric or magnetic fields;

e) exposure to extreme climatic conditions;

f) attack by fungus or small creatures;

g) installation in locations where fire or explosion hazards exist;

h) exposure to heavy vibration, shocks, seismic occurrences;

i) installation in such a manner that the current-carrying capacity is affected, for example equipment built into machines or recessed into walls;

j) exposure to conducted and radiated disturbances other than electromagnetic, and electromagnetic disturbances in environments other than those described in 9.4;

k) exceptional overvoltage conditions or voltage fluctuations;

l) excessive harmonics in the supply voltage or load current;

m) exposure to radiation (for example, X-rays, microwave, ultraviolet other than solar, lasers);

n) heavily polluted atmosphere.

7.3 Conditions during transport, storage and installation

A special agreement shall be made between the assembly manufacturer and the user if the conditions during transport, storage and installation, for example temperature and humidity conditions, differ from those defined in 7.1.

8 Constructional requirements

8.1 Strength of materials and parts

8.1.1 General

Under the responsibility of the original manufacturer, all design activities shall be carried out or supervised by a competent person.

The external shape of the assembly enclosure, if any, can vary to suit the application and use. Some examples are;

- cubicle-type assembly (see 3.3.4);
- multi-cubicle-type assembly (see 3.3.5);
- desk-type assembly (see 3.3.6);
- box-type assembly (see 3.3.7);
- multi-box-type assembly (see 3.3.8);
- wall-mounted surface type assembly (see 3.3.9);

- wall-mounted recessed type assembly (see 3.3.10); and
- floor-standing type assembly (3.3.11).

These enclosures may be constructed from various materials, e.g. insulating, metallic or a combination of these.

Assemblies shall be constructed of materials capable of withstanding the mechanical, electrical, thermal and environmental stresses that are likely to be encountered in specified service conditions.

In the case of special service conditions that can be present in the physical environment in which the assembly is to be installed (for example, dust, acids, corrosive gases, salts), the assemblies shall be adequately protected against contaminants (see Annex C). When the assembly is subject to radiation (for example, X-rays, microwave, ultraviolet, lasers), additional measures shall be taken to avoid malfunctioning of the assembly and accelerated deterioration of the insulation. When such measures are necessary, an agreement is required between the assembly manufacturer and the user.

When the assembly is subject to undesirable effects of vibration or shock, e.g. caused by a machine and its associated equipment, the selection of suitable equipment, or mounting it away from the source of the vibration, or the provision of anti-vibration mountings shall be considered.

All the apparatus shall be placed inside the enclosure fitted with such removable panels, cover plates or doors as applicable for connection or maintenance with the possible exception of the items mentioned in 8.101 provided that they withstand the service conditions of Clause 7 and the requirements of 8.1.2 and 8.1.6.

8.1.2 Protection against corrosion

Protection against corrosion shall be ensured by the use of suitable materials or by protective coatings to the exposed surface taking account of the normal service conditions (see 7.1) and/or special service condition (see 7.2). Compliance to this requirement is checked by the test of 10.2.2.

8.1.3 Properties of insulating materials

8.1.3.1 Thermal stability

Enclosures or parts of enclosures made of insulating material(s), not already certified to their own product standard, e.g. louvers, meshes, shall be capable of operation at temperatures of at least 70 °C. Thermal stability shall be verified according to 10.2.3.1.

8.1.3.2 Resistance of insulating materials to heat and fire

8.1.3.2.1 General

Parts of insulating materials, which can be exposed to thermal stresses due to internal electrical effects, and the deterioration of which can impair the safety of the assembly, shall not be adversely affected by normal (operational) heat, and abnormal heat or fire.

8.1.3.2.2 Resistance of insulating materials to normal heat

The original manufacturer shall select insulating materials which are suitable for the maximum temperatures to which they are exposed in normal operation, in accordance with 9.2 and Table 6. The applied temperature-rise limit (see 9.2) for parts of insulating materials shall be justified based on, for example, the methods of IEC 60216 (all parts), or thermal class identified in accordance with IEC 60085:2007.

NOTE With recognition of the differences to other methods, insulating materials can also be selected based on the relative thermal index (RTI), UL 746B.

8.1.3.2.3 Resistance of insulating materials to abnormal heat and fire due to internal electric effects

Insulating materials used for parts necessary to retain current carrying parts in position and parts which can be exposed to thermal stresses due to internal electrical effects, of which the deterioration can impair the safety of the assembly, shall not be adversely affected by abnormal heat and fire and shall be verified by the glow-wire test in 10.2.3.2. For the purpose of this test, a protective conductor (PE) is not considered as a current-carrying part.

8.1.4 Resistance to ultra-violet (UV) radiation

For enclosures and external parts made of insulating materials, resistance to ultra-violet radiation shall be verified according to 10.2.4.

For external parts made of insulating material of components covered by other IEC standard (for examples socket-outlets, handles of switch, push buttons, etc.), this test is not required.

NOTE For assemblies exposed to UV radiation, other than solar radiation, the means of verification for resistance of the enclosures and external parts made of insulating material or external metal parts that are coated on their exposed surface(s) by synthetic material, are subject to agreement between the user and the manufacturer.

8.1.5 Mechanical strength

All enclosures or partitions, including locking means and hinges for doors, shall be of a mechanical strength sufficient to withstand the stresses to which they may be subjected in normal service, (see also 10.2.8) and during short-circuit conditions (see also 10.11).

The mechanical operation of removable parts, including any insertion interlock, shall be verified by test according to 10.2.8.

The ACS shall be constructed to withstand mechanical shocks having an acceleration of 500 m/s^2, a pulse shape of a half-sine wave of 11 ms duration (commensurate with equipment being carried loose in normal road or rail vehicles for long periods).

Compliance is verified according to 10.2.6.

8.1.6 Lifting provision

Lifting rings and/or handles (or any other equivalent system) shall be provided on the ACS and be firmly attached to the enclosure or supporting framework.

Compliance is checked according to the test of 10.2.5.

8.2 Degree of protection provided by an assembly enclosure

8.2.1 Protection against mechanical impact (IK code)

The minimum degree of protection provided by an assembly enclosure against mechanical impact, if necessary, shall be defined by the relevant assembly standards.

Compliance is verified according to 10.2.6.

The ACS shall also withstand impacts of 6 joules energy representing collisions with site construction mechanical handling equipment (see IEC 60068-2-27).

For protection against mechanical impact refer to 10.2.6.

NOTE In addition to 8.2.1, It is possible to make reference also to the IK code in case the enclosure has been tested according to other IEC 61439 parts.

8.2.2 Protection against contact with live parts, ingress of solid foreign bodies and water (IP code)

The degree of protection provided by an ACS against contact with live parts, ingress of solid foreign bodies and water is indicated by the IP code according to IEC 60529 and verified according to 10.3.

The degree of protection of the ACS shall be at least IP 44, with all doors closed and all removable panels and cover plates fitted.

Ventilation and drainage holes shall not reduce this degree of protection.

The degree of protection for an operating face inside a door shall be not less than IP 21 provided that the door can be closed under all conditions of use. Where the door cannot be closed the degree of protection for the operating face shall be at least IP 44.

Unless otherwise specified, the degree of protection indicated by the original manufacturer applies to the complete ACS, when it is installed in accordance with the original manufacturer's instructions.

Socket-outlets not protected by the enclosure of the ACS shall have a degree of protection at least equivalent to IP 44, both when the plug is removed or fully inserted.

Where the ACS does not have the same IP rating throughout, the original manufacturer shall declare in its technical documentation supplied with the ACS the IP rating for the separate parts. Example: IP 44, operating face IP 21.

No IP codes can be given unless the appropriate verifications have been made according to 10.3.

8.2.3 Assembly with removable parts

The degree of protection (IP) indicated for assemblies normally applies to the connected position (see 3.2.3) of the removable parts.

If, after the removal of a removable part, it is not possible to maintain the original degree of protection (e.g. by closing a door), the assembly manufacturer shall make available covers or similar to restore the original degree of protection. If these measures are not available, the IP tests shall be carried out without the removable part in place.

When shutters are used to provide adequate protection to live parts, they shall be secured to prevent unintentional removal.

8.3 Clearances and creepage distances

8.3.1 General

The requirements for clearances and creepage distances are based on the principles of IEC 60664-1:2007 and are intended to provide insulation coordination within the installation.

NOTE Further information is available in IEC TR 60664-2-1:2011.

The clearances and creepage distances of equipment that form part of the assembly shall comply with the requirements of the relevant product standard.

When incorporating equipment into the assembly, the specified clearances and creepage distances shall be maintained during normal service conditions.

For dimensioning clearances and creepage distances between separate circuits, the highest voltage ratings shall be used (rated impulse withstand voltage for clearances and rated insulation voltage for creepage distances).

The clearances and creepage distances apply to line to line, line to neutral, and, except where a conductor is connected directly to earth, line to earth and neutral to earth.

For bare live conductors and terminations, the clearances and creepage distances shall at least be equivalent to those specified for the equipment with which they are directly associated.

The effect of a short-circuit up to and including the declared rating(s) of the assembly shall not reduce permanently the clearances or creepage distances between busbars and/or connections below the values specified for the assembly. Deformation of parts of the enclosure or of the internal partitions, barriers and obstacles due to a short-circuit shall not reduce permanently the clearances or creepage distances below those specified in 8.3.2 and 8.3.3 (see also 10.11.5.5).

8.3.2 Clearances

The clearances shall be sufficient to enable the declared rated impulse withstand voltage (U_{imp}) of a circuit to be achieved. The clearances shall be at least as specified in Table 1; if not, a design verification test and a routine impulse withstand voltage test are carried out in accordance with 10.9.3 and 11.3, respectively.

The method of determining clearances by measurement is given in Annex F.

8.3.3 Creepage distances

The original manufacturer shall select a rated insulation voltage(s) (U_i) for the circuits of the assembly from which the creepage distance(s) shall be determined. For any given circuit, the rated insulation voltage shall not be less than the rated operational voltage (U_e).

The creepage distances shall not, in any case, be less than the associated minimum clearances.

Creepage distances shall correspond to a pollution degree as specified in 7.1.2 and to the corresponding material group at the rated insulation voltage given in Table 2.

The method of determining creepage distances by measurement is given in Annex F.

For inorganic insulating materials, e.g. glass or ceramics, which do not track, creepage distances need not be greater than their associated clearances. However, the risk of disruptive discharge should be considered.

By using ribs of a minimum height of 2 mm, the creepage distance may be reduced but, irrespective of the number of ribs, shall be not less than 0,8 times the value of Table 2 and not less than the associated minimum clearance. The minimum base of the rib is determined by mechanical requirements (see Clause F.2).

8.4 Protection against electric shock

8.4.1 General

The apparatus and circuits in the assembly shall be so arranged as to facilitate their operation and maintenance with the required protection against electric shock.

The following requirements are intended to ensure that the required protective measures are obtained when an assembly is installed in an electrical system conforming to the IEC 60364 series.

NOTE For generally accepted protective measures, refer to IEC 61140:2016 and IEC 60364-4-41:2005, and IEC 60364-4-41:2005/AMD1:2017.

Those protective measures, which are of particular importance for an assembly, are reproduced in 8.4.2 to 8.4.6.

8.4.2 Basic protection

8.4.2.1 General

Basic protection is intended to provide protection against electric shock under normal conditions, preventing direct contact with hazardous live parts.

Basic protection can be achieved either by appropriate constructional measures on the assembly itself or by additional measures to be taken during installation; this may require information to be given by the assembly manufacturer.

An example of additional measures to be taken is the installation of an open-type assembly without further provisions in a location where access is only permitted for authorized person(s).

Where basic protection is achieved by constructional measures, one or more of the protective measures given in 8.4.2.2 and 8.4.2.3 may be selected. The choice of the protective measure shall be declared by the assembly manufacturer if not specified within the relevant assembly standard.

8.4.2.2 Basic insulation provided by insulating material

Hazardous live parts shall be completely covered with insulation that can only be removed by destruction or by the use of a tool.

The insulation shall be made of suitable materials capable of durably withstanding the mechanical, electrical and thermal stresses to which the insulation may be subjected in service.

EXAMPLES Electrical devices embedded in insulation and insulated conductors.

Paints, varnishes and lacquers alone are generally not considered to satisfy the requirements for basic insulation. This does not preclude the use of specifically designed insulating coatings that fulfil the dielectric requirements specified in 10.9.6.

8.4.2.3 Barriers or enclosures

Air-insulated live parts shall be inside enclosures or behind barriers. The enclosures or barriers shall provide a degree of protection of at least IPXXB.

Horizontal top surfaces of accessible enclosures having a height equal to or lower than 1,6 m above the standing area shall provide a degree of protection of at least IPXXD.

Barriers and enclosures shall be firmly secured in place and have sufficient stability and durability to maintain the required degrees of protection and appropriate separation from live parts under normal service conditions, taking account of relevant external influences. The distance between a conductive barrier or enclosure and the live parts they protect shall not be less than the values specified for the clearances and creepage distances in 8.3.

Where it is necessary to remove barriers or open enclosures or to remove parts of enclosures (see 8.4.6), this shall be possible only if one of the conditions a) to c) is fulfilled.

a) By the use of a key or tool, i.e. any mechanical aid, to open the door, cover or override an interlock.

b) After isolation of the supply to live parts, against which the barriers or enclosures afford basic protection, restoration of the supply being possible only after replacement or reclosure of the barriers or enclosures. In TN-C and TN-C-S systems, the PEL, PEM or PEN conductor shall not be isolated or switched. In TN-S and TN-C-S systems, the mid-point and neutral conductors need not be isolated or switched (see IEC 60364-5-53:2001, 536.1.2).

   EXAMPLE By interlocking the door(s) with a disconnector so that they can only be opened when the disconnector is in the isolated position and closing of the disconnector without the use of a tool is impossible while the door is open.

c) Where an intermediate barrier providing a degree of protection of at least IPXXB prevents contact with live parts, such a barrier being removable only by the use of a key or tool.

8.4.3 Fault protection

8.4.3.1 Installation conditions

The ACS shall include protective measures and be suitable for installations designed to be in accordance with IEC 60364-7-704:2017.

Such provisions are subject to agreement between the user and the manufacturer.

8.4.3.2 Requirements for the protective conductor to facilitate automatic disconnection of the supply

8.4.3.2.1 General

Each assembly shall have a protective conductor to facilitate automatic disconnection of the supply for:

a) protection against the consequences of earth faults within the class I assembly;

b) protection against the consequences of earth faults in external circuits supplied through the class I and class II assembly. In the case of a class II assembly, the protective conductor may or may not be incorporated within the assembly: it is permissible for it to pass the assembly externally.

NOTE The enclosure can be or be part of the protective circuit.

The requirements to be complied with are given in 8.4.3.2.2 and 8.4.3.2.3.

Requirements for identification of the protective conductor (PE, PEN, PEM, PEL) are given in 8.6.6.

8.4.3.2.2 Requirements for earth continuity providing protection against the consequences of faults within the class I assembly

All exposed-conductive-parts of the assembly shall be interconnected together and to the protective conductor of the supply or via an earthing conductor to the earthing arrangement.

These interconnections may be achieved either by metal screwed connections, welding or other conductive connections, or by a separate conductor providing earth continuity.

With metal parts of the assembly where abrasion-resistant finishes are used (e.g. gland plates with powder coatings), interconnections providing earth continuity requires the removal or the penetration of the coating.

The method to verify the earth continuity between the exposed-conductive-parts of the assembly and the protective conductor is given in 10.5.2.

For the continuity of these connections, the following shall apply:

a) When a part of the assembly is removed, for example for routine maintenance, the earth continuity for the remainder of the assembly shall not be interrupted.

   Means used for assembling the various metal parts of an assembly are considered sufficient for ensuring earth continuity if the precautions taken guarantee permanent good conductivity.

   Flexible or pliable metal conduits shall not be used as protective conductors unless they are designed for that purpose.

b) For lids, doors, cover plates and the like, the usual metal screwed connections and metal hinges are considered sufficient to ensure continuity provided that no electrical equipment is attached to them except equipment which is part of a PELV or SELV system.

If devices with a voltage exceeding the limits of PELV or SELV systems, as appropriate, are attached to lids, doors, or cover plates, additional measures shall be taken to ensure earth continuity. These parts (lids, doors or covers) shall be fitted with a protective conductor (PE) whose cross-sectional area is in accordance with Table 3 depending on the highest rated operational current I_e of the devices attached. Alternatively, if the rated operational current of the attached devices is less than or equal to 16 A an equivalent electrical connection specifically designed and verified for this purpose shall be provided (e.g. sliding contact, hinges protected against corrosion).

Exposed conductive parts of a device that cannot be interconnected for earthing continuity by the fixing means of the device shall be connected to the earthing arrangement of the assembly by a conductor whose cross-sectional area is chosen according to Table 3.

Certain exposed-conductive-parts of an assembly that do not constitute a danger need not be connected to the earthing arrangement, either;

– because they cannot be touched on large surfaces or grasped with the hand; or
– because they are of small size (approximately 50 mm by 50 mm) or so located as to exclude any contact with live parts.

This applies to screws, rivets and nameplates. It also applies to electromagnets of contactors or relays, magnetic cores of transformers, certain parts of releases, or similar, irrespective of their size.

When removable parts are equipped with a metal supporting surface, these surfaces shall be considered sufficient for ensuring earth continuity provided that the pressure exerted on them is sufficiently high.

8.4.3.2.3 Requirements for protective conductors providing protection against the consequences of earth faults in external circuits supplied through the class I or class II assemblies

A protective conductor within the assembly shall be designed so that it can withstand the highest thermal and dynamic stresses arising from earth fault currents in external circuits supplied through the assembly in its installed location. Conductive structural parts may be used as a protective conductor or a part of it. Additional requirements for protective conductors for class II assemblies are given in 8.4.4 c).

Except where verification of the short-circuit withstand strength is not required in accordance with 10.11.2, verification shall be made in accordance with 10.5.3.

In principle, with the exception of the cases mentioned below, protective conductors within an assembly shall not include a disconnecting device (switch, disconnector, etc.).

– In the run of protective conductors, links shall be permitted which are removable by means of a tool and accessible only to authorized person(s) (these links may be required for certain tests).
– Where continuity can be interrupted by means of connectors or plug-and-socket devices, the protective circuit shall be interrupted only after the live conductors have been interrupted and continuity shall be established before the live conductors are reconnected.

In the case of an assembly containing structural parts, frameworks, enclosures, etc. made of conducting materials, a protective conductor, if provided, need not be insulated from these parts. Conductors to voltage-operated fault detection devices, including the conductors connecting them to a separate earth electrode, shall be insulated when specified by their manufacturer. This can also apply to the earth connection of the transformer neutral.

The cross-sectional area of protective conductors (PE, PEL, PEM, PEN) in an assembly to which external conductors are intended to be connected shall be not less than the value calculated with the aid of the formula indicated in Annex B using the highest earth fault current and fault duration that may occur and taking into account the limitation of the SCPDs that protect the corresponding live conductors. The short-circuit withstand strength is verified according to 10.5.3.

For PEL, PEM and PEN conductors, the following additional requirements apply.

– The minimum cross-sectional area shall be 10 mm^2 for copper or 16 mm^2 for aluminium.
– The PEN and PEM conductor shall have a cross-sectional area not less than that required for a neutral and mid-point conductor (see 8.6.1).
– The PEN, PEL and PEM conductors need not be insulated within a class I assembly.
– Structural parts shall not be used as a PEN, PEL and PEM conductor; however, mounting rails according to IEC 60947-7-2:2009, Annex A, made of copper or aluminium may be used.

For details of requirements for terminals for external protective conductors, see 8.8.

8.4.3.3 Electrical separation

Electrical separation of individual circuits is intended to prevent electrical shock through contact with exposed-conductive-parts, which can become live when basic insulation of the circuit fails.

For this type of protection, see IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017.

8.4.4 Additional requirements for class II assemblies

a) For basic and fault protection, by double or reinforced insulation, the following additional requirements shall be met.The electrical equipment shall be enclosed in insulating material which is equivalent of double or reinforced insulation. The enclosure shall carry the symbol ☐ which shall be visible from the outside of the protected space.

NOTE 1 The enclosure can be the protected space or the protected space can be behind a barrier behind the door of an enclosure.

NOTE 2 The requirement of a class II assembly can be fulfilled by means of a metal enclosure separated from hazardous live parts and protective PEL, PEM and PEN conductors by double or reinforced insulation.

b) The enclosure shall at no point be pierced by conducting parts in such a manner that there is the possibility of a fault voltage being brought out of the enclosure.

This means that metal parts, such as actuator shafts that, for constructional reasons, have to be brought through the enclosure, shall be insulated on the inside or the outside of the enclosure from the live parts for the maximum rated insulation voltage and the maximum rated impulse withstand voltage of all circuits in the assembly.

If an actuator, or similar, is made of metal (whether covered by insulating material or not), it shall be provided with insulation rated for the maximum rated insulation voltage and the maximum impulse withstand voltage of all circuits in the assembly.

c) If an actuator, or similar, is principally made of insulating material, any of its metal parts which may become accessible in the event of insulation failure shall also be insulated from live parts for the maximum rated insulation voltage and the maximum rated impulse withstand voltage of all circuits in the assembly. The enclosure or protected space, when the class II assembly is ready for operation and connected to the supply, shall enclose all live parts, exposed-conductive-parts and parts belonging to a protective circuit in such a manner that they cannot be touched. The enclosure shall give at least the degree of protection IP2XC (see IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013).

If an external protective PEL, PEM or PEN conductor is passed through the class II assembly, the assembly should be provided with a suitably identified terminal.

d) Inside the enclosure or protected space of a class II assembly, the protective conductor, (PE, PEL, PEM or PEN conductor) and its terminal shall be insulated from the live parts and the exposed-conductive-parts. Exposed-conductive-parts within the assembly shall not be connected to the protective conductor. This applies also to built-in apparatus, even if they have a connecting terminal for a protective conductor.

e) This item of IEC 61439-1:2020 is not applicable.

8.4.5 Limitation of steady-state touch currents and charge

If the assembly contains items of equipment that may retain charges after they have been switched off (capacitors banks without internal basic protection, etc.), a warning label is required.

Small capacitors such as those used for arc extinction, for delaying the response of relays, etc., shall not be considered dangerous.

Unintentional contact is not considered dangerous if the voltages resulting from static charges fall below a DC voltage of 60 V in less than 5 s after disconnection from the power supply.

Touch currents are limited by ensuring exposed-conductive-parts are effectively connected to the protective conductor. See 10.5.2.

8.4.6 Operating and servicing conditions

8.4.6.1 Devices to be operated or components to be replaced by ordinary persons

Protection against any contact with live parts shall be maintained when operating devices or when replacing components.

The minimum degree of protection shall be IPXXC. During the replacement of certain lamps or fuselinks, openings larger than those defined by the degree of protection IPXXC are allowed.

8.4.6.2 Requirements related to accessibility in service by authorized persons

This subclause of IEC 61439-1:2020 is not applicable.

8.5 Incorporation of switching devices and components

8.5.1 Fixed parts

For fixed parts (see 3.2.1), the connections of the main circuits (see 3.1.3) shall only be connected or disconnected when the assembly is not energized. Removal and installation of fixed parts requires the use of a tool.

The disconnection of a fixed part shall require the isolation of the complete assembly or part of it.

In order to prevent unauthorized operation, the switching device may be provided with means to secure it in one or more of its positions.

8.5.2 Removable parts

The removable parts shall be so constructed that their electrical equipment can be safely removed from, or connected to, the main circuit even if this circuit is live. The removable parts may be provided with an insertion interlock (see 3.2.5).

Clearances and creepage distances (see 8.3) shall be complied with during transfer from one position to another.

A removable part shall be fitted with a device that ensures that it can only be removed and inserted after its main circuit has been switched off from the load.

If unauthorized operation, can occur, then the removable parts shall be provided with a locking means to secure them in one or more of their positions.

8.5.3 Selection of switching devices and components

Switching devices and components incorporated in assemblies shall comply with the relevant IEC standards.

The switching devices and components shall be suitable for the particular application with respect to the external design of the assembly (e.g. open type or enclosed), their rated voltages, rated currents, rated frequency, service life, making and breaking capacities, short-circuit withstand strength, etc.

The rated insulation voltage, and rated impulse withstand voltage of the devices installed in the circuit shall be equal or higher than the corresponding value assigned to that circuit. In some cases, overvoltage protection may be necessary (e.g. for equipment fulfilling overvoltage category II (see 3.6.11)). The switching devices and components having a short-circuit withstand strength and/or a breaking capacity which is insufficient to withstand the stresses likely to occur at the place of installation, shall be protected by means of protective devices with suitable current-limiting characteristics, for example fuses or current-limiting circuit-breakers. When selecting current-limiting protective devices for built-in switching devices, the maximum permissible values specified by the device manufacturer shall be taken into account with due regard to coordination (see 9.3.4).

Coordination of switching devices and components shall comply with the relevant IEC standards. Coordination of motor starters with short-circuit protective devices shall comply with IEC 60947-4-1:2018. See also 9.3.4.

NOTE Guidance is given in IEC TR 61912-1:2007 and IEC TR 61912-2:2009.

Plugs of different rated currents or voltages shall not be interchangeable, so as to avoid errors in connecting (see IEC 60309-1 and IEC 60309-2).

Connections for three-phase socket-outlets shall be made in such a way as to retain the same order of phases.

8.5.4 Installation of switching devices and components

Switching devices and components shall be installed and wired in the assembly in accordance with instructions provided by their manufacturers and in such a manner that their proper functioning is not impaired by interaction, such as heat, switching emissions, vibrations, electromagnetic fields, which are present in normal operation. In the case of electronic equipment, this may necessitate the separation or screening of all electronic signal processing circuits.

When fuses are installed, the original manufacturer shall state the type and rating of the fuse-links to be used.

8.5.5 Accessibility

Adjusting and resetting devices, that have to be operated inside the assembly, shall be easily accessible.

Functional units mounted on the same support (mounting plate, mounting frame) and their terminals for external conductors shall be so arranged as to be accessible for mounting, wiring, maintenance and replacement.

Assuming the base of the assembly and the normal standing area for operational personnel are at the same level, the following accessibility requirements associated with floor-standing assemblies shall apply.

– The terminals, excluding terminals for protective conductors, shall be situated at least 0,2 m above the base of the assembly and, moreover, be so placed that the cables can be easily connected to them with their respective bending radii respected.
– Indicating instruments that need to be read by the operator shall be located within a zone between 0,2 m and 2,2 m above the base of the assembly.
– Operating devices such as handles, push buttons, or similar shall be located at such a height that they can easily be operated; this means that their centreline shall be located within a zone between 0,2 m and 2 m above the base of the assembly. Devices which are infrequently operated (e.g. less than once per month) may be installed at a height up to 2,2 m.
– Actuators for emergency switching devices (see 536.4.2 of IEC 60364-5-53:2001) shall be accessible within a zone between 0,8 m and 1,6 m above the base of the assembly.

8.5.6 Barriers

Barriers for manual switching devices shall be so designed that the switching emissions do not present a danger to the operator.

To minimize danger when replacing fuse-links, interphase barriers shall be applied, unless the design and location of the fuses makes this unnecessary.

8.5.7 Direction of operation and indication of switching positions

The operational positions of components and devices shall be clearly identified. Operational positions are the "on" and the "off" position (see 8.1.6 of IEC 60947-1:2020). A tripped position is not considered as an operational position and need not to be indicated. If the direction of operation is not in accordance with IEC 60447:2004, then the direction of operation shall be clearly identified.

8.5.8 Indicator lights and push-buttons

Unless otherwise specified in the relevant product standard, the colours of indicator lights and push-buttons shall be in accordance with IEC 60073:2002.

8.5.9 Power factor correction banks

For power factor correction banks incorporated in assemblies, the requirements of IEC 61921:2017 shall be met.

NOTE IEC 61439 standard is the principal reference for the verification required by IEC 61921:2017.

8.5.101 Accessible parts of ACS

Only the socket-outlets, operating handles and control buttons can be accessible without the use of a key or tool. The actuator of the main switch shall be easily accessible (see 704.536.2.2 of IEC 60364-7-704:2017).

8.6 Internal electrical circuits and connections

8.6.1 Main circuits

The busbars (bare or insulated, see 3.1.5) shall be arranged in such a manner that an internal short-circuit is not to be expected. They shall be rated at least in accordance with the requirements concerning the short-circuit withstand strength (see 9.3) and designed to withstand at least the short-circuit stresses limited by the protective device(s) on the supply side of the busbars.

Within one section, the conductors (including distribution busbars) between the main busbars and the supply side of functional units – or in the case of a single section assembly, between the load terminals of the incoming device and the supply terminals of each outgoing SCPD – as well as the components included in these units, may be rated on the basis of the reduced short-circuit stresses occurring on the load side of the respective short-circuit protective device within each unit. This is provided that these conductors are arranged so that under normal operation, an internal short-circuit between live parts and/or between live parts and earth is not to be expected (see 8.6.4).

The minimum cross-sectional area of the neutral conductor within a three-phase and neutral circuit shall be:

– for circuits with a line conductor cross-sectional area up to and including 16 mm^2, 100 % of that of the corresponding lines;
– for circuits with a line conductor cross-sectional area above 16 mm^2, 50 % of that of the corresponding lines with a minimum of 16 mm^2.

NOTE There are specific applications when a smaller neutral conductor is acceptable to the user.

It is assumed that the neutral:

a) current does not exceed 50 % of the line currents;

b) conductor is made of the same material as the line conductors. Where this is not the case, the neutral conductor shall have at least the same conductance or current carrying capacity as that provided when the neutral conductor is of the same material as the line conductors.

For certain applications, which lead to high values of zero sequence harmonics (e.g. third order harmonics), higher cross-sections of the neutral conductor may be required as these harmonics of the lines are added in the neutral conductor and lead to high current load at higher frequencies. This is subject to special agreement between the assembly manufacturer and the user.

The PEL, PEM and PEN conductors shall be dimensioned as specified in 8.4.3.2.3.

8.6.2 Auxiliary circuits

The design of the auxiliary circuits shall take into account the auxiliary circuit(s) earthing and ensure that an earth fault shall not cause unintentional dangerous operation.

In general, auxiliary circuits shall be protected against the effects of short-circuits. However, a short-circuit protective device shall not be provided if its operation is liable to cause a danger. In such a case, the conductors of auxiliary circuits shall be arranged in such a manner that a short-circuit is not to be expected (see 8.6.4).

NOTE Further information on the requirements for auxiliary circuits is given in IEC 60364-5-55:2011, IEC 60364-5-55:2011/AMD1:2012 and IEC 60364-5-55:2011/AMD2:2016, 557.3.4.

8.6.3 Bare and insulated conductors

The connections of current-carrying parts shall not suffer undue alteration as a result of normal temperature-rise, ageing of the insulating materials and vibrations occurring in normal operation. The effects of thermal expansion, electrolytic action in the case of dissimilar metals, and the ageing due to the temperatures attained shall be taken into consideration.

Connections to devices mounted on doors or to other movable parts shall be made using flexible conductors, e.g. Class 5 or Class 6 according to IEC 60228:2004, to allow the movement of the part. The conductors shall be anchored to the fixed part and to the movable part independent of the electrical connection terminals.

Connections between current-carrying parts shall be established by means that ensure a sufficient and durable contact pressure.

If the verification of temperature-rise is carried out on the basis of tests (see 10.10.2), the selection of conductors and their cross-sections used inside the assembly shall be the responsibility of the original manufacturer. If verification of temperature-rise is made following the assessment rules of 10.10.4, the conductors shall have a minimum cross-section according to IEC 60364-5-52:2009. Examples on how to use this document for conditions inside an assembly are given in Tables H.1 and H.2. In addition to the current-carrying capacity of the conductors, the selection is governed by:

– the mechanical stresses to which the assembly may be subjected;
– the method used to lay and secure the conductors;
– the type of insulation;
– the type of components being connected (e.g. switchgear and controlgear in accordance with IEC 60947 series; electronic devices or equipment).

In the case of insulated solid or flexible conductors, the following criteria apply:

– They shall be rated for at least the rated insulation voltage (see 5.2.3) of the circuit concerned.

- Conductors connecting two termination points shall have no intermediate joint, e.g. spliced or soldered.
- Conductors with only basic insulation shall be prevented from coming into contact with bare live parts at different potentials.
- Contact of conductors with sharp edges shall be prevented.
- Supply conductors to apparatus and measuring instruments in covers or doors shall be so installed that no mechanical damage can occur to the conductors as a result of movement of these covers or doors.
- Soldered connections to apparatus shall be permitted in assemblies only in cases where provision is made for this type of connection on the apparatus and the specified type of conductor is used.
- For apparatus other than those mentioned above, soldering cable lugs or soldered ends of stranded conductors are not acceptable under conditions of heavy vibration. In locations where, heavy vibrations exist during normal operation, for example in the case of dredger and crane operation, operation on board ships, lifting equipment and locomotives, attention should be given to the support of conductors.
- Generally, only one conductor should be connected to a terminal clamping unit; the connection of two or more conductors to one terminal clamping unit is permissible only in those cases where the terminal clamping units are designed for this purpose.
- Conductors of different circuits may be laid side by side, may occupy the same duct (for example conduit, trunking system), or may be in the same multiconductor cable if the arrangement does not impair the proper functioning of the respective circuits. Where those circuits operate at different voltages, the conductors shall be separated by suitable barriers. Alternatively, all conductors within the same duct or any conductors in multicore cables shall be insulated for the highest voltage to which any conductor within the same duct can be subjected, for example line to line voltage for unearthed systems and line to earth voltage for earthed systems.

8.6.4 Selection and installation of non-protected live conductors to reduce the possibility of short-circuits

Live conductors in an assembly that are not protected by short-circuit protective devices (see 8.6.1 and 8.6.2) shall be selected and installed throughout the entire assembly in accordance with Table 4. Non-protected live conductors selected and installed as in Table 4 shall have a total length not exceeding 3 m between the main busbar and each respective SCPD or, in the case of a single section assembly, between the load terminals of the incoming device and the supply terminals of each outgoing SCPD.

8.6.5 Identification of the conductors of main and auxiliary circuits

Except for the cases mentioned in 8.6.6, the method and the extent of identification of conductors, for example by arrangement, colours or symbols, on the terminals to which they are connected or on the end(s) of the conductors themselves, is the responsibility of the assembly manufacturer and shall be in agreement with the indications on the wiring diagrams and drawings. Where appropriate, identification according to IEC 60445:2017 shall be applied.

8.6.6 Identification of the protective conductor (PE, PEL, PEM, PEN) and of the neutral conductor (N) and the mid-point conductor (M) of the main circuits

The protective conductor (PE, PEL, PEM or PEN) shall be readily distinguishable by location and/or marking or colour. If identification by colour or marking is used it shall be in accordance with IEC 60445:2017. When the protective conductor is an insulated single-core cable, this colour identification shall be used, preferably throughout the whole length.

Any neutral or mid-point conductor of the main circuit shall be readily distinguishable by location and/or marking or colour (see IEC 60445:2017 where blue is required).

8.6.7 Conductors in AC circuits passing through ferromagnetic enclosures or plates

Where conductors in AC circuits with a current rating exceeding 200 A pass through ferromagnetic enclosures, sections or plates, they shall:

- be arranged such that the conductors are only collectively surrounded by ferromagnetic material, e.g. pass through the same hole; or
- arrangements where conductors pass through separate holes shall have been verified by temperature-rise test(s).

It is permitted for an additional protective conductor to enter the ferrous enclosure individually.

8.7 Cooling

If special precautions are required at the place of installation to ensure proper cooling, the assembly manufacturer shall furnish the necessary information (for instance indication of the need for spacing with respect to parts that are liable to impede the dissipation of heat or produce heat themselves).

8.8 Terminals for external cables

Based on information from the original manufacturer, the assembly manufacturer shall indicate whether the terminals are suitable for connection of copper or aluminium conductors, or both. The terminals shall be such that the external conductors may be connected by a means (screws, connectors, etc.) that ensures that the necessary contact pressure corresponding to the current rating and the short-circuit strength of the apparatus and the circuit is maintained.

In the absence of a specific information that larger cables are to be used, which require larger terminals, the terminals shall be capable of accommodating copper conductors from the smallest to the largest cross-sectional areas corresponding to the rated current of the circuit protective device I_n, (see Annex A). For adjustable protective devices, the rated current is the current setting selected.

Where aluminium conductors are to be terminated, the type, size and termination method of the conductors shall be as agreed between the assembly manufacturer and the user.

All connections for external cables shall be re-wireable or shall be socket-outlets. Socket-outlets shall conform with the relevant standards and have a current rating of at least 16 A.

In the case where external conductors for electronic circuits with low-level currents and voltages (less than 1 A and less than 50 V AC or 120 V DC) have to be connected to an assembly, Table A.1 does not apply.

The available wiring space shall permit proper connection of the external conductors of the indicated material and, in the case of multicore cables, spreading of the cores.

The conductors shall not be subjected to stresses which are likely to reduce their normal life expectancy. In the absence of a specific information that larger cables are to be used, which require larger terminals, on three-phase and neutral circuits, terminals for the neutral conductor shall allow the connection of copper conductors having a minimum cross-sectional area:

- equal to half the cross-sectional area of the line conductor, with a minimum of 16 mm^2, if the size of the line conductor exceeds 16 mm^2;
- equal to the full cross-sectional area of the line conductor, if the size of the latter is less than or equal to 16 mm^2.

For conductors, other than copper conductors, the above cross-sections should be replaced by cross-sections of equivalent conductance, which may require larger terminals.

For certain applications, which lead to high values of zero sequence harmonics (e.g. third order harmonics), higher cross-sections of the neutral conductor may be required as these harmonics of the lines are added in the neutral conductor and lead to high current load at higher frequencies. This is subject to special agreement between the assembly manufacturer and the user.

If connecting facilities for incoming and outgoing neutral, mid-point, protective, PEL, PEM and PEN conductors are provided, they shall be arranged near the associated line conductor terminals.

NOTE IEC 60204-1:2016 requires a minimum cross-section of the conductor and does not allow the connection of PEN into the electrical equipment of the machinery.

Openings in cable entries, cover plates, etc. shall be so designed that, when the cables are properly installed, the stated protective measures against contact and degree of protection shall be obtained. This implies the selection of means of entry suitable for the application as stated by the assembly manufacturer.

The terminals for external protective conductors shall be marked according to IEC 60445:2017. As an example, see graphical symbol ⏚ IEC 60417-5019:2006-08-25. This symbol is not required where the external protective conductor is intended to be connected to an internal protective conductor that is clearly identified with the colours green and yellow.

The terminals for external protective conductors (PE, PEL, PEM, PEN) and metal sheathing of connecting cables (steel conduit, lead sheath, etc.) shall, where required, be bare and, unless otherwise specified, suitable for the connection of copper conductors. A separate terminal of adequate size shall be provided for the outgoing protective conductor(s) of each circuit.

In the absence of a specific information that larger cables are to be used, which require larger terminals, terminals for protective conductors shall allow the connection of copper conductors having a cross-section depending on the cross-section of the corresponding line conductors according to Table 5. Terminals for PEN conductors shall be the same as for neutral conductors.

In the case of enclosures and conductors of aluminium or aluminium alloys, particular consideration shall be given to the danger of electrolytic corrosion. The connecting means to ensure the continuity of the conductive parts with external protective conductors shall have no other function.

Special precautions can be necessary with metal parts of the assembly, particularly gland plates, where abrasion-resistant finishes, for example powder coatings, are used.

Identification of terminals shall comply with IEC 60445:2017 unless otherwise stated.

8.101 Supports and securing devices of ACS

Every ACS shall be fitted with supports enabling it to stand on a horizontal surface (e.g. feet or legs, articulated or not) and/or a system for fixing it to a vertical wall, attached to the enclosure or supporting framework.

These various supports or securing devices shall be external to the enclosure but firmly attached to it. They shall be appropriate to the constructional features (weight, environment, etc.) and service characteristics of the ACS and shall be tested together with the ACS (Clause 10).

8.102 Cable outlet

The cable outlet shall be at a minimum distance from the ground compatible with the bending radius of the largest cable that can be connected to the ACS.

Compliance is checked by inspection.

9 Performance requirements

9.1 Dielectric properties

9.1.1 General

Each circuit of the assembly shall be capable of withstanding:

– temporary overvoltages;
– transient overvoltages.

The ability to withstand temporary overvoltages, and the integrity of solid insulation, is verified by the power-frequency withstand voltage and the ability to withstand transient overvoltages is verified by the impulse withstand voltage.

In the case of variable frequency drives or converters, reflected voltage waves, recurring peak voltages and frequency can require special attention.

NOTE IEC 60664-1:2007 contains the requirements for supplementary and reinforced insulation (Class II).

9.1.2 Power-frequency withstand voltage

The circuits of the assembly shall be capable of withstanding the appropriate power-frequency withstand voltages given in Table 8 and Table 9 (see 10.9.2). The rated insulation voltage of any circuit of the assembly shall be equal to or higher than its maximum rated operational voltage.

Enclosures and external operating handles manufactured from or covered with insulating materials shall be capable of withstanding the power frequency dielectric tests as given in 10.9.4 and 10.9.5.

Conductors covered with insulating material to provide protection against electric shock shall be capable of withstanding the power frequency dielectric test as given in 10.9.6. This test is not required for insulated conductors which are verified to be suitably insulated according to their product standard (e.g. cables).

9.1.3 Impulse withstand voltage

9.1.3.1 Impulse withstand voltages of main circuits

Clearances from live parts to exposed-conductive-parts and between live parts of different potential shall be capable of withstanding the test voltage given in Table 10 as appropriate for the rated impulse withstand voltage.

The rated impulse withstand voltage for a given rated operational voltage shall not be less than that corresponding in Annex G to the type of supply system and the nominal voltage of the supply system of the circuit at the point where the assembly is to be used and the appropriate overvoltage category.

9.1.3.2 Impulse withstand voltages of auxiliary circuits

a) Auxiliary circuits that are connected to the main circuit and operate at the rated operational voltage without any means for reduction of overvoltage shall comply with the requirements of 9.1.3.1.

b) Auxiliary circuits that are not connected to the main circuit may have an overvoltage withstand capacity different from that of the main circuit. The clearances of such circuits – AC or DC – shall be capable of withstanding the appropriate impulse withstand voltage in accordance with Annex G.

9.1.4 Protection of surge protective devices

When overvoltage conditions require surge protective devices (SPDs) to be connected to the main circuit, such SPDs shall be protected to prevent uncontrolled short-circuit conditions as specified by the SPD manufacturer.

The installation of the SPD needs to respect the instructions of the SPD manufacturer, for example, the total length of conductors between the terminals of the SPD to the line and earth, as applicable.

9.2 Temperature-rise limits

9.2.1 General

The assembly and its circuits shall be able to carry their rated currents under specified conditions (see 5.3.1, 5.3.2, 5.3.3 and 5.4), taking into consideration the ratings of the components, their disposition and application, without exceeding the limits given in Table 6 when verified in accordance with 10.10. The temperature-rise limits given in Table 6 apply for a daily average ambient air temperature of 35 °C.

The temperature-rise of an element or part is the difference between the temperature of this element or part measured in accordance with 10.10.2.3.3 and the ambient air temperature outside the assembly. If the mean ambient air temperature is higher than 35 °C, then the temperature-rise limits shall be adapted for this special service condition, so that the sum of the ambient air temperature and the individual temperature-rise limit remains the same. If the daily average ambient air temperature is lower than 35 °C, the same adaptation of the temperature-rise limits is allowed subject to agreement between the user and the assembly manufacturer.

In some cases, for example, manual operating means, accessible external covers and enclosures, higher temperatures are permitted, but not higher than maximum limits from Table 6. See Table 6, footnote h.

The temperature-rise shall not cause damage to current-carrying parts or adjacent parts of the assembly. In particular, for insulating materials, the original manufacturer shall demonstrate compliance either by reference to the temperature index, for example, by the methods of IEC 60216 (all parts) or in accordance with IEC 60085:2007.

9.2.2 Adjustment of rated currents for alternative ambient air temperatures

If the temperature-rise limits have been changed to cover a different ambient air temperature, then the rated currents of all busbars, functional units, etc. may need to be changed accordingly. The original manufacturer shall state the measures to be taken, if any, to ensure compliance with the temperature limits. If an adaptation for lower ambient air temperatures is made, then the rated currents of the devices published by the device manufacturers shall not be exceeded.

If a temperature-rise test has been previously carried out applying the temperature-rise limits for a daily average ambient air temperature of 35 °C, then, up to a daily average ambient air temperature of 50 °C, the rated currents verified by test can be adjusted by calculation as given in 10.10.3.6.

9.3 Short-circuit protection and short-circuit withstand strength

9.3.1 General

Assemblies shall be capable of withstanding the thermal and dynamic stresses resulting from short-circuit currents not exceeding the rated values.

NOTE 1 The short-circuit stresses can be reduced by the use of current-limiting devices, e.g. inductance, current-limiting fuses or other current-limiting switching devices.

NOTE 2 When a short-circuit results from the operation of arc quenching device (AQD) according to IEC 60947-9-1 or any other intentional short-circuiting device, this results in the maximum stress on the circuits concerned.

Assemblies shall be protected against short-circuit currents by means of, for example, circuit-breakers, fuses or combinations of both, which may either be incorporated in the assembly or arranged outside of it.

For assemblies intended for use in IT systems, the short-circuit protective device should have a sufficient breaking capacity on each single pole at line-to-line voltage to clear a double earth fault. (See IEC 60364-5-53:2001, IEC 60364-5-53:2001/AMD1:2002 and IEC 60364-5-53:2001/AMD2:2015).

Unless otherwise specified in the assembly manufacturer's operating and maintenance instructions, assemblies that have been subjected to a short-circuit may not be suitable for future service without inspection and/or maintenance by skilled person(s).

9.3.2 Information concerning short-circuit withstand strength

For assemblies with a SCPD incorporated in the incoming unit, the assembly manufacturer shall declare the maximum allowable value of the prospective short-circuit current at the input terminals of the assembly. This value shall not exceed the appropriate rating(s) (see 5.3.4, 5.3.5, and 5.3.6). The corresponding power factor and peak values shall be those shown in 9.3.3.

If a circuit-breaker with a time-delay release is used as the short-circuit protective device, the assembly manufacturer shall state the maximum time-delay and the current setting corresponding to the indicated prospective short-circuit current.

For assemblies where the short-circuit protective device is not incorporated in the incoming unit, the assembly manufacturer shall indicate the short-circuit withstand strength in one or both of the following ways:

a) rated short-time withstand current (I_{cw}) together with the associated duration (see 5.3.5) and rated peak withstand current (I_{pk}) (see 5.3.4);

b) rated conditional short-circuit current (I_{cc}) including the current-limiting characteristics of the upstream SCPD (see 3.1.11).

For times up to a maximum of 3 s, the relationship between the rated short-time current and the associated duration is given by the formula I^2t = constant, provided that the peak value does not exceed the rated peak withstand current.

The last two paragraphs of this subclause of IEC 61439-1:2020 are not applicable.

9.3.3 Relationship between peak current and short-time current

For determining the electrodynamic stresses, the value of peak current shall be obtained by multiplying the RMS value for AC applications and mean value for DC applications of the short-circuit current by the factor n. The values for the factor n and the corresponding power factor for AC applications are given in Table 7. The peak factor for DC applications is subject to agreement between the manufacturer and the user.

NOTE For DC applications, if the user has not stated a peak current value, the value of n = 1,42 is typically used.

9.3.4 Coordination of protective devices

The coordination of protective devices within the assembly with those to be used externally to the assembly shall be the subject of an agreement between the assembly manufacturer and the user. Information given in the assembly manufacturer's catalogue may take the place of such an agreement.

If the operating conditions require maximum continuity of supply, the settings or selection of the short-circuit protective devices within the assembly should, where possible, be so coordinated that a short-circuit occurring in any outgoing circuit is cleared by the SCPD installed in the circuit without affecting the other outgoing circuits, thus ensuring selectivity of the protective system.

Where short-circuit protective devices are connected in series and are intended to operate simultaneously to reach the required short-circuit switching capability (i.e. back-up protection), the assembly manufacturer shall inform the user (e.g. by a warning label in the assembly or in the operating instructions, see 6.2) that none of the protective devices are allowed to be replaced by another device which is not of identical type and rating, unless the device is tested and approved in combination with the back-up device since the switching capability of the whole combination can otherwise be compromised.

Further guidance is given in IEC TR 61912-1:2007 and IEC TR 61912-2:2009. See also 8.5.3.

9.4 Electromagnetic compatibility (EMC)

For EMC-related performance requirements, see J.9.4.

10 Design verification

10.1 General

Under the responsibility of the original manufacturer, all design verifications shall be carried out or supervised by a competent person.

Design verification is intended to verify compliance of the design of an assembly or assembly system with the requirements of the IEC 61439 series.

Design verifications shall cover all declared mounting orientations.

Where tests on the assembly have been conducted in accordance with the IEC 60439 series (withdrawn) or previous editions of the IEC 61439 series, and the test results fulfil the requirements of the current edition of the relevant part of IEC 61439 series, the verification of these requirements need not be repeated.

Repetition of verifications in the product standards of switching devices or components including conductors incorporated in the assembly, which have been selected in accordance with 8.5.3 and installed in accordance with the instructions of their manufacturer is not required. Tests on individual devices and components including conductors to their respective product standards are not an alternative to the design verifications in this document for the assembly.

If modifications are made to a verified assembly, Clause 10 shall be used to check if these modifications affect the performance of the assembly. New verifications shall be carried out if an adverse effect is likely.

The various methods include:

– verification testing;
– verification comparison with a reference design(s);
– verification assessment, i.e. confirmation of the correct application of calculations and design rules, including use of appropriate safety margins.

See Annex D for the full list of design verifications to be covered.

When there is more than one method for the same verification, they are considered equivalent and the selection of the appropriate method is the responsibility of the original manufacturer.

The tests shall be performed on a representative sample of an assembly in a clean and new condition.

The performance of the assembly may be affected by the verification tests (e.g. short-circuit test). These tests should not be performed on an assembly that is intended to be placed in service.

An assembly which is verified in accordance with this document by an original manufacturer (see 3.10.1) and manufactured or assembled by another does not require the original design verifications to be repeated if all the requirements and instructions specified and provided by the original manufacturer are met in full. Where the assembly manufacturer incorporates their own arrangements not included in the original manufacturer's verification, the assembly manufacturer is deemed to be the original manufacturer in respect of these arrangements and is responsible for verification of these alternate arrangements.

Design verification shall comprise the following.

a) Construction:
   - 10.2 Strength of materials and parts;
   - 10.3 Degree of protection of assemblies (IP Code);
   - 10.4 Clearances and creepage distances;
   - 10.5 Protection against electric shock and integrity of protective circuits;
   - 10.6 Incorporation of switching devices and components;
   - 10.7 Internal electrical circuits and connections;
   - 10.8 Terminals for external conductors.

b) Performance:
   - 10.9 Dielectric properties;
   - 10.10 Temperature-rise;
   - 10.11 Short-circuit withstand strength;
   - 10.12 Electromagnetic compatibility.

The reference designs, the number of assemblies or parts thereof used for verification, the selection of the verification method when applicable, and the order in which the verification is carried out shall be at the discretion of the original manufacturer.

The data used, calculations made, and comparisons undertaken for the verification of assemblies shall be recorded in verification reports.

10.2 Strength of materials and parts

10.2.1 General

The mechanical, electrical and thermal capability of constructional materials and parts of the assembly shall be deemed to be proven by verification of construction and performance characteristics.

Where an empty enclosure in accordance with IEC 62208 is used, and it has not been modified so as to degrade the performance of the enclosure, no repetition of the enclosure testing to 10.2, with the exception of 10.2.6, is required unless the ACS is declared for heavily polluted atmosphere (see 7.2 item m).

10.2.2 Resistance to corrosion

10.2.2.1 Verification by test

The resistance to corrosion of representative samples of ferrous metallic enclosures, including internal and external ferrous metallic constructional parts of the assembly, shall be verified.

The test shall be carried out on:

– an enclosure or representative sample enclosure with representative internal parts in place and door(s) closed as in normal use, or
– representative enclosure parts and internal parts separately.

In all cases, hinges, locks and fastenings shall also be tested unless they have previously been subjected to an equivalent test and their resistance to corrosion has not been compromised by their application.

Where the enclosure is subjected to the test, it shall be mounted as in normal use according to the original manufacturer's instructions.

The test specimens shall be new and in a clean condition and shall be subjected to severity test A or B, as detailed in 10.2.2.2 and 10.2.2.3.

NOTE The salt mist test provides an atmosphere that accelerates corrosion and does not imply that the assembly is suitable for a salt-laden atmosphere.

10.2.2.2 Severity test A

This test is applicable to:

– ferrous metallic indoor enclosures;
– external ferrous metallic parts of indoor assemblies;
– internal ferrous metallic parts of indoor and outdoor assemblies upon which intended mechanical operation may depend.

The test consists of:

six cycles of 24 h each to damp heat cycling test according to IEC 60068-2-30:2005 (Test Db) at (40 ± 2) °C. Variant 1 or 2 to be selected as recommended by Annex A of IEC 60068-2-30:2005,

followed by,

two cycles of 24 h each to salt mist test according to IEC 60068-2-11:1981 (Test Ka: Salt mist) at a temperature of (35 ± 2) °C.

10.2.2.3 Severity test B

This test is applicable to:

– ferrous metallic outdoor enclosures;
– external ferrous metallic parts of outdoor assemblies.

The test comprises two identical 12-day periods.

Each 12-day period comprises:

five cycles of 24 h each to damp heat cycling test according to IEC 60068-2-30:2005 (Test Db) at (40 ± 2) °C. Variant 1 or 2 to be selected as recommended by Annex A of IEC 60068-2-30:2005,

followed by:

seven cycles of 24 h each to salt mist test according to IEC 60068-2-11:1981 (Test Ka: Salt mist) at a temperature of (35 ± 2) °C.

10.2.2.4 Results to be obtained

After the test, the enclosure or samples shall be washed in running tap water for 5 min, rinsed in distilled or demineralized water, then shaken or subjected to an air blast to remove water droplets. The specimen under test shall then be stored under normal service conditions for 2 h.

Compliance is checked by visual inspection to determine that:

– there is no evidence of cracking or other deterioration other than iron oxide as allowed by ISO 4628-3:2016 for a degree of rusting Ri1 (considering the sample as a whole). However, surface deterioration of the protective coating is allowed. In case of doubt associated with paints and varnishes, reference shall be made to ISO 4628-3:2016 to verify that the samples conform to the specimen Ri1;
– the mechanical integrity is not impaired;
– seals are not damaged;
– doors, hinges, locks, and fastenings work without abnormal effort.

10.2.2.5 Verification by comparison to reference design

Similar enclosures, enclosure parts and internal ferrous metallic parts, irrespective of their shape and size, are covered by the corrosion test on the representative samples if they are manufactured from the same materials and with the same surface treatments, using the same manufacturing process.

10.2.2.101 Verification of the resistance to corrosion in a heavily polluted atmosphere

a) Principle

This test is intended to assess the corrosive effects of an industrial atmosphere, i.e. an atmosphere polluted with sulphur dioxide.

The complete and fully equipped ACS shall be continuously exposed to this atmosphere for ten days.

b) Method of test and test atmosphere

The complete and fully equipped ACS shall be tested in accordance with IEC 60068-2-42.

c) Results to be obtained

The ACS is declared satisfactory, if

– no trace of corrosion is found either inside or outside (except for the sharp edges) and;
– no damaging effect appears in the ACS, verified by applying the tests of 10.9.1 of IEC 61439-1:2020, between 24 h and 36 h after the ACS has been removed from the test chamber.

10.2.3 Properties of insulating materials

10.2.3.1 Thermal stability

10.2.3.1.1 Verification of thermal stability of enclosures by test

The thermal stability of enclosures manufactured from insulating material shall be verified by the dry heat test. The test shall be carried out according to IEC 60068-2-2:2007 (Test Bb), at a temperature of 70 °C, with natural air circulation, for a duration of 168 h and with a recovery of 96 h.

Parts intended for decorative purposes that have no technical significance shall not be considered for the purpose of this test.

The enclosure, mounted as in normal use, is subjected to a test in a heating cabinet with an atmosphere having the composition and pressure of the ambient air and ventilated by natural circulation. If the dimensions of the enclosure are too large for the available heating cabinet, the test may be carried out on a representative sample of the enclosure.

The use of an electrically heated cabinet is recommended.

Natural circulation may be provided by holes in the walls of the cabinet.

The enclosure or sample shall show no crack visible to normal or corrected vision without additional magnification nor shall the material have become sticky or greasy, this being judged as follows:

– With the forefinger wrapped in a dry piece of rough cloth, the sample is pressed with a force of 5 N.

NOTE The force of 5 N can be obtained in the following way: the enclosure or sample is placed on one of the pans of a balance and the other pan is loaded with a mass equal to the mass of the sample plus 500 g. Equilibrium is then restored by pressing the sample with the forefinger wrapped in a dry piece of rough cloth.

No traces of the cloth shall remain on the sample, and the material of the enclosure or the sample shall not stick to the cloth.

10.2.3.1.2 Verification of thermal stability of enclosures by comparison

Enclosures or parts attached to the enclosure of same materials, same colour, same or greater thickness of the walls and same general construction, but with, for example, other dimensions, are covered by the test on the representative samples.

10.2.3.2 Verification of resistance of insulating materials to abnormal heat and fire due to internal electric effects

10.2.3.2.1 Verification by test

The glow-wire test principles of IEC 60695-2-10:2013 and the details given in IEC 60695-2-11:2014 shall be used to verify the suitability of the materials used:

a) on parts of assemblies, or
b) on specimens taken from these parts.

The test shall be carried out on material with the minimum thickness used for the parts in a) or b).

For a description of the test, see Clause 8 of IEC 60695-2-11:2014. The apparatus to be used shall be as described in Clause 5 of IEC 60695-2-11:2014.

The temperature of the tip of the glow-wire shall be as follows:

- 960 °C for parts necessary to retain current-carrying parts in position;
- 850 °C for enclosures to be installed in hollow walls;
- 650 °C for all other parts, including parts necessary to retain the protective conductor and enclosure parts intended to be embedded in and mounted on walls which are combustion-resistant.

NOTE 1 Tolerances for temperatures of the tip are included in IEC 60695-2-11:2014.

NOTE 2 Parts of the assembly made from insulating material are considered to be end products and are to be tested in accordance with IEC 60695-2-11:2014.

For small parts having surface dimensions not exceeding 14 mm × 14 mm, an alternative test may be used (e.g. needle flame test, according to IEC 60695-11-5:2016). The same procedure may be applicable for other practical reasons where the metal material of a part is large compared to the insulating material.

10.2.3.2.2 Verification by comparison to a reference design

If a part made from an identical material, having the same or greater thickness than the reference part that has already satisfied the requirements of 8.1.3.2.3, then the test need not be performed. It is the same for all parts which have been previously tested according to their own specifications.

10.2.3.2.3 Verification by assessment

As an alternative, the original manufacturer shall provide data on the suitability of materials from the insulating material manufacturer to demonstrate compliance with IEC 60695-2-12 for the materials used and applicable temperature according to 10.2.3.2.1.

10.2.4 Resistance to ultraviolet (UV) radiation

10.2.4.1 Verification by test

This test applies only to enclosures and external parts of assemblies intended to be installed outdoors and which are constructed of insulating materials or enclosures that are entirely coated by synthetic material. Representative samples of such parts shall be subjected to the following test.

10.2.4.1.1 Verification for enclosures and external parts of assemblies constructed of insulating materials

Test samples:

- six test specimens of standard size according to ISO 178:2010; and
- six test specimens of standard size according to ISO 179-1:2010, ISO 179-2:1997 and ISO 179-2:1997/AMD:2011,

shall be prepared.

The test specimens shall be made under the same conditions as those used for the manufacture of the enclosure being considered.

Test sequence:

a) UV test on all twelve samples according to ISO 4892-2:2013, Method A, Cycle 1 providing a total test period of 500 h.

b) Verification of the flexural strength in accordance with ISO 178 (method A) with six of the samples. The surface of the sample exposed to UV radiation shall be turned face down and the pressure applied to the non-exposed surface.

c) Verification of the Charpy impact in accordance with ISO 179 on the other six samples. No notches shall be cut into the sample and the impact shall be applied to the exposed surface.

Results to be obtained:

i) Samples shall not show cracks or deterioration visible to normal or corrected vision without additional magnification.

ii) The flexural strength according to ISO 178 shall have 70 % minimum retention.

iii) The Charpy impact according to ISO 179 shall have 70 % minimum retention. For materials whose impact bending strength cannot be determined prior to exposure because no rupture has occurred, not more than three of the exposed test specimens shall be allowed to break.

10.2.4.1.2 Verification for enclosures and external parts of assemblies coated on their exposed surface(s) by synthetic material

Test sample: Three representative samples of suitable size shall be tested. The test specimens shall be made under the same conditions as those used for the manufacture of the enclosure being considered.

Test sequence:

a) UV test on all three samples according to ISO 4892-2:2013, Method A, Cycle 1 providing a total test period of 500 h.

b) Verification of the retention of the coating according to ISO 2409.

Results to be obtained:

The adherence of the synthetic material shall have a minimum retention of category 3 according to ISO 2409.

10.2.4.2 Verification by comparison to a reference design

Enclosures and external parts made of the same insulating materials, irrespective of their shape and size, are covered by the test on the representative samples.

10.2.4.3 Verification by assessment

As an alternative, the original manufacturer shall provide data on the suitability of materials of the same type and thickness or thinner from the insulating material supplier to demonstrate compliance with the requirements of 8.1.4.

10.2.5 Lifting

10.2.5.1 Verification by test

If the original manufacturer makes provision for lifting other than by manual means, compliance is verified with the following tests.

The maximum number of sections allowed by the original manufacturer to be lifted together shall be equipped with components and/or weights to achieve a weight of 1,25 times its maximum shipping weight. With doors closed, it shall be lifted with the specified lifting means and, in the manner, defined by the original manufacturer.

From a standstill position, the transport unit shall be raised smoothly without jerking in a vertical plane to a height ≥ 1 m and lowered in the same manner to a standstill position. This test is repeated a further two times after which the transport unit is raised up and suspended clear of the floor for 30 min without any movement.

Following the above test and using the same transport unit, the transport unit shall be raised smoothly without jerking from a standstill position to a height ≥ 1 m and moved (10 ± 0,5) m horizontally, then lowered to a standstill position. This sequence shall be carried out three times at uniform speed, each sequence being carried out within 1 min.

After the test, with the test weights in place, the transport unit shall show no cracks or permanent distortions, visible to normal or corrected vision without additional magnification, that could impair any of its characteristics.

10.2.5.2 Verification by comparison to a reference design

Enclosures with the same or equal constructional design and arrangements for lifting are verified if having an equal or lower weight than that tested as the representative sample.

10.2.6 Verification of mechanical strength

10.2.6.1 General

a) These tests shall be applied to the ACS, the test sample being in working order but disconnected from the sample supply.

   The test sample shall be completely unpackaged.

b) The tests include two distinct procedures:

   – impact test;
   – shock test.

Tests shall be carried out at an ambient air temperature of (20 ± 5) °C after the ACS has been kept at this temperature for at least 12 h.

10.2.6.2 Impact test

a) Principle

   The complete ACS (with all components mounted inside and fitted on suitable supports and securing devices (see 8.101) if these form part of the ACS) shall be subjected to a series of impacts of 6 J applied to the enclosure (not to the components inside it) (see 8.1.6).

b) Method of test

   The equipment to be tested shall be fixed on a support of adequate rigidity to restrict movement of the ACS to 0,1 mm under the effect of the prescribed impact. Three successive impacts shall be applied to each face of the ACS under test by means of either:

   1) a solid smooth steel sphere approximately 50 mm in diameter and with a mass of (500 ± 25) g, which shall be allowed to fall freely from rest through a vertical height of 1,2 m onto the enclosure surface held in a horizontal plane. The hardness of the sphere shall be not less than 50 HR and not more than 58 HR, or

   2) a similar steel sphere, shall be suspended by a cord and swing as a pendulum in order to apply a horizontal impact, falling through a vertical distance of 1,2 m.

   See Figure 101 for the test setup.

   Sloping surfaces can be tested using the pendulum but if this is not convenient the surface will be aligned in the horizontal plane by turning the unit on the support and the test 1) is used. Before each test an inspection of the sphere shall be made to ensure that it is free from burrs and defects.

The test shall be so arranged that the impacts are applied at positions where weaknesses are most likely to be revealed. A total of 18 impacts shall be applied to the ACS.

The test is not applicable to components such as socket-outlets, operating handles, illuminating lights, pushbuttons, actuators, etc., when these components are mounted in recesses with respect to the main surfaces, so that the distance between the most exposed parts of these components and the said surfaces is at least 1 cm.

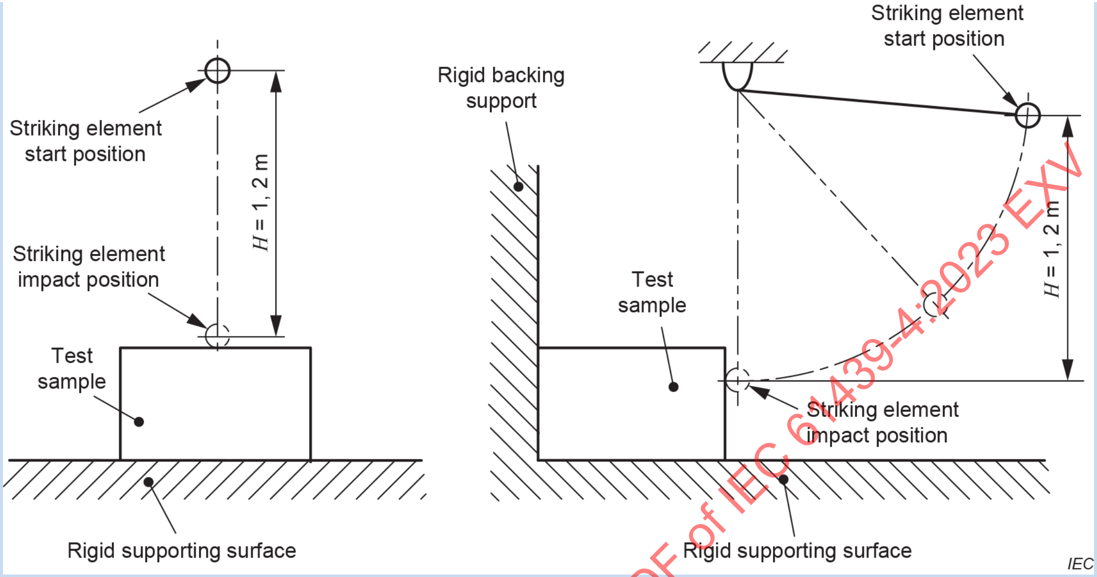


Figure 101 – Impact test using striking element

10.2.6.3 Shock test

a) Principle

The ACS shall be subjected to a single pulse half-sine wave, the shock test having a severity of 500 m/s^2 (50 g) peak acceleration and a duration of 11 ms.

b) Method of test

The ACS in working order shall be tested according to IEC 60068-2-27. Subject to agreement between manufacturer and user, the test can be carried out at separate SECTIONS of the ACS.

10.2.6.4 Results to be obtained

After the test, the enclosure shall continue to provide the degrees of protection specified in 8.2.2; any distortions or deformations of the enclosure and components shall neither be detrimental to the proper functioning of the ACS nor decrease creepage distances and clearances to below the required values; actuators, handles, etc., shall still be operable.

Distortion or deformation of plastic parts that can return in correct position by simple action (such as opening and reclosing of the cover) are not considered to be detrimental to the proper functioning of the ACS.

Superficial damage, paint removals, small indentations, cracks not visible with normal or corrected vision without further magnification, or surface cracks shall not constitute failure of the test.

10.2.7 Marking

10.2.7.1 Verification by test

Marking made by moulding, pressing, engraving or similar, including labels with a laminated plastic covering, shall not be submitted to the following test.

The test is made by rubbing the marking by hand for 15 s with a piece of cloth soaked in water and then for 15 s with a piece of cloth soaked with petroleum spirit.

NOTE The petroleum spirits n-hexane or heptane are suitable solvents for this test.

After the test, the marking shall be legible to normal or corrected vision without additional magnification.

10.2.7.2 Verification by comparison to a reference design

Markings of a same material and method of printing are covered by the tests completed on the reference samples.

10.2.8 Mechanical operation

10.2.8.1 Verification by test

This verification test shall not be made on such devices of the assembly which have already been type tested according to their relevant product standard (e.g. withdrawable circuit-breaker) unless their mechanical operation has been modified by their mounting arrangements differing from those given in the device manufacturer's instructions.

For parts that need to be verified through testing (see 8.1.5), intended mechanical operation shall be verified after installation in the assembly. The number of operating cycles shall be 200. Where a device has been tested in accordance with its own product standard, but the mounting arrangement is not in accordance with the manufacturer's instructions, the number of operations shall be in accordance with the product standard.

At the same time, the operation of the mechanical interlocks associated with these movements shall be checked. The test is passed if the operating conditions of the apparatus, interlocks, the specified degree of protection and position indication, if any, have not been impaired and if the effort required for operation is practically the same as before the test. For devices that have specific operational criteria the device product standard and/or the manufacturer's instructions should be consulted.

10.2.8.2 Verification by comparison to a reference design

Enclosures with the same or equal constructional solution for mechanical operation are covered by tests completed on the reference samples.

10.3 Degree of protection of assemblies (IP Code)

The degree of protection provided in accordance with 8.2.2, 8.2.3 and 8.4.2.3 shall be verified in accordance with IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013; the test may be carried out on one representative equipped assembly in a condition stated by the original manufacturer. Where an empty enclosure in accordance with IEC 62208:2011 or an assembly enclosure tested in accordance with the IEC 61439 series is used, a verification assessment shall be performed to ensure that any external modification that has been carried out does not result in a deterioration of the degree of protection. Such an assessment can, for example, be a visual check to confirm that a device with a suitable degree of protection (IP code) has been installed in an opening in an enclosure in accordance with the device manufacturer's installation instructions. In this case, no further testing is required.

Degree of protection (IP code) tests shall be carried out:

- with all covers and doors in place and closed as in normal service, irrespective of whether they can be opened or removed, with or without the use of key or tool;
- in a de-energized state (main and auxiliary circuits);

– where the assembly is made up of multiple sections or is described as extendable, joined sections shall be included.

Assemblies having a degree of protection of IP5X shall be tested according to category 2 in 13.4 of IEC 60529:1989 and IEC 60529:1989/AMD1:1999;

Assemblies having a degree of protection of IP6X shall be tested according to category 1 in 13.4 of IEC 60529:1989 and IEC 60529:1989/AMD1:1999;

NOTE The tests given in IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013; related to water and dust are accelerated tests and do not represent actual operating conditions for the assembly. The test simulates the conditions for the assembly over its life in a short period of time. In true life a slow pollution takes place which is removed by regular maintenance.

The test device for IPX3 and IPX4 as well as the type of support for the enclosure during the IPX4 test shall be stated in the test report.

The IPX1 test may be carried out by moving the drip box instead of rotating the assembly. If the dimensions of the surface of the assembly to be tested are larger than the dimensions of the drip box, the test shall be repeated as often as necessary to cover all relevant surfaces of the assembly. Each separate test shall take 10 min.

Ingress of water in the IPX1 to IPX6 tests on an assembly is permissible only if its route of entry is obvious and the water is only in contact with the enclosure at a location where it will not reduce the clearance and creepage distances. If clearances and creepage distances are reduced, they shall not be below the minimum specified in Table 1 and Table 2, respectively.

The IP5X test is deemed to be a failure if dust is visible on creepage paths housed within the enclosure and creepage distances are reduced below the minimum specified in Table 2, see IEC 60529:1989, 13.5.2.

10.4 Clearances and creepage distances

It shall be verified that the clearances and creepage distances comply with the requirements of 8.3.

The creepage distances shall be measured in accordance with Annex F.

Clearances are verified by measurement according to Annex F or by test according to 10.9.3.

10.5 Protection against electric shock and integrity of protective circuits

10.5.1 General

The effectiveness of the earth continuity and the protective circuit is verified for the following functions:

1) protection against the consequences of a fault within the class I assembly (internal faults) as outlined in 10.5.2; and
2) protection against the consequences of faults in external circuits supplied through the assembly (external faults) as outlined in 10.5.3.

10.5.2 Effective earth continuity between the exposed-conductive-parts of the class I assembly and the protective circuit

It shall be verified that the different exposed-conductive-parts of the assembly are effectively connected to the terminal for the incoming external protective conductor.

Verification shall be made using a resistance-measuring instrument that is capable of driving a current of at least 10 A (AC or DC). The current is passed between each exposed-conductive-part and the terminal for the external protective conductor. The resistance shall not exceed 0,1 Ω.

It is recommended to limit the duration of the test where low-current equipment is used; otherwise it can be adversely affected by the test.

10.5.3 Short-circuit withstand strength of the protective circuit

10.5.3.1 General

The rated short-circuit withstand strength shall be verified. Verification may be carried out by a comparison to a reference design(s) (see 10.5.3.3 or 10.5.3.4) or with a test as detailed in 10.5.3.5.

The original manufacturer shall determine the reference design(s) that will be used in 10.5.3.3 and 10.5.3.4.

10.5.3.2 Protective circuits that are exempted from short-circuit withstand verification

Where a separate protective conductor is provided in accordance with 8.4.3.2.3, short-circuit testing is not required if one of the conditions of 10.11.2 is fulfilled.

10.5.3.3 Verification by comparison with reference designs – Using a checklist

Verification is achieved when the comparison of the assembly to be verified with already tested designs using items 1 to 6 and 8 to 10 of the checklist given in Table 13 shows no deviations.

To ensure the same current-carrying capacity for that portion of the fault current that flows through the exposed-conductive-parts, the design, number and arrangement of the parts that provide contact between the protective conductor and the exposed-conductive-parts shall be the same as in the reference design.

10.5.3.4 Verification by comparison with reference designs – Using calculation

Verification by comparison with reference designs based on calculation is to be carried out in accordance with 10.11.4.

To ensure the same current-carrying capacity for that portion of the fault current that flows through the exposed-conductive-parts, the design, number and arrangement of the parts that provide contact between the protective conductor and the exposed-conductive-parts shall be the same as in the reference design.

10.5.3.5 Verification by test

Subclause 10.11.5.6 applies.

10.6 Incorporation of switching devices and components

10.6.1 General

Compliance with the design requirements of 8.5 for the incorporation of switching devices and components shall be confirmed by the original manufacturer's inspection.

NOTE If the assembly manufacturer carries out a modification to the original manufacturer's design, then the assembly manufacturer assumes the responsibility of the original manufacturer for that design change and is responsible for carrying out the original manufacturer's inspection. See 10.1.

10.6.2 Electromagnetic compatibility

The performance requirements of J.9.4 for electromagnetic compatibility shall be confirmed by inspection or, where necessary, by testing (see 10.12).

10.7 Internal electrical circuits and connections

Compliance with the design requirements of 8.6 for internal electrical circuits and connections shall be confirmed by the original manufacturer’s inspection.

NOTE If the assembly manufacturer carries out a modification to the original manufacturer’s design, then the assembly manufacturer assumes the responsibility of the original manufacturer for that design change and is responsible for carrying out the original manufacturer’s inspection. See 10.1.

10.8 Terminals for external conductors

Compliance with the design requirements of 8.8 for terminals for external conductors shall be confirmed by the original manufacturer’s inspection.

NOTE If the assembly manufacturer carries out a modification to the original manufacturer’s design, then the assembly manufacturer assumes the responsibility of the original manufacturer for that design change and is responsible for carrying out the original manufacturer’s inspection. See 10.1.

10.9 Dielectric properties

10.9.1 General

For this test, all the electrical equipment of the assembly shall be connected, except those items of apparatus which, according to the relevant specifications, are designed for a lower test voltage; current-consuming apparatus (e.g. windings, measuring instruments, voltage surge suppression devices) in which the application of the test voltage would cause the flow of a current, shall be disconnected. Such apparatus shall be disconnected at one of their terminals unless they are not designed to withstand the full test voltage, in which case all terminals may be disconnected.

For test voltage tolerances and the selection of test equipment, see IEC 61180:2016.

10.9.2 Power-frequency withstand voltage

10.9.2.1 Main and auxiliary circuits

Main circuits and auxiliary circuits that are connected to the main circuit shall be subjected to the test voltage according to Table 8.

Auxiliary circuits, whether AC or DC, that are not connected to the main circuit shall be subjected to the test voltage according to Table 9. This test is not carried out on auxiliary circuits:

– which contain only insulated conductors with the appropriate insulation strength as stated by their manufacturers; and
– which are protected by short-circuit protective devices with the rating not exceeding 16 A; and
– if an electrical function test has been carried out previously at the rated operational voltage for which the auxiliary circuits are designed.

10.9.2.2 Test voltage

Circuits intended for AC applications shall preferably be tested with an AC test voltage. Substitution of an AC voltage test by a DC voltage test should only be considered when the specimen does not allow testing with AC, e.g. in the case of filters, capacitors and similar, (see IEC 60664-1:2007, 6.1.3.4.1, fifth paragraph).

NOTE A test with a DC test voltage of a value equal to the peak value of the AC test voltage will be less stringent than the AC voltage test.

Circuits for DC applications shall be tested with AC or DC test voltages corresponding to the rated insulation voltage U_i.

Where an AC test voltage is used, it shall have a substantially sinusoidal waveform and a frequency equal to the rated frequency of the assembly with a tolerance of ±25 %. A DC test voltage shall have negligible ripple.

The high-voltage source used for the test shall be so designed that, when the output terminals are short-circuited after the output voltage has been adjusted to the appropriate test voltage, the output current is sufficient to trip the overcurrent relay and it is greater than 100 mA.

The overcurrent relay shall not trip when the output current is less than 100 mA.

The value of the test voltage shall be that specified in Table 8 or Table 9 as appropriate with a permitted tolerance of ±3 %.

10.9.2.3 Application of the test voltage

The test voltage at the moment of application shall not exceed 50 % of the full test value. It shall then be increased progressively to this full value and maintained for 60_{0}^{+2} s as follows:

a) between all live parts of the main circuit connected together (including the auxiliary circuits connected to the main circuit) and exposed-conductive-parts, with the main contacts of all switching devices in the closed position or bridged by a suitable low resistance link;
b) between each live part of different potential of the main circuit and, the other live parts of different potential and exposed-conductive-parts connected together, with the main contacts of all switching devices in the closed position or bridged by a suitable low resistance link;
c) between each auxiliary circuit not normally connected to the main circuit and the
   - main circuit;
   - other circuits;
   - exposed-conductive-parts.

NOTE Power-frequency withstand voltage tests carried out with the voltage maintained for at least 5 s prior to the publication of this document are considered acceptable and need not be repeated.

10.9.2.4 Acceptance criteria

The overcurrent relay shall not operate and there shall be no disruptive discharge (see 3.6.17) during the tests.

10.9.3 Impulse withstand voltage

10.9.3.1 General

Verification shall be made by test.

In place of the impulse withstand voltage test of 10.9.3.2, the original manufacturer may perform, at their discretion, an equivalent AC or DC voltage test, in accordance with 10.9.3.3 or 10.9.3.4.

10.9.3.2 Impulse withstand voltage test

The impulse voltage generator shall be adjusted to the required impulse voltage with the assembly connected. The value of the test voltage shall be that specified in 9.1.3. The tolerance of the applied peak voltage shall be ±3 %. When the manufacturer agrees, the positive tolerance of the test voltage may be exceeded.

Auxiliary circuits not connected to main circuits shall be connected to the earth for the tests a) and b) below. The 1,2/50 µs impulse voltage shall be applied to the assembly five times for each polarity at intervals of 1 s minimum as follows:

a) between all the live parts of different potential of the main circuit connected together (including the auxiliary circuits connected to the main circuit) and exposed-conductive-parts, with the main contacts of all switching devices in the closed position or bridged by a suitable low-resistance link;

b) between each live part of different potential of the main circuit and the other live parts of different potential and exposed-conductive-parts connected together, with the main contacts of all switching devices in the closed position or bridged by a suitable low-resistance link;

c) between each auxiliary circuit not normally connected to the main circuit and the
   - main circuit;
   - other circuits;
   - exposed-conductive-parts.

This test is not carried out on auxiliary circuits:

- which contain only insulated conductors with the appropriate insulation strength as stated by their manufacturers; and
- which are protected by short-circuit protective devices with a rating not exceeding 16 A; and
- if an electrical function test has been made previously at the rated operational voltage for which the auxiliary circuits are designed.

For an acceptable result, there shall be no disruptive discharge during the impulse voltage tests.

Some conductor arrangements retain a considerable charge after an impulse test, and for these cases care should be taken when reversing the polarity. To allow the arrangement to discharge, the use of appropriate methods, such as the application of three impulses at about 80 % of the test voltage in the reverse polarity before the test, is recommended.

10.9.3.3 Alternative power-frequency voltage test

The test voltage shall have a substantially sinusoidal waveform at the rated frequency with a tolerance of ± 25 %.

The high-voltage source used for the test shall be so designed that, when the output terminals are short-circuited after the output voltage has been adjusted to the appropriate test voltage, the output current is sufficient to trip the overcurrent relay and it is greater than 100 mA.

The overcurrent relay shall not trip when the output current is less than 100 mA.

The value of the test voltage shall be that specified in 9.1.3 and Table 10 as appropriate with a permitted tolerance of ± 3 %.

The power-frequency voltage shall be applied once, at full value, for three cycles (see IEC 60664-1:2007, 6.1.2.2.2.2). It shall be applied to the assembly in the manner described in 10.9.3.2 a), b) and c) above.

For an acceptable result, the overcurrent relay shall not operate and there shall be no disruptive discharge during the tests.

10.9.3.4 Alternative DC voltage test

The test voltage shall have negligible ripple.

The high-voltage source used for the test shall be so designed that, when the output terminals are short-circuited after the output voltage has been adjusted to the appropriate test voltage, the output current is sufficient to trip the overcurrent relay and it is greater than 100 mA.

The overcurrent relay shall not trip when the output current is less than 100 mA.

The value of the test voltage shall be that specified in 9.1.3 and Table 10 as appropriate with a permitted tolerance of ± 3 %.

The DC voltage shall be applied three times for each polarity for a duration of 10 ms (see IEC 60664-1:2007, 6.1.2.2.2.3).

It shall be applied to the assembly in the manner described in 10.9.3.2 a) and b) above.

For an acceptable result the overcurrent relay shall not operate and there shall be no disruptive discharge during the tests.

10.9.3.5 Verification assessment

Clearances shall be verified by measurement, or verification of measurements on design drawings, employing the measurement methods stated in Annex F. The clearances shall be at least 1,5 times the values specified in Table 1.

NOTE The 1,5 factor applied to the values in Table 1 is to avoid impulse withstand voltage tests for design verification. It is a safety factor that takes into consideration manufacturing tolerances.

It shall be verified by assessment of the device manufacturer's data that all incorporated devices are suitable for the specified rated impulse withstand voltage (U_{imp}).

10.9.4 Testing of enclosures made of insulating material

For assemblies with enclosures made of insulating material, an additional dielectric test shall be carried out by applying an AC test voltage between a metal foil laid on the outside of the enclosure over openings and joints, and the interconnected live and exposed-conductive-parts within the assembly located next to the openings and joints. For this additional test, the test voltage shall be equal to 1,5 times the values indicated in Table 8.

10.9.5 External door or cover mounted operating handles of insulating material

In the case of handles made of or covered by insulating material, a power-frequency withstand voltage test shall be carried out by applying a test voltage equal to 1,5 times the test voltage indicated in Table 8 between the live parts and a metal foil wrapped round the whole surface of the representative handle. During this test, the exposed-conductive-parts shall not be earthed or connected to any other circuit.

10.9.6 Testing of conductors and hazardous live parts covered by insulating material to provide protection against electric shock

Conductors and hazardous live parts covered by insulating material in direct contact with the conductor so as to provide protection against electric shock, excluding those previously verified to their own product standard (e.g. cables), shall be subjected to an additional dielectric test. This test shall be carried out by applying an AC test voltage between a metal foil laid on the outside of the conductor insulation including openings and joints in the insulation, and the interconnected conductive parts within the insulation. For this additional test, the test voltage shall be equal to 1,5 times the values indicated in Table 8.

10.10 Temperature-rise

10.10.1 General

It shall be verified that the temperature-rise limits specified in 9.2 for the different parts of the assembly or assembly system will not be exceeded.

Verification shall be made with one or more of the following methods (see Annex L for guidance):

a) testing (10.10.2);

b) comparison with a reference design (10.10.3);

c) not applicable.

In assemblies rated for frequencies above 60 Hz verification of temperature-rise by test (10.10.2) or by derivation from a similar design tested at the same intended frequency (10.10.3) is always required.

The current-carrying capacity of the circuits to be verified is determined by;

- the group rated current of a main circuit I_{ng} (see 5.3.3); or
- the rated current of the main circuit I_{nc} (see 5.3.2) and the RDF (see 5.4).

NOTE In addition to I_{ng}, I_{nc} can be stated to allow assessment of the current-carrying capacity in lightly loaded sections, see 5.3.2.

For assemblies incorporating power factor correction banks, verification of temperature-rise shall meet the additional requirements of IEC 61921:2017.

10.10.2 Verification by testing

10.10.2.1 General

Verification through testing consists of the following.

a) If the assembly system to be verified comprises a number of variants, the most onerous arrangement(s) for the assembly system shall be selected according to 10.10.2.2.

b) The assembly variant(s) selected shall be verified by one of the following methods (see Annex L):

   1) considering individual functional units, the main and distribution busbars and the assembly collectively according to 10.10.2.3.5;

   2) considering individual functional units separately, and the complete assembly including the main and distribution busbars according to 10.10.2.3.6;

   3) considering individual functional units and the main and distribution busbars separately as well as the complete assembly according to 10.10.2.3.7.

c) When the assembly variant(s) tested are the most onerous variants of an assembly system, then the test results can be used to establish the ratings of similar variants without further testing. Comparison rules for such derivations are given in 10.10.3.

10.10.2.2 Selection of the representative arrangement

10.10.2.2.1 General

The test shall be made on one or more representative arrangements loaded with one or more representative load combinations chosen to determine with reasonable accuracy the maximum temperature-rise under normal operating and installation conditions. The selection of the representative arrangements to be tested is given in 10.10.2.2.2 and 10.10.2.2.3 and is the responsibility of the original manufacturer. The original manufacturer shall take into consideration in the selection for testing the configurations to be derived from the tested arrangements according to 10.10.3.

10.10.2.2.2 Busbars

For busbar systems consisting of single or multiple rectangular sections of conductor, where the variants differ only in the reduction of one or more of;

– height,
– thickness,
– quantity of bars per conductor,

and have the same;

– geometric arrangement of bars,
– centre line spacing of conductors,
– enclosure, and
– busbar compartment (if any),

the busbars with the greatest cross-sectional area shall be selected as the representative arrangement as a minimum for the test. For ratings of smaller busbar size variants or other materials, see 10.10.3.3.

10.10.2.2.3 Functional units

a) Selection of comparable functional unit groups

   Functional units intended to be used at different rated currents can be considered to have a similar thermal behaviour and form a comparable range of units if they fulfil the following conditions:

   1) the function and basic wiring diagram of the main circuit is the same (e.g. incoming unit, reversing starter, cable feeder);
   2) the devices are of the same frame size and belong to the same series;
   3) the mounting structure is of the same type;
   4) the mutual arrangement of the devices is the same;
   5) the type and arrangement of conductors is the same;
   6) the cross-section of the main circuit conductors within a functional unit shall have a rating at least equal to that of the lowest rated device in the circuit. Selection of cables shall be as tested or in accordance with IEC 60364-5-5:2009. Examples on how to adapt this document for conditions inside an assembly are given in Table H.1 and Table H.2. The cross-section of bars shall be as tested or as given in Annex K.

b) Selection of a critical variant out of each comparable group as a specimen for test

   The maximum possible current rating for each variant of functional unit is established. For functional units containing only one device, this is the rated current of the device. For functional units with several devices, it is that of the device with the lowest rated current. For each functional unit, the power loss is calculated at the maximum possible current using the data given by the device manufacturer for each device together with the power losses of the associated conductors.

For functional units with currents up to and including 630 A, the critical unit in each range is the functional unit with the highest total power loss.

For functional units with currents above 630 A, the critical unit in each range is that which has the highest rated current. This ensures that additional thermal effects relating to eddy currents and current displacement are taken into consideration.

The critical functional unit shall at least be tested:

– inside the smallest compartment (if any) which is intended for this functional unit; and
– with the worst variant of internal separation (if any) with respect to size of ventilation openings; and
– with the enclosure with the highest installed power loss per volume; and
– with the worst variant of ventilation of the enclosure with respect to the kind of ventilation (natural or forced convection) and size of ventilation openings.

If the functional unit can be arranged in different orientations (horizontal, vertical), then the most onerous arrangement shall be tested.

Additional tests may be made at the discretion of the original manufacturer for less critical arrangements and variants of functional units, if any.

10.10.2.3 Methods of test

10.10.2.3.1 General

In 10.10.2.3.5 to 10.10.2.3.7, three methods of testing are given, which differ in the number of tests needed and in the range of applicability of the test results. 10.10.2.3.5 provides a means of testing a complete assembly where the group rated current I_{ng} is the test result. 10.10.2.3.6 provides a means of testing an assembly where additionally the rated current I_{nc} of the outgoing circuits is determined with fewer tests than specified in 10.10.2.3.7. An explanation is provided in Annex L.

The temperature-rise test on the individual circuits shall be made with the type of current for which they are intended, and at the design frequency. Any convenient value of the test voltage may be used to produce the desired current. Current consuming items such as, electronic components, coils of relays, contactors, releases, etc. shall be supplied with their rated operational voltages.

For assemblies with active cooling, the cooling equipment shall be operational, as in normal service.

The assembly shall be mounted as in normal use, with all covers including bottom cover plates, etc. in place.

If the assembly includes fuses, it shall be fitted for the test with fuse-links as specified by the manufacturer.

Details of the fuse-links used for the test, i.e. the manufacturer's name and reference, the rated current, the power loss of the fuse-link, and the breaking capacity, shall be given in the test report. The type test with the specified fuse-links shall be deemed to cover the use of any other fuse-link having a power loss, at the conventional thermal current of the combination unit, not exceeding the power loss of the fuse-link used for the test.

The size and the disposition of external conductors used for the test shall be stated in the test report.

The test shall be carried out for a time sufficient for the temperature-rise to reach a constant value. In practice, this condition is reached when the variation at all measured points (including the ambient air temperature) does not exceed 1 K/h.

To shorten the test, if the devices allow it, the current may be increased during the first part of the test, with it being reduced to the specified test current afterwards.

When a control electro-magnet is energized during the test, the temperature is measured when thermal equilibrium is reached in both the main circuit and the control electro-magnet.

The average value of the actual incoming test currents shall be between 100 % and 103 % of the intended value. Each phase shall be within ±5 % of the intended value.

Tests on an individual section of the assembly are acceptable. To make the test representative, the external surfaces at which additional sections may be connected shall be thermally insulated with a covering to prevent any undue cooling.

When the performance of a single functional unit in one compartment is being tested as part of a complete assembly (or part of an assembly) as required by 10.10.2.3.7 d) taking into account the influence of other functional units in their own compartments, these other functional units can be replaced by heating resistors if the rating of each does not exceed 630 A and their rating is not to be verified with this test.

In assemblies where there is a possibility that additional auxiliary circuits or devices may be incorporated, heating resistors shall simulate the power dissipation of these additional items.

To reduce the testing required to determine the rated current of a circuit I_1 at the maximum permissible temperature-rise ΔT_1, the current rating may be calculated from the actual test current I_2 if the measured temperature-rise ΔT_2 of the current carrying parts (e.g. busbars and terminals) deviates from the permissible value by not more than ±5 K, using the following formula:

$$\frac{I_1}{I_2} = \left(\frac{\Delta T_1}{\Delta T_2}\right)^{0,61}$$

[SOURCE: Copper Development Association; Publication No. 22:1996 formula No. 8.]

The formula can only be applied if the power loss of the devices and conductors is substantially proportional to I^2.

EXAMPLE A busbar has reached ΔT_2 = 102 K (ΔT_1 = 105 K allowed) under test at a current of 973 A; by using the formula, the reported value of the test will be 990 A at 105 K.

NOTE For the limited range of temperature adjustments being considered, the formula is also applicable to aluminium conductors.

Care shall be taken to ensure that all other measurement points will not reach their maximum temperature at this higher current. Any adjusted current ratings shall be clearly identified in the test documentation by the recording of results obtained during the test. Care is required when determining the number of points where this calculation is applied so as to ensure the effects of changing several currents having an influence on other measuring points (including internal air temperature) due to the changed power loss.

10.10.2.3.2 Test conductors

In the absence of detailed information concerning the external conductors and the service conditions, the cross-section of the external test conductors shall be chosen considering the rated current of each circuit as follows:

a) For values of rated current up to and including 400 A:

1) The conductors shall be single-core, copper cables or insulated wires with cross-sectional areas as given in Table 11;
2) As far as practicable, the conductors shall be in free air;
3) The minimum length of each temporary connection from terminal to terminal shall be:
   – 1 m for cross-sections up to and including 35 mm^2;
   – 2 m for cross-sections larger than 35 mm^2.

b) For values of rated current higher than 400 A but not exceeding 1 600 A:
   1) The conductors shall be single-core copper cables with cross-sectional areas as given in Table 12, or the equivalent copper bars given in Table 12 as specified by the original manufacturer.
   2) Cables or copper bars shall be spaced at approximately the distance between terminals. Multiple parallel cables per terminal shall be bunched together and arranged with approximately 10 mm of air space between each other. Multiple copper bars per terminal shall be spaced at a distance approximately equal to the bar thickness. If the sizes stated for the bars are not suitable for the terminals or are not available, it is permissible to use other bars having the same cross-sectional dimensions ±10 % and the same or smaller cooling surfaces. Cables or copper bars shall not be interleaved.
   3) For single-phase or multi-phase tests, the minimum length of any temporary connection to the test supply shall be 2 m. The minimum length to a star point may be reduced to 1,2 m where agreed by the original manufacturer.

c) For values of rated current higher than 1 600 A but not exceeding 7 000 A:
   1) The conductors shall be copper bars of the sizes stated in Table 12 unless the assembly is designed only for cable connection. In this case, the size and arrangement of the cables shall be as specified by the original manufacturer.
   2) Copper bars shall be spaced at approximately the distance between terminals. Multiple copper bars per terminal shall be spaced at a distance approximately equal to the bar thickness. If the sizes stated for the bars are not suitable for the terminals or are not available, it is permissible to use other bars having the same cross-sectional dimensions ±10 % and the same or smaller cooling surfaces. Copper bars shall not be interleaved.
   3) For single-phase or multi-phase tests, the minimum length of any temporary connection to the test supply shall be 3 m, but this can be reduced to 2 m provided that the temperature-rise at the supply end of the connection is not more than 5 K below the temperature-rise in the middle of the connection length. The minimum length to a star point shall be 2 m.

d) For values of rated current higher than 7 000 A:

   The original manufacturer shall determine all relevant items of the test, such as type of supply, number of lines and frequency (where applicable), cross-sections of test conductors, etc. This information shall form part of the test report.

10.10.2.3.3 Measurement of temperatures

Thermocouples or thermometers shall be used for temperature measurements. For windings, the method of measuring the temperature by resistance variation shall generally be used. In cases where this is not practical, thermocouples may be used to determine the temperature-rise on the surface of the coil.

The thermometers or thermocouples shall be protected against air currents and heat radiation.

The temperature shall be measured at all points where a temperature-rise limit (see 9.2) shall be observed. Particular attention shall be given to joints in conductors and terminals within the main circuits. For measurement of the temperature of the air inside an assembly, several measuring devices shall be arranged in convenient places.

10.10.2.3.4 Ambient air temperature

The ambient air temperature shall be measured by means of at least two thermometers or thermocouples equally distributed around the assembly at approximately half its height and at a distance of approximately 1 m from the assembly. The thermometers or thermocouples shall be protected against air currents and heat radiation.

The ambient air temperature during the test shall be between +10 °C and +40 °C.

10.10.2.3.5 Verification of the complete assembly

The main circuits of the assembly shall be loaded with their estimated group rated currents, I_{ng}, (see 5.3.3) (see Annex L).

If the group rated current, I_{ng}, of the incoming circuit or distribution busbar system is less than the sum of the group rated currents, I_{ng}, of all outgoing circuits, then the outgoing circuits shall be split into test sets corresponding to the group rated current of the incoming circuit or distribution busbar system. The test sets shall be formed in a manner so that the highest possible temperature-rise is obtained. Enough test sets shall be formed and tests undertaken to include all different variants of functional units in at least one test set.

Where the fully-loaded circuits do not distribute exactly the total incoming current, the remaining current shall be distributed via any other appropriate circuit. This test shall be repeated until all types of outgoing circuit have been verified at their group rated currents.

Change in the arrangement of functional units within a verified assembly, or section of an assembly, may necessitate additional tests as the thermal influence of the adjacent units may differ significantly.

10.10.2.3.6 Verification considering individual functional units separately and the complete assembly

The group rated currents, I_{ng}, according to 5.3.3 and the rated currents, I_{nc}, of the outgoing main circuits according to 5.3.2 shall be verified in two stages:

– The rated current, I_{nc}, of each critical variant of outgoing functional unit as defined in 10.10.2.2.3 b) shall be verified separately in accordance with 10.10.2.3.7 c).
– The assembly is verified by loading the incoming circuit and all outgoing functional units collectively to their estimated group rated currents, I_{ng}.

If the group rated current, I_{ng}, of the incoming circuit or distribution busbar system is less than the sum of the currents, I_{ng}, of all outgoing circuits, then the outgoing circuits shall be split into test sets corresponding to the group rated current of the incoming circuit or distribution busbar system. The test sets shall be formed in a manner so that the highest possible temperature-rise is obtained. Sufficient test sets shall be formed and tests undertaken to include all different variants of functional units in at least one test set.

Where the fully loaded circuits do not distribute exactly the total incoming current, the remaining current shall be distributed via any other appropriate circuit. This test shall be repeated until all types of outgoing circuit have been verified at their test current.

Change in the arrangement of functional units within a verified assembly, or section of an assembly, may necessitate additional tests as the thermal influence of the adjacent units may differ significantly.

If I_{nc} and I_{ng} are verified, the RDF is calculated by dividing I_{ng} by I_{nc} for the individual circuits being considered.

10.10.2.3.7 Verification considering functional units and the main and distribution busbars separately as well as the complete assembly

Assemblies shall be verified by separate verification of standard elements a) to c) as selected in accordance with 10.10.2.2.2 and 10.10.2.2.3, and verification of a complete assembly d) under worst case conditions as detailed below.

a) Main busbars shall be tested separately. They shall be mounted in the assembly enclosure as in normal use with all covers and all partitions that separate the main busbars from other compartments in place. If the main busbar has joints, then they shall be included in the test. The test shall be carried out at the rated current. The test current shall pass through the full length of the busbars. Where the design of the assembly permits, and, to minimize the influence of the external test conductors on the temperature-rise, the length of the main busbar within the enclosure for the test shall be a minimum of 2 m and include a minimum of one joint when the busbars are extendable.

b) Each distribution busbar shall be tested separately from the outgoing units. They shall be mounted in the enclosure as in normal use with all covers and all partitions that separate the busbar from other compartments in place. Distribution busbars shall be connected to the main busbar. No other conductors (e.g. connections to functional units) shall be connected to the distribution busbar. In order to consider the most onerous condition, the test shall be carried out at the rated current, and the test current shall pass through the full length of the distribution busbar. If the rated current of the main busbar is higher than the test current, it shall be fed with additional current so that it carries its rated current to its junction with the distribution busbar.

c) If the manufacturer declares I_{nc}, the relevant functional units shall be tested individually. The functional unit shall be mounted in the enclosure as in normal use with all covers and all internal partitions in place. If it can be mounted at different places, the most unfavourable place shall be used. It shall be connected to the main or the distribution busbar as in normal use. If the main busbar and/or the distribution busbar (if any) are intended to supply other circuits and they are rated for a higher current, they shall be fed with additional currents so that they carry their individual rated currents to the respective junction points. The test shall be carried out at the estimated rated current I_{nc} for the functional unit.

d) The complete assembly shall be verified by temperature-rise testing of the most onerous arrangement(s) possible in service and as defined by the original manufacturer. For this test the incoming circuit and each outgoing functional unit are loaded to their group rated current I_{ng} where I_{ng} is equal to I_{nc} multiplied by RDF when I_{nc} is declared. If the group rated current of the incoming circuit or distribution busbar system is less than the sum of the test currents of all outgoing circuits (i.e. their group rated currents), then the outgoing circuits shall be split into test sets corresponding to the rated current of the incoming circuit or distribution busbar system. If the main busbar and/or the distribution busbar (if any) are rated for a higher current, they shall be fed with additional currents so as to maintain the rating achieved in a) and b). The test sets shall be formed in a manner so that the highest possible temperature-rise is obtained. Enough test sets shall be formed and tests undertaken to include all different variants of functional units in at least one test set.

If I_{nc} and I_{ng}, are verified the RDF is calculated by dividing I_{ng} by I_{nc} for the individual circuits being considered.

10.10.2.3.8 Results to be obtained

The estimated rated currents in 10.10.2.3.5, 10.10.2.3.6 and 10.10.2.3.7, as verified by test(s), determine the final I_{nc} and/or I_{ng}, as applicable.

At the end of the test, the temperature-rise shall not exceed the values specified in Table 6.

If tests according to 10.10.2.3.6 or 10.10.2.3.7 have been carried out to verify I_{nc} in addition to I_{ng}, for the outgoing circuits, then the rated diversity factor may be calculated (see 3.8.11 and 5.4).

10.10.3 Verification by comparison

10.10.3.1 General

The following subclauses define how the rated currents of variants can be verified by derivation from similar arrangements verified by testing.

Tests carried out at a particular frequency are applicable at the same current rating to lower frequencies including DC.

Temperature-rise tests on the circuit(s) carried out at 50 Hz are applicable to 60 Hz for rated currents up to and including 800 A. In the absence of tests at 60 Hz for currents above 800 A, the rated current at 60 Hz shall be reduced to 95 % of that at 50 Hz. Alternatively, where the maximum temperature-rise at 50 Hz does not exceed 90 % of the permissible value, then de-rating for 60 Hz is not required.

10.10.3.2 Assemblies

Assemblies verified by derivation from a similar tested arrangement shall comply with the following:

a) the functional units shall belong to the same group(s) as the functional unit(s) selected for test (see 10.10.2.2.3);
b) the same type of construction as used for the test;
c) the same or increased overall dimensions as used for the test;
d) the same or increased cooling conditions as used for the test (forced or natural convection, same or larger ventilation openings);
e) the same or reduced internal separation as used for the test (if any);
f) the same or reduced power losses in the same section as used for the test.

The assembly being verified may comprise all or only part of the electrical circuits of the assembly previously verified. Alternative arrangement(s) of functional units within the assembly or section compared to the tested variant is allowed as long as the thermal influences of the adjacent units are not more severe.

Thermal tests performed on 3-phase, 3-wire assemblies are considered as representing 3-phase, 4-wire and single-phase, 2-wire or 3-wire assemblies, provided that the neutral conductor is sized equal to or greater than the line conductors and arranged in the same manner.

10.10.3.3 Busbars

Ratings established for aluminium busbars are valid for copper busbars with the same cross-sectional dimensions and configuration. However, ratings established for copper busbars shall not be used to establish ratings of aluminium busbars.

The ratings of variants not selected for test according to 10.10.2.2.2 shall be determined by multiplying their cross-section with the current density of a larger cross-section busbar of the same design that has been verified by testing.

If, additionally, a smaller cross-section than the one to be derived has been tested, which also fulfils the conditions of 10.10.2.2.2, then the rating of the intermediate variants may be established by interpolation.

Modification of the connection between main and distribution busbar is permissible if the modification is verified by a test in which the temperature-rise in the new arrangement is not higher than in a comparable test on the reference design.

10.10.3.4 Functional units

After the critical variant of each group of comparable functional units (see 10.10.2.2.3 a)) has been subjected to a test for verification of temperature-rise, the actual rated currents I_{ng}, and if determined, I_{nc}, of all other functional units in the group shall be calculated using the results of these tests.

For each functional unit tested, a de-rating factor (rated current, I_{nc} or I_{ng}, resulting from the test divided by the maximum possible current of this functional unit, see 10.10.2.2.3 b)) shall be calculated.

The rated current, I_{nc} or I_{ng}, of each non-tested functional unit in the range shall be the maximum possible current of the functional unit multiplied by the de-rating factor established for the variant tested in the range.

Modification of the connection between functional unit and the main or distribution busbar is permissible if the modification is verified by a test in which the temperature-rise in the new arrangement is not higher than in a comparable test on the reference design.

10.10.3.5 Functional units – Temperature-rise considerations for device substitution

A device with a rated current I_n not exceeding 1 600 A may be substituted with a similar device from another series from the same or a different device manufacturer to that used in the original verification, provided that the power loss and terminal temperature-rise of the substituting device is the same as or lower than the device used in the original verification, when both are tested in accordance with the devices' product standard.

Alternatively, and without a limit on current rating, when the original device and the substituting device are from the same device manufacturer, the device manufacturer may issue a declaration of temperature-rise performance. The declaration shall confirm that the substituting device can replace the original device with no further need for verification in respect of temperature-rise. The declaration shall include statements indicating that the power loss for the substituting device is the same or lower than the original device.

In addition, for both the above options the physical arrangement within the functional unit shall be maintained. The rating of a functional unit shall not be increased.

The physical arrangements shall include terminal shields, conductor type, material, and connection sizes, mounting orientation, clearances to other parts, ventilation arrangements and terminal arrangement.

The performance data on terminal temperatures and power loss may be obtained from the device manufacturer or from comparison tests undertaken by those responsible for the substitution. Any test shall be conducted on new samples.

Refer to Table D.1 for other design characteristics, including short-circuit withstand (see Table 13, Item 6), that require consideration when substituting devices.

10.10.3.6 Calculation of currents based on adjustment of ambient air temperature

Once a temperature-rise test has been carried out applying the temperature-rise limits for a daily average ambient air temperature of 35 °C, the rated currents confirmed by testing for a daily average ambient air temperature of 35 °C can be adjusted by calculation to determine rated current for daily average ambient air temperatures between 20 °C and 50 °C, assuming that the temperature-rise of each component or device is proportional to the power loss generated in this component.

Caution should be taken to ensure the devices being assessed have a power loss substantially proportional to I^2 and not applied to devices that have substantially fixed or linear losses. By agreement between the user and the manufacturer, in assemblies where the power loss of conductors and devices is substantially proportional to I^2, the rated current of the circuits at ambient air temperatures (outside the enclosure) between 20 °C and 50 °C may be calculated using the following formula:

$$\frac{I_1}{I_2} = \left(\frac{\Delta T_1}{\Delta T_2}\right)^{0,61}$$

[SOURCE: Copper Development Association; Publication No. 22:1996 formula No. 8.]

NOTE For the limited range of temperature adjustments being considered, the formula is also applicable to aluminium conductors.

where

I_1 is the current at which the temperature-rise test is carried out;

I_2 is the current rating to be determined at the specific ambient air temperature between 20 °C and 50 °C;

ΔT_1 is the temperature-rise measured by test with a current of I_1;

ΔT_2 is maximum permissible temperature-rise at the specific ambient air temperature between 20 °C and 50 °C.

I_2 cannot exceed the rated current of any device, (e.g. I_n for a circuit-breaker), within the circuit being considered, e.g. a circuit including a 1 600 A circuit-breaker cannot be assigned a current rating of 1 750 A in an ambient air temperature of 20 °C.

10.10.4 Verification assessment

This subclause of IEC 61439-1:2020 is not applicable.

10.11 Short-circuit withstand strength

10.11.1 General

The short-circuit current ratings declared shall be verified except where exempt, see 10.11.2. Verification may be made by comparison with a reference design(s) (10.11.3 and 10.11.4) or by testing (10.11.5). For verification, the following apply.

a) If the assembly system to be verified comprises a number of variants, the most onerous arrangement(s) of the assembly shall be selected, taking into account the rules in 10.11.3 and 10.11.4.

b) The assembly variants selected for test shall be verified according to 10.11.5.

c) When the assemblies tested are the most onerous variants of the larger product range of an assembly system, then the test results can be used to establish the ratings of similar variants without further testing. Rules for such derivations are given in 10.11.3 and 10.11.4.

10.11.2 Circuits of assemblies which are exempted from the verification of the short-circuit withstand strength

A verification of the short-circuit withstand strength is not required for the following:

a) assemblies having a rated short-time withstand current (see 5.3.5) or rated conditional short-circuit current (see 5.3.6) not exceeding 10 kA RMS for AC and 10 kA mean average for DC;

b) assemblies, or circuits of assemblies, protected by current-limiting devices having a cut-off current not exceeding 17 kA with the maximum allowable prospective short-circuit current at the terminals of the incoming circuit of the assembly;

c) auxiliary circuits of assemblies intended to be connected to transformers whose rated power does not exceed 10 kVA for a rated secondary voltage of not less than 110 V, or 1,6 kVA for a rated secondary voltage less than 110 V, and whose short-circuit impedance is not less than 4 %;

d) circuits protected by frequency converters where the outputs are provided with electronic short-circuit protection that limits the cut-off current to not more than 17 kA, as declared by the manufacturer.

All other circuits shall be verified.

10.11.3 Verification by comparison with a reference design – Using a checklist

The verifications are undertaken by comparison of the assembly to be verified with a reference design(s) using the checklist provided in Table 13.

Should any elements identified in the checklist not comply with the requirements of the checklist and be marked ‘NO’, one of the following means of verification shall be used (see 10.11.4 and 10.11.5).

A fuse link used in the reference design can be replaced by a fuse link of another make or series without any further testing if:

– the rating of the fuse links shall be the same;
– the utilization category is the same (e.g. gG);
– the fuse system is the same (e.g. NH); and
– power loss is the same or lower.

10.11.4 Verification by comparison with a reference design(s) – Using calculation

Assessment of the rated short-time withstand current of an assembly and its circuits, by calculation, shall be undertaken by a comparison of the assembly to be assessed with an assembly already verified by testing. The assessment to verify the main circuits of an assembly shall be in accordance with Annex M. In addition, each of the circuits of the assembly to be assessed shall meet the requirements of items 6, 8, 9 and 10 in Table 13.

The data used, calculations made and the comparison undertaken shall be stated in the verification documentation.

If the assessment in accordance with Annex M does not pass or any of the items listed above are not fulfilled, then the assembly and its circuits shall be verified by test in accordance with 10.11.5.

10.11.5 Verification by test

10.11.5.1 Test arrangements

The assembly or its parts as necessary to complete the test shall be mounted as in normal use. It is sufficient to test a single functional unit if the remaining functional units are of the same construction. Similarly, it is sufficient to test a single busbar configuration if the remaining busbar configurations are of the same construction. Table 13 provides clarification on items not requiring additional tests.

10.11.5.2 Performance of the test

If the test circuit incorporates fuses, fuse-links with the maximum let-through current and, if required, of the type indicated by the original manufacturer as being acceptable, shall be used.

The supply conductors and the short-circuit connections required for testing the assembly shall have sufficient strength to withstand short-circuits and be so arranged that they do not introduce any additional stresses on the assembly.

Unless otherwise agreed, the test circuit shall be connected to the input terminals of the assembly. Three-phase assemblies shall be connected on a three-phase basis.

All parts of the equipment intended to be connected to the protective conductor in service, including the enclosure, shall be connected as follows:

a) for assemblies suitable for use on three-phase four-wire systems with an earthed star point and marked accordingly, to the neutral point of supply or to a substantially inductive artificial neutral permitting a prospective fault current of at least 1 500 A;

b) for assemblies also suitable for use in three-phase three-wire as well as on three-phase four-wire systems and marked accordingly, to the line conductor least likely to arc to earth.

Except for assemblies according to 8.4.4, the connection mentioned in a) and b) shall include a fusible element consisting of a copper wire of 0,8 mm diameter and at least 50 mm long, or of an equivalent fusible element for the detection of a fault current. The prospective fault current in the fusible element circuit shall be 1 500 A ± 150 A, except as stated in Notes 2 and 3. If necessary, a resistor limiting the current to that value shall be used.

NOTE 1 A copper wire of 0,8 mm diameter will melt at 1 500 A in approximately half a cycle at a frequency between 45 Hz and 67 Hz (or 0,01 s for DC).

NOTE 2 The prospective fault current can be less than 1 500 A in the case of small equipment, according to the requirements of the relevant product standard, with a smaller diameter copper wire (see Note 4) corresponding to the same melting time as in Note 1.

NOTE 3 In the case of a supply having an artificial neutral, a lower prospective fault current can be accepted, subject to the agreement of the assembly manufacturer, with a smaller diameter copper wire (see Note 4) corresponding to the same melting time as in Note 1.

NOTE 4 The relationship between the prospective fault current in the fusible element circuit and the diameter of the copper wire is given in Table 14.

10.11.5.3 Testing of main circuits

10.11.5.3.1 General

Circuits shall be tested with the highest thermal and dynamic stresses that may result from short-circuit currents up to the rated values for one or more of the following conditions as declared by the original manufacturer.

a) Not dependent upon a SCPD: the assembly shall be tested with the rated peak withstand current and the rated short-time withstand current for the specified duration (see 5.3 and 9.3.2 a)).

b) Dependent upon an incoming SCPD included within the assembly: the assembly shall be tested with an incoming prospective short-circuit current for a period of time that is limited by the incoming SCPD.

c) Dependent upon an upstream SCPD: the assembly shall be tested to the let-through values permitted by the upstream SCPD as defined by the original manufacturer.

Where an incoming or outgoing circuit includes a SCPD that reduces the peak and/or duration of the fault current, then the circuit shall be tested allowing the SCPD to operate and interrupt the fault current (see 5.3.6 rated conditional short-circuit current I_{cc}). If the SCPD contains an adjustable short-circuit release, then this shall be set to the maximum allowed value (see 9.3.2, second paragraph).

NOTE In some cases, where protective functions of the device can be disabled, this can result in higher peak currents and let through energy.

One of each type of circuit shall be subject to a short-circuit test as described in 10.11.5.3.2 to 10.11.5.3.5.

10.11.5.3.2 Outgoing circuits

The outgoing terminals of outgoing circuits shall be provided with a bolted short-circuit connection. When the protective device in the outgoing circuit is a circuit-breaker, the test circuit may include a shunting resistor in accordance with 9.3.4.1.2 b) of IEC 60947-1:2020 in parallel with the reactor used to adjust the short-circuit current.

For circuit-breakers having a rated current up to and including 630 A, a conductor 0,75 m in length having a cross-sectional area corresponding to the rated current (see Table 11 and Table 12) shall be included in the test circuit. At the original manufacturer's discretion, a shorter connection than 0,75 m may be used.

The switching device shall be closed and held closed in the manner normally used in service. The test voltage shall then be applied once for a magnitude and duration as given in 10.11.5.4. In the case of outgoing circuits which do not include an SCPD, the magnitude and duration shall be as specified for the main busbars by the original manufacturer. Testing of outgoing circuits may also result in the operation of the incoming SCPD.

10.11.5.3.3 Incoming circuit and main busbars

Assemblies containing main busbars shall be tested to prove the short-circuit withstand strength of the main busbars and the incoming circuit including at least one joint where the busbars are intended to be extendable. The short-circuit shall be placed such that the length of main busbar included in the test is (2 ± 0,4) m. For the verification of rated short-time withstand current (see 5.3.5) and rated peak withstand current (see 5.3.4), this distance may be increased and the test conducted at any convenient voltage providing the test current is the rated value (see 10.11.5.4 b)). Where the design of the assembly is such that the length of the busbars to be tested is less than 1,6 m and the assembly is not intended to be extended, then the complete length of busbar shall be tested, the short-circuit being established at the end of these busbars. If a set of busbars consists of different sections (as regards cross-sections, centre line spacing of the conductors, type and number of supports per metre), each section shall be tested separately or concurrently, provided that the above conditions are met.

10.11.5.3.4 Connections to the supply side of outgoing units

Where an assembly contains conductors, including any distribution busbars, between a main busbar and the supply side of outgoing functional units that do not fulfil the requirements of 8.6.4, one circuit of each type shall be subjected to an additional test.

A short-circuit is obtained by bolted connections on the conductors connecting the busbars to a single outgoing unit, as near as practicable to the terminals on the busbar side of the outgoing unit. The value and duration of the short-circuit current shall be the same as that for the main busbars.

10.11.5.3.5 Neutral or mid-point conductor

10.11.5.3.5.1 Neutral conductor

If a neutral conductor exists within a circuit, it shall be subjected to one test to prove its short-circuit withstand strength in relation to the nearest line conductor of the circuit under test including any joints. Line to neutral short-circuit connections shall be applied as specified in 10.11.5.3.3.

Unless otherwise agreed between the original manufacturer and the user, the value of the test current in the neutral conductor shall be at least 60 % of the line current during the three-phase test.

The test need not be executed if the test is intended to be made with a current of 60 % of the line current and if the neutral conductor is:

– the same shape and cross-section as the line conductors;
– supported in an identical manner as the line conductors and with support centres along the length of the conductor not greater than that of the phases;
– spaced at a distance from the nearest phase(s) not less than that between phases;
– spaced at a distance from earthed metalwork not less than the line conductors.

If a 4-pole busbar system is sectioned by a three pole device, the short-time withstand current test including the neutral need not be executed if the test is intended to be made with a current of 60 % of the line current and:

a) the criteria listed above are met; and
b) the neutral pole is part of a 4-pole busbar system that includes a 3-pole device, and
c) the 3-pole device does not result in any changes to the support system that would be necessary to support the line and neutral conductors if the 3-pole device were not present.

10.11.5.3.5.2 Mid-point conductor

The mid-point conductor shall be subjected to one test to prove its short-circuit withstand strength in relation to the line conductor of the circuit under test including any joints. Mid-point to line short-circuit connections shall be applied as specified in 10.11.5.3.3.

Unless otherwise agreed between the original manufacturer and the user, the value of the test current in the mid-point conductor shall be 100 % of the line to line test current.

The test need not be executed if the mid-point conductor is not positioned between the line conductors if the following are fulfilled:

– it is the same shape and cross-section as the line conductors;
– it is supported in an identical manner as the line conductors and with support centres along the length of the conductor not greater than that of the line conductors;
– it is spaced at an equal or greater distance than the distance between the line conductor(s).

In the case of a short-time withstand current, the test need not be executed if:

a) the criteria listed above are met; and
b) the mid-point pole is part of a 3-pole busbar system that includes a device; and
c) the device does not result in any changes to the support system that would be necessary to support the line and mid-point conductors if the device were not present.

10.11.5.4 Value and duration of the short-circuit current

For all short-circuit withstand ratings, the dynamic and thermal stresses shall be verified with a prospective current at the supply side of the specified protective device, if any, equal to the value of the rated short-time withstand current, rated peak withstand current or rated conditional short-circuit current.

For the verification of all the short-circuit withstand ratings (see 5.3.4 to 5.3.6 inclusive), the value of the prospective short-circuit current shall be within a tolerance of 0 % to +5 % at a test voltage equal to 1,05 times the rated operational voltage U_e of the circuit. The value of the short-circuit current shall be determined from a calibration oscillogram, which is taken with the supply conductors to the assembly short-circuited by a connection of negligible impedance placed as near as possible to the input supply of the assembly. The oscillogram shall show that there is a constant flow of current such that it is measurable at a time equivalent to the operation of the protective device incorporated in the assembly or for the specified duration (see 9.3.2 a)).

The value of current during the calibration is:

– for a test with AC, the RMS value of the AC component and the average of currents of all phases in a poly-phase system; or
– for a test with DC, the mean value in sustained conditions.

When making the tests at maximum operational voltage, the calibration current shall be equal to the rated short-circuit current with a tolerance of 0 % to +5 %. In poly-phase systems, this tolerance applies to the average of all line currents, while each individual line current may have a tolerance of ±5 % of the rated value. For AC tests, the power factor shall be within a tolerance of 0,00 and −0,05.

The peak current and power factor in the case of an AC test shall be in accordance with 9.3.3. All tests for AC applications shall be carried out at the rated frequency of the assembly with a tolerance of ± 25 %. With the following exception, tests for DC applications shall be carried out with DC.

An AC short-time current test may be used to verify a rated DC short-time withstand current and a rated DC peak withstand current providing the test with AC has a peak current equal to the rated DC peak withstand current and the RMS value of the short-time current is at least equal to the rated DC short-time withstand current. When substituting a DC test by an AC test, it should be recognized that the thermal and dynamic stresses of the AC test are higher than those of the equivalent DC test.

a) For a test at the rated conditional short-circuit current I_{cc}, whether the protective devices are in the incoming circuit of the assembly or elsewhere, the test voltage shall be applied for a time sufficiently long to enable the short-circuit protective devices to operate to clear the fault and, in any case, for not less than 10 cycles for AC and 200 ms for DC. The test shall be conducted at 1,05 times the rated operational voltage with prospective short-circuit currents, at the supply side of the specified protective device, equal to the value of the rated conditional short-circuit current. Tests at lower voltages are not permitted.
b) For a test at the rated short-time withstand current and at the rated peak withstand current, the dynamic and thermal stresses shall be verified with a prospective current equal to the value of rated short-time withstand current and rated peak withstand current declared. The current shall be applied for the specified time during which the RMS value of its AC component in the case of a test with AC, or the DC value in the case of a test with DC, shall remain constant.

In the event of difficulties in carrying out the short-time or peak withstand tests at the maximum operational voltage with the test station, the tests according to 10.11.5.3.3, 10.11.5.3.4 and 10.11.5.3.5 may be carried out at any convenient voltage with the original manufacturer's agreement, the actual test current being in this case equal to the rated short-time current or peak withstand current. This shall be stated in the test report. If, however, any momentary contact separation occurs in a contact arrangement (e.g. within a switching device or a plug-in contact), during the test, the test shall be repeated at the maximum operational voltage.

If necessary, due to test limitations, a different test period is permissible; in such a case, the test current should be modified in accordance with the formula I^2t = constant, provided that the peak value does not exceed the rated peak withstand current without the original manufacturer's consent and that the RMS value in the case of a test with AC, or DC value in the case of a test with DC, of the short-time current is not less than the rated value in at least one phase for at least 0,1 s after current initiation.

The peak current withstand test and the short-time current test may be separated. In this case, the time during which the short-circuit is applied for the peak current withstand test shall be such that the value I^2t is not larger than the equivalent value for the short-time current test, but it shall be not less than 60 ms.

Where the required test current in each phase cannot be achieved, the positive tolerance may be exceeded with the agreement of the original manufacturer.

10.11.5.5 Results to be obtained

After the test, deformation of busbars and conductors is acceptable provided that the clearances and creepage distances specified in 8.3 are still complied with. In case of any doubt, clearances and creepage distances shall be measured (see 10.4).

The characteristics of the insulation shall remain such that the mechanical and dielectric properties of the equipment satisfy the requirements of the relevant assembly standard. A busbar support or cable restraint shall not have separated into two or more pieces. Also, there shall be no cracks appearing on opposite sides of a support and no cracks, including surface cracks, running the full length or width of the support. In case of any doubt that the insulation properties of the assembly are not maintained, an additional power frequency test at two times U_e with a minimum of 1 000 V shall be performed in accordance with 10.9.2.

There shall be no loosening of parts used for the connection of conductors and the conductors shall not separate from the outgoing terminals.

Distortion of the busbars or supporting structure of the assembly that impairs its normal use shall be deemed a failure.

Any distortion of the busbars or supporting structure of the assembly that impairs normal insertion or removal of the removable parts shall be deemed a failure.

Deformation of the enclosure or of the internal partitions, barriers and obstacles due to the short-circuit current is permissible to the extent that the degree of protection is not apparently impaired and the clearances or creepage distances are not reduced to values that are less than those specified in 8.3.

Additionally, after the tests of 10.11.5.3 incorporating short-circuit protective devices, the tested equipment shall be capable of withstanding the power-frequency withstand voltage test of 10.9.2 at a voltage value for the "after-test" condition prescribed in the relevant short-circuit protective device standard for the appropriate short-circuit test, as follows:

a) between all live parts and the exposed-conductive-parts of the assembly, and

b) between each pole and all other poles connected to the exposed-conductive-parts of the assembly.

If tests a) and b) above are conducted, they shall be carried out with any fuses replaced and with any switching device closed.

In case of any doubt, it shall be checked that the equipment incorporated in the assembly is in a condition as prescribed in the relevant product standards and/or device manufacturer’s information, e.g. can be manually opened and closed. The fusible element (see 10.11.5.2), if any, shall not indicate a fault current. There shall be neither arcing nor flashover between poles of the protective device, or between poles and enclosure.

10.11.5.6 Testing of the protective circuit

10.11.5.6.1 General

This test does not apply for circuits according to 10.11.2.

A single-phase test supply shall be connected to the incoming terminal of one phase and to the terminal for the incoming protective conductor. When the assembly is provided with a separate protective conductor, the nearest line conductor shall be used. Where the assembly is extendable, the protective circuit tested shall include at least one joint. For each representative outgoing unit, a separate test shall be carried out with a bolted short-circuit connection between the corresponding outgoing phase terminal of the unit and the terminal for the relevant outgoing protective conductor.

Each outgoing unit on test shall be fitted with its intended protective device. Where alternative protective devices can be incorporated in the outgoing unit, the protective device which lets through the maximum values of peak current and I^2t shall be used.

For this test, the frame of the assembly shall be insulated from the earth. The test voltage shall be equal to 1,05 times the single-phase value of the rated operational voltage. Unless otherwise agreed between the original manufacturer and the user, the value of the test current in the protective conductor shall be at least 60 % of the line current during the three-phase test of the assembly.

All other conditions of this test shall be analogous to 10.11.5.2 to 10.11.5.4 inclusive.

10.11.5.6.2 Results to be obtained

The continuity and the short-circuit withstand strength of the protective circuit, whether it consists of a separate conductor or the frame or enclosure of the assembly, shall not be significantly impaired. Besides visual inspection, this may be verified by measurements with a current of the order of the rated current of the relevant outgoing unit. The earth continuity between the exposed-conductive-parts of a class I assembly and the protective circuit shall remain effective. If in doubt, measurements according to 10.5.2 shall be carried out. Deformation of the enclosure or of the internal partitions, barriers and obstacles due to the short-circuit current is permissible to the extent that the degree of protection is not apparently impaired and the clearances or creepage distances are not reduced to values that are less than those specified in 8.3.

Where the frame or enclosure of the assembly is used as a protective conductor, sparks and localized heating at joints are permitted, provided they do not impair the electrical continuity and provided that adjacent flammable parts are not ignited.

NOTE A comparison of the resistances measured before and after the test, between the terminal for the incoming protective conductor and the terminal for the relevant outgoing protective conductor, gives an indication of conformity with this condition.

10.12 Electromagnetic compatibility (EMC)

For EMC tests, see J.10.12.

11 Routine verification

11.1 General

Under the responsibility of the assembly manufacturer, all routine verification including testing, installation and commissioning shall be carried out or supervised by a competent person.

Routine verification is intended to detect faults in materials and workmanship and to ascertain proper functioning of the manufactured assembly. It is made on every assembly. The assembly manufacturer shall determine if routine verification is carried out during and/or after manufacture. Routine verification shall confirm that the assembly manufacturing instructions have been adhered to.

Routine verification is not required to be carried out on devices and self-contained components incorporated in the assembly when they have been selected in accordance with 8.5.3 and installed in accordance with 8.5.4.

Verification shall comprise the following categories:

a) Construction (see 11.2 to 11.8):
   1) degree of protection against contact with hazardous live parts, ingress of solid foreign bodies and water of enclosures;
   2) clearances and creepage distances;
   3) protection against electric shock and integrity of protective circuits;
   4) incorporation of built-in components;
   5) internal electrical circuits and connections;
   6) terminals for external conductors;
   7) mechanical operation.
b) Performance (see 11.9 to 11.10):
   1) dielectric properties;
   2) wiring, operational performance and function.

   NOTE This verification includes the proper connection and operation of any communicating devices.
c) Confirmation that documents that are intended to be supplied with the assembly are provided and include those required in 6.2.1.

11.2 Degree of protection against contact with hazardous live parts, ingress of solid foreign bodies and water of enclosures

A visual inspection is necessary to confirm that the assembly meets the prescribed measures to achieve the designated degree of protection.

11.3 Clearances and creepage distances

Where the clearances are:

– less than the values given in Table 1, an impulse voltage withstand test in accordance with 10.9.3 shall be carried out;
– not evident by visual inspection to be larger than the values given in Table 1 (see 10.9.3.5), verification shall be by physical measurement or by an impulse voltage withstand test in accordance with 10.9.3;
– evidently larger by visual inspection than the values given in Table 1, verification may be carried out only by visual inspection.

The prescribed measures with regard to creepage distances (see 8.3.3) shall be subject to a visual inspection. Where it is not evident by visual inspection, verification shall be by physical measurement. No reduction on the values given in Table 2 is acceptable.

11.4 Protection against electric shock and integrity of protective circuits

The prescribed protective measures with regard to basic protection and fault protection (see 8.4.2 and 8.4.3) shall be subject to a visual inspection.

The protective circuits shall be checked by inspection to ascertain that the measures prescribed in the manufacturer’s instructions are adhered to and verified. When it is not obvious by inspection that the earth continuity of the protective circuits meets the requirement of 8.4.3.2, a continuity test according to 10.5.2 shall be made.

Screwed and bolted connections shall be checked for the correct tightness on a random basis.

11.5 Incorporation of built-in components

The installation and identification of built-in components shall be in accordance with the assembly's manufacturing instructions.

11.6 Internal electrical circuits and connections

The connections, especially screwed and bolted connections, shall be checked for the correct tightness on a random basis.

Conductors shall be checked in accordance with the assembly's manufacturing instructions.

11.7 Terminals for external conductors

The number, type and identification of terminals shall be checked in accordance with the assembly's manufacturing instructions.

11.8 Mechanical operation

The effectiveness of mechanical actuating elements, interlocks and locks, including those associated with removable parts, shall be checked.

Where a device's operating handle is used to indicate the switching position of the device, and it detaches from the device when the door is open, it shall be confirmed that, when the door is closed, the handle provides positive and unambiguous indication of the device's open and closed positions.

11.9 Dielectric properties

A power-frequency withstand test shall be performed on all circuits in accordance with 10.9.1 and 10.9.2 but for a duration of 1 s and with a tripping current not less than 3,5 mA.

This test need not be made on auxiliary circuits:

– that are protected by a short-circuit protective device with a rating not exceeding 16 A;

– if an electrical function test has been made previously at the rated operational voltage for which the auxiliary circuits are designed.

As an alternative for assemblies with incoming protection rated up to 630 A and a rated voltage U_n not exceeding 500 V, the verification of insulation resistance may be by measurement using an insulation measuring device at a voltage of at least 500 V DC.

In this case, the test is satisfactory if the insulation resistance between circuits and exposed-conductive-parts is at least 1 MΩ.

11.10 Wiring, operational performance and function

It shall be verified that the information and markings specified in Clause 6 are complete.

Depending on the complexity of the assembly, it may be necessary to inspect the wiring and to carry out an electrical function test. The test procedure and the number of tests depend on whether or not the assembly includes complicated interlocks, sequence control facilities, etc.

By agreement between the user and the assembly manufacturer, communicating devices that are included and connected in a system within the assembly may need to be checked for basic operation and functionality.

In some cases, it may be necessary to make or repeat this test on site before putting the installation into operation.

101 Particular features of ACS

101.1 General requirements and functions

An ACS consists of one incoming unit and one or more outgoing units and can incorporate METERING UNIT(s) and TRANSFORMER UNIT(s).

Outgoing unit(s) can provide different functions such as: supply other ACS, lighting, machines or electric tools or other construction site equipment.

An ACS can be intended to be interconnected to form an installation or part of an installation in the form of a series of ACS. Apart from all their characteristics, they are covered by the same rules for protection against electric shock and provide, if possible, selective protection by a suitable choice, for example of breaking capacity, current setting and operating time.

These various characteristics are laid down by the manufacturer or are the subject of an agreement between manufacturer and user taking into account the nature of supply and/or distribution network and relevant installation requirements.

According to the relevant installation standards IEC 60364 series SPDs should be considered to protect against overvoltages.

101.2 Incoming unit

The cable connection facilities (terminals, connecting devices, connectors or plug and socket-outlet accessory) shall be compatible with the current rating of the ACS.

An isolating device and an over-current protective device shall be provided.

There shall be means for securing the isolating device in the open position.

However, the over-current protective device can be omitted if the ACS is adequately protected by an over-current protective device located in an upstream (supplying) ACS. In this case the assembly manufacturer shall provide the relevant information to the user for the correct choice of the upstream device.

According to IEC 60364-5-53, plug and socket-outlet arrangements can be used as isolating devices.

101.3 Metering unit

The METERING UNIT shall be designed by or in agreement with the energy suppliers if it is intended to accept metering device(s) to measure the energy consumed for the purpose of payment of energy to the said suppliers.

METERING UNITS not intended for the purpose of payment of energy to the suppliers are not necessarily designed by or in agreement with those suppliers.

101.4 Transformer unit

101.4.1 General

This unit can include a low-voltage/extra low-voltage (LV/ELV) transformer and/or low-voltage/low-voltage TRANSFORMER UNITS (LV/LV).

101.4.2 LV/ELV unit

This unit can be either of the LV/SELV or of the LV/PELV type.

The requirements of IEC 60364-4-41:2005, Clause 414 apply.

This type of unit essentially consists of:

a) the protective and control devices in the primary circuit;
b) the transformer, which shall be in accordance with IEC 61558-2-23;
c) the protective and control devices for the output circuit(s).

101.4.3 LV/LV units

The requirements of IEC 60364-4-41:2005, Clause 413 apply.

Each LV/LV unit consists essentially of:

a) the protective and control devices on the primary circuit;
b) the LV/LV transformer, which shall be an isolating transformer in accordance with IEC 61558-2-23;
c) the protective and control devices for the output circuit(s);
d) the outlets, either terminals or socket-outlets. Socket-outlets shall be protected as required in 101.5 e).

Notwithstanding item b), the transformer shall not be an isolating transformer if the neutral point is connected by a cable to an earthing terminal outside the enclosure. This cable shall be identified by a label placed inside the enclosure as close as possible to the terminal. Also in this case requirements a), c) and d) apply.

101.5 Outgoing units

Each unit consists of one or several outgoing circuits:

a) There shall be means for isolation, load switching, over-current protection and for fault protection. These functions can be provided by one or more devices.
b) The load switching device shall be easily accessible without the use of a key or tool in normal use.

NOTE 1 This means that an ACS can have doors closed by key or tools for other purposes (e.g. closing at the end of working time) and they are opened during the normal use.

c) The switching device shall operate simultaneously on all poles and involve all the phase conductors. For switching the neutral conductor, see IEC 60364-5-53:2019, Clause 536.
d) The connection of the outgoing circuits can made with socket outlets or by terminals for direct connection.
e) Circuits supplying socket-outlets shall be provided with provisions to ensure:
   – basic protection or fault protection according to IEC 60364-7-704:2017.

     Where RCD's are used, the same RCD can protect several socket-outlets. However, consideration should be given to the effects of unintended tripping e.g. when the RCD protects more than 6 socket outlet;

   – the protection against overcurrent with protective devices with a rated current not exceeding the rated current of the socket-outlet. A protective device can protect more than one socket-outlet (not applicable to IT systems).

     Consideration should be given to effects of unintended tripping e.g. when an overcurrent protective device protects more than one socket outlet.

NOTE 2 Measures for unwanted tripping are given in Clause 531 of IEC 60364-5-53:2019 and IEC 60364-5-53:2019/AMD1:2020

Table 1 – Minimum clearances in air (8.3.2)

Rated impulse withstand voltage, U_{imp} kV	Minimum clearance[a] mm
≤ 2,5	1,5
4,0	3,0
6,0	5,5
8,0	8,0
12,0	14,0

[a] Based on inhomogeneous field conditions and pollution degree 3.

Table 2 – Minimum creepage distances (8.3.3)

Rated insulation voltage, U_i	Minimum creepage distance mm							
	Pollution degree							
	1	2			3			
	Material group[c]	Material group[c]			Material group[c]			
V[b]	All material groups	I	II	IIIa and IIIb	I	II	IIIa	IIIb
32	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5
40	1,5	1,5	1,5	1,5	1,5	1,6	1,8	1,8
50	1,5	1,5	1,5	1,5	1,5	1,7	1,9	1,9
63	1,5	1,5	1,5	1,5	1,6	1,8	2	2
80	1,5	1,5	1,5	1,5	1,7	1,9	2,1	2,1
100	1,5	1,5	1,5	1,5	1,8	2	2,2	2,2
125	1,5	1,5	1,5	1,5	1,9	2,1	2,4	2,4
160	1,5	1,5	1,5	1,6	2	2,2	2,5	2,5
200	1,5	1,5	1,5	2	2,5	2,8	3,2	3,2
250	1,5	1,5	1,8	2,5	3,2	3,6	4	4
320	1,5	1,6	2,2	3,2	4	4,5	5	5
400	1,5	2	2,8	4	5	5,6	6,3	6,3
500	1,5	2,5	3,6	5	6,3	7,1	8,0	8,0
630	1,8	3,2	4,5	6,3	8	9	10	10
800	2,4	4	5,6	8	10	11	12,5	
1 000	3,2	5	7,1	10	12,5	14	16	[a]
1 250	4,2	6,3	9	12,5	16	18	20	
1 600	5,6	8	11	16	20	22	25	

NOTE 1 The CTI values in footnote c refer to the values obtained in accordance with IEC 60112:2003 and IEC 60112:2003/AMD1:2009, test solution A, for the insulating material used.

NOTE 2 Values taken from IEC 60664-1:2007, but maintaining a minimum value of 1,5 mm.

[a] Insulation of material group IIIb is not recommended for use in pollution degree 3 above 630 V.

[b] As an exception, for rated insulation voltages of 127 V, 208 V, 415 V, 440 V, 660 V/690 V and 830 V, creepage distances corresponding to the lower values 125 V, 200 V, 400 V, 630 V and 800 V may be used.

[c] Material groups are classified as follows, according to the range of values of the comparative tracking index (CTI) (see 3.6.16):

– Material group I 600 ≤ CTI

– Material group II 400 ≤ CTI < 600

– Material group IIIa 175 ≤ CTI < 400

– Material group IIIb 100 ≤ CTI < 175

Table 3 – Cross-sectional area of a copper protective conductor (8.4.3.2.2)

Rated operational current, I_e A	Minimum cross-sectional area of a protective conductor mm²
$I_e \leq 20$	S [a]
$20 < I_e \leq 25$	2,5
$25 < I_e \leq 32$	4
$32 < I_e \leq 63$	6
$63 < I_e$	10
[a] S is the cross-sectional area of the line conductor (mm²).	

Table 4 – Conductor selection and installation requirements (8.6.4)

Type of conductor	Requirements
Bare conductors or single-core conductors with basic insulation, for example cables according to IEC 60227-3:1993 and IEC 60227-3:1993/AMD1:1997.	Mutual contact or contact with conductive parts shall be avoided, for example by use of spacers.
Single-core conductors with basic insulation and a permissible conductor operating temperature of at least 90 °C, for example cables according to IEC 60245-3:1994, or heat-resistant thermo-plastic (PVC) insulated cables according to IEC 60227-3:1993 and IEC 60227-3:1993/AMD1:1997.	Conductors with basic insulation shall comply with the requirements of 8.6.3. Mutual contact or contact with exposed-conductive-parts is permitted where there is no applied external pressure as a result of manufacture or foreseen during or after installation. Contact with sharp edges shall be avoided. Conductors with basic insulation may only be loaded such that an operating temperature of 80 % of the maximum permissible conductor operating temperature is not exceeded.
Conductors with basic insulation, for example cables according to IEC 60227-3:1993 and IEC 60227-3:1993/AMD1:1997, having additional secondary insulation, for example individually covered cables with shrink sleeving or individually run cables in plastic conduits.	No additional requirements
Conductors insulated with a very high mechanical strength material, for example Ethylene Tetrafluoro Ethylene (ETFE) insulation, or double-insulated conductors with an enhanced outer sheath rated for use up to 3 kV, for example cables according to IEC 60502.	
Single or multicore sheathed cables, for example cables according to IEC 60245-4:2011 or IEC 60227-4:1992 and IEC 60227-4:1992/AMD1:1997.	

Table 5 – Minimum terminal capacity for copper protective conductors (PE) (8.8)

Cross-sectional area of line conductors, S mm²	Minimum cross-sectional area of the corresponding protective conductor (PE), S_p mm²
$S \leq 16$	S
$16 < S \leq 35$	16
$35 < S \leq 400$	$S/2$
$400 < S \leq 800$	200
$800 < S$	$S/4$

Table 6 – Temperature-rise limits (9.2)

Parts of assemblies	Temperature-rise K
Built-in components [a]	In accordance with the relevant product standard requirements for the individual components or, in accordance with the component manufacturer's instructions[f], taking into consideration the temperature in the assembly
Terminals for external insulated conductors	70[b]
Busbars and conductors	Limited by[f]: – mechanical strength of conducting material[g]; – possible effect on adjacent equipment; – permissible temperature limit of the insulating materials in contact with the conductor; – effect of the temperature of the conductor on the apparatus connected to it; – for plug-in contacts, nature and surface treatment of the contact material
Manual operating means: – of metal – of insulating material	 15[c,h] 25[c,h]
Accessible external enclosures and covers: – metal surfaces – insulating surfaces	 30[d,h] 40[d,h]
Discrete arrangements of plug and socket-type connections	Determined by the limit for those components of the related equipment of which they form part[e]

The temperature-rise limits given in this table apply for a daily average ambient air temperature up to 35 °C under service conditions (see 7.1). During verification a different ambient air temperature is permissible (see 10.10.2.3.4).

[a] The term "built-in components" means:
- conventional switchgear and controlgear;
- electronic sub-assemblies (e.g. rectifier bridge, printed circuit);
- parts of the equipment (e.g. regulator, stabilized power supply unit, operational amplifier).

[b] The temperature-rise limit of 70 K is a value based on the conventional test of 10.10. An assembly used or tested under installation conditions may have connections, the type, nature and disposition of which will not be the same as those adopted for the test, and a different temperature-rise of terminals may result and may be required or accepted. Where the terminals of the built-in component are also the terminals for external insulated conductors, the lower of the corresponding temperature-rise limits shall be applied. The temperature-rise limit is the lower of the maximum temperature-rise specified by the component manufacturer and 70 K. In the absence of manufacturer's instructions, it is the limit specified by the built-in component product standard but not exceeding 70 K. For terminals of the built-in component that are terminals for external insulated conductors, the thermocouple for the temperature-rise test shall not be placed on the test conductor insulation.

[c] Manual operating means within assemblies which are only accessible after the assembly has been opened, for example draw-out handles which are not operated while the assembly is in normal service, are permitted to sustain a 25 K increase on these temperature-rise limits.

[d] Unless otherwise specified, in the case of covers and enclosures, which are accessible but need not be touched during normal operation, a 10 K increase on these temperature-rise limits is permissible. External surfaces and parts over 2 m from the base of the assembly are considered inaccessible.

[e] This allows a degree of flexibility in respect of equipment (e.g. electronic devices) which is subject to temperature-rise limits different from those normally associated with switchgear and controlgear.

[f] For temperature-rise tests according to 10.10, the temperature-rise limits have to be specified by the original manufacturer. It is the responsibility of the original manufacturer to take into account any additional measuring points and limits imposed by the component manufacturer.

[g] Assuming all other criteria listed are met, a maximum temperature-rise of 105 K for copper busbars and conductors shall not be exceeded. The 105 K relates to the temperature above which annealing of copper is likely to occur. In the absence of a declaration from the original manufacturer, regarding the reliability and stability of the ageing behaviour of the electrical contact or joint, a maximum temperature-rise of 55 K for bare (uncoated) aluminium busbars and conductors is applicable.

[h] Where an assembly is installed in an ambient air temperature exceeding a daily average of 35 °C, a higher absolute temperature (°C) may be permitted. Temperature-rise (K) shall not exceed the values given in this table. See also 9.2. In such a case warning label according to ISO 7010 W017 shall be provided.

Table 7 – Values for the factor n[a] (9.3.3)

RMS value of the short-circuit current kA	cos φ	n
$I \le 5$	0,7	1,5
$5 < I \le 10$	0,5	1,7
$10 < I \le 20$	0,3	2,0
$20 < I \le 50$	0,25	2,1
$50 < I$	0,2	2,2

[a] Values of this table represent the majority of applications. In special locations, for example in the vicinity of transformers or generators, lower values of power factor may be found, whereby the maximum prospective peak current may become the limiting value instead of the RMS value of the short-circuit current.

Table 8 – Power-frequency withstand voltage for main circuits (10.9.2)

Rated insulation voltage, U_i (line to line AC or DC) V	Dielectric test voltage AC RMS V	Dielectric test voltage DC V
$U_i \le 60$	1 000	1 415
$60 < U_i \le 300$	1 500	2 120
$300 < U_i \le 690$	1 890	2 670
$690 < U_i \le 800$	2 000	2 830
$800 < U_i \le 1\,000$	2 200	3 110
$1\,000 < U_i \le 1\,500$[a]	2 700	3 820

[a] For DC only.

Table 9 – Power-frequency withstand voltage for auxiliary circuits (10.9.2)

Rated insulation voltage, U_i (line to line) V	Dielectric test voltage AC RMS V	Dielectric test voltage DC V
$U_i \le 12$	250	355
$12 < U_i \le 60$	500	710
$60 < U_i$	See Table 8	See Table 8

Table 10 – Impulse withstand test voltages (10.9.3)

Rated impulse withstand voltage, U_{imp} kV	Test voltages and corresponding altitudes during test									
	$U_{1,2/50}$, AC peak and DC kV					AC RMS kV				
	Sea level	200 m	500 m	1 000 m	2 000 m	Sea level	200 m	500 m	1 000 m	2 000 m
2,5	2,95	2,8	2,8	2,7	2,5	2,1	2,0	2,0	1,9	1,8
4,0	4,8	4,8	4,7	4,4	4,0	3,4	3,4	3,3	3,1	2,8
6,0	7,3	7,2	7,0	6,7	6,0	5,1	5,1	5,0	4,7	4,2
8,0	9,8	9,6	9,3	9,0	8,0	6,9	6,8	6,6	6,4	5,7
12,0	14,8	14,5	14,0	13,3	12,0	10,5	10,3	9,9	9,4	8,5

Table 11 – Copper test conductors for rated currents up to 400 A inclusive (10.10.2.3.2)

Range of rated current[a] A		Conductor cross-sectional area[b,c]	
		mm²	AWG/MCM
0	8	1,0	18
8	12	1,5	16
12	15	2,5	14
15	20	2,5	12
20	25	4,0	10
25	32	6,0	10
32	50	10	8
50	65	16	6
65	85	25	4
85	100	35	3
100	115	35	2
115	130	50	1
130	150	50	0
150	175	70	00
175	200	95	000
200	225	95	0000
225	250	120	250
250	275	150	300
275	300	185	350
300	350	185	400
350	400	240	500

[a] The value of the rated current shall be greater than the first value in the first column and less than or equal to the second value in that column.

[b] For convenience of testing and with the manufacturer's consent, smaller test conductors than those given for a stated rated current may be used.

[c] Either of the two conductors specified may be used.

Table 12 – Copper test conductors for rated currents from 400 A to 7 000 A (10.10.2.3.2)

Range of rated current[a]	Test conductors[c]			
	Cables[c]		Copper bars[b]	
A	Quantity	Cross-sectional area mm²	Quantity	Dimensions mm (width × depth)
400 < I ≤ 500	2	150	2	30 × 5
500 < I ≤ 630	2	185	2	40 × 5
630 < I ≤ 800	2	240	2	50 × 5
800 < I ≤ 1 000	3	185	2	60 × 5
1 000 < I ≤ 1 250	3	240	2	80 × 5
1 250 < I ≤ 1 600	4 or 3	240 300	2	100 × 5
1 600 < I ≤ 2 000			3	100 × 5
2 000 < I ≤ 2 500			4	100 × 5
2 500 < I ≤ 3 150			3	100 × 10
3 150 < I ≤ 4 000			4	100 × 10
4 000 < I ≤ 5 000			5	100 × 10
5 000 < I ≤ 6 000			6	100 × 10
6 000 < I ≤ 7 000			7	100 × 10

[a] The value of the rated current shall be greater than the first value and less than or equal to the second value.

[b] Bars are assumed to be arranged with their long faces (W) vertically. Arrangements with long faces horizontally may be used if specified by the manufacturer. Bars may be painted.

[c] For rated currents higher than 1 600 A and when the terminals are designed to be connected to a cable system, cables in parallel, with a total cross-section not exceeding that of the copper bars in this table, can be used as test conductors.

Table 13 – Short-circuit verification by comparison with reference designs: checklist (10.5.3.3, 10.11.3 and 10.11.4)

Item No.	Requirements to be considered	YES	NO
1	Is the short-circuit withstand rating of each circuit of the assembly to be assessed less than or equal to that of the reference design?		
2	Are the cross-sectional dimensions of the busbars and conductors of each circuit of the assembly to be assessed greater than or equal to those of the reference design?		
3	Is the centre line spacing of the busbars and conductors of each circuit of the assembly to be assessed greater than or equal to those of the reference design?		
4	Are the busbar and conductor fixing means of each circuit of the assembly to be assessed of the same type, shape and material and have the same or smaller centre line spacing along the length of the busbar and conductor as the reference design? And is the mounting structure for the busbar and conductor fixing means of the same design and mechanical strength?		
5	Are the material and the material properties of the conductors of each circuit of the assembly to be assessed the same as those of the reference design?		
6	Are the short-circuit protective devices of each circuit of the assembly to be assessed equivalent, that is of the same make and series?[a] In addition, does the short-circuit protective devices of each circuit of the assembly to be assessed • have a breaking capacity not less than the short-circuit rating of the assembly at the rated operational voltage of the assembly? • in the case of a current-limiting protective device: have a peak let-through current and let-through energy equal to or smaller than the reference design at the short-circuit rating and the rated operational voltage of the assembly? • in the case of a non current-limiting device: have a rated short-time withstand current I_{cw} equal to or higher than the reference design? • fulfil the requirements of coordination with upstream and downstream devices (see 9.3.4), if required? • have the same arrangement as in the reference design?		
7	Is the length of unprotected live conductors, in accordance with 8.6.4, of each non-protected circuit of the assembly to be assessed less than or equal to those of the reference design?		
8	If the assembly to be assessed includes an enclosure, did the reference design include an enclosure when verified by test?		
9	Is the enclosure of the assembly to be assessed of the same design, type and have at least the same dimensions as that of the reference design?		
10	Are the compartments of each circuit of the assembly to be assessed of the same mechanical design and at least the same dimensions as those of the reference design?		
"YES" to all requirements – no further verification required. "NO" to any one requirement – further verification is required.			
[a] Short-circuit protective devices of the same manufacturer, but of a different series, may be considered equivalent where the device manufacturer declares the performance characteristics to be the same or better in all relevant respects compared to the series used for verification, e.g. limitation characteristics (I^2t, I_{lt}), and critical distances.			

Table 14 – Relationship between prospective fault current and diameter of copper wire

Diameter of copper wire mm	Prospective fault current in the fusible element circuit A
0,1	50
0,2	150
0,3	300
0,4	500
0,5	800
0,8	1 500

Table 15 – Climatic conditions

Environmental parameter	Unit	Indoor installations		Outdoor installations	
		Lower limit	Upper limit	Lower limit	Upper limit
(1) Ambient air temperature	°C	−5[a]	+40[a] (average over a period of 24 h does not exceed 35 °C)	−25	+40[b] (average over a period of 24 h does not exceed 35 °C)
(2) Relative humidity	%	5[b,c]	95[b, c]	15[b]	100[b]
(3) Rate of change of temperature (average over a period of 5 min)	°C/min	0,5			
(4) Altitude[f]	m	Not specified	2 000 (corresponding to an air pressure of the site of installation not less than 80 kPa)[d, e]	Not specified	2 000 (corresponding to an air pressure of the site of installation not less than 80 kPa)[d, e]
(5) Condensation		Yes – moderate condensation may occasionally occur due to variations in temperature		Yes	
(6) Wind-driven precipitation (rain, snow, hail, etc.) and/or dust		No		Yes	
(7) Water from sources other than rain		According to user requirement: none / vertically dripping water / water sprayed at an angle up to 60° on either side of the vertical / water splashed from any direction / water projected in jets from any direction / water projected in powerful jets from any direction			
(8) Formation of ice		No		Yes	

[a] Equal to Class AA4 of IEC 60364-5-51:2005.

[b] Relationship between air temperature and humidity is given in IEC 60721-3-3:2019, Figure A.1.

[c] Equal to Class AB4 of IEC 60364-5-51:2005.

[d] See IEC 60664-1:2007, Table A.2. For equipment to be used at higher altitudes, it is necessary to take into account the reduction of the dielectric strength, the switching capability of the devices and of the cooling effect of the air.

[e] Equal to Class AC1 of IEC 60364-5-51:2005.

[f] The majority of the devices are suitable to be used up to 2 000 m. For some electronic equipment to be used at altitudes above 1 000 m, it may be necessary to take into account the reduction of the cooling effect of the air.

Table 101 – Values of assumed loading

Type of load	Assumed loading factor
Distribution – 2 and 3 circuits	0,9
Distribution – 4 and 5 circuits	0,8
Distribution – 6 to 9 circuits	0,7
Distribution – 10 or more circuits	0,6

Annex A
(normative)

Minimum and maximum cross-section of copper cables suitable for connection to terminals for external cables (see 8.8)

Table A.1 below applies for the connection of one copper cable per terminal.

Table A.1 – Cross-section of copper cables suitable for connection to terminals for external cables

Rated current	Solid or stranded cables		Flexible cables	
	Cross-sections		Cross-sections	
	min.	max.	min.	max.
A	mm^2		mm^2	
6	0,75	1,5	0,5	1,5
8	1	2,5	0,75	2,5
10	1	2,5	0,75	2,5
13	1	2,5	0,75	2,5
16	1,5	4	1	4
20	1,5	6	1	4
25	2,5	6	1,5	4
32	2,5	10	1,5	6
40	4	16	2,5	10
63	6	25	6	16
80	10	35	10	25
100	16	50	16	35
125	25	70	25	50
160	35	95	35	70
200	50	120	50	95
250	70	150	70	120
315	95	240	95	185

If the external cables are connected directly to built-in apparatus, the cross-sections indicated in the relevant specifications are valid.

In cases where it is necessary to provide for cables other than those specified in Table A.1, special agreement shall be reached between the assembly manufacturer and the user.

Annex B
(normative)

Method of calculating the cross-sectional area of protective conductors with regard to thermal stresses due to currents of short duration

The following formula shall be used to calculate the cross-section of the protective conductors necessary to withstand the thermal stresses due to currents with a duration of the order of 0,2 s to 5 s.

$$S_p = \frac{\sqrt{I^2 t}}{k}$$

where

S_p is the cross-sectional area (mm²);

I is the value (RMS) of AC or the mean value of DC fault current for a fault of negligible impedance which can flow through the protective device (A);

t is the operating time of the disconnecting device (s);

k is the factor dependent on the material of the protective conductor, the insulation and the initial and final temperatures, see Table B.1.

NOTE 1 A duration of 5 s is considered as the maximum for an adiabatic thermal behaviour calculation to remain valid.

Account should be taken of the current-limiting effect of the circuit impedances and the limiting capability (Joule integral) of the protective device.

Table B.1 – Values of k for insulated protective conductors not incorporated in cables or bare protective conductors in contact with cable covering

	Insulation of protective conductor or cable covering		
	Thermo-plastic (PVC)	**XLPE EPR Bare conductors**	**Butyl rubber**
Maximum temperature of conductor under short-circuit current conditions[a]	160 °C	250 °C	220 °C
	Factor k		
Material of conductor:			
Copper	143	176	166
Aluminium	95	116	110
Steel	52	64	60

[a] The initial temperature of the conductor is assumed to be 30 °C.

More detailed information is to be found in IEC 60364-5-54:2011, IEC 60724:2000 and IEC 60724:2000/AMD1:2008.

NOTE 2 Information on limiting temperatures for other types of cables can be found in EN 50565-2.

Annex C
(informative)

User information template

Table C.1 is intended as a template for the identification of items necessary for the assembly manufacturer which is provided by the user.

It is intended to be used and developed in the relevant assembly standards.

Table C.1 – Items subject to agreement between the assembly manufacturer and the user

Characteristics	Reference clause or subclause	Default arrangement [b]	Options listed in standard	User requirement [a]
Electrical system				
Earthing system	5.6, 8.4.3.1, 8.4.3.2.3, 8.6.2, 10.5, 11.4	Manufacturer's standard, selected to suit local requirements	TT / TN-C / TN-C-S / IT, TN-S	
Nominal voltage (V)	3.8.9.1, 5.2.1, 8.5.3	Local, according to installation conditions	max 1 000 V AC or 1 500 V DC	
Transient overvoltages	5.2.4, 8.5.3, 9.1	Determined by the electrical system	Overvoltage category I / II / III / IV	
Temporary overvoltages	9.1	Nominal system voltage + 1 200 V	None	
Rated frequency f_n (Hz)	3.8.12, 5.5, 8.5.3, 10.10.2.3, 10.11.5.4	According to local installation conditions	DC/50 Hz/60 Hz	
Additional on-site testing requirements: wiring, operational performance and function	11.10	Manufacturer's standard, according to application	None	
Short-circuit withstand capability				
Prospective short-circuit current at supply terminals I_{cp} (kA)	3.8.7	Determined by the electrical system	None	
Prospective short-circuit current in the neutral	10.11.5.3.5	Max. 60 % of phase values	None	
Prospective short-circuit current in the protective circuit	10.11.5.6	Max. 60 % of phase values	None	
SCPD in the incoming functional unit requirement	9.3.2	According to local installation conditions	Yes / No	
Co-ordination of short-circuit protective devices including external short-circuit protective device details	9.3.4	According to local installation conditions	None	
Data associated with loads likely to contribute to the short-circuit current	9.3.2	No loads likely to make a significant contribution allowed for	None	

Characteristics	Reference clause or subclause	Default arrangement [b]	Options listed in standard	User requirement [a]
Protection of persons against electric shock in accordance with IEC 60364-4-41				
Type of protection against electric shock – Basic protection	8.4.2	Basic protection	According to local installation regulations	
Type of protection against electric shock – Fault protection	8.4.3	According to local installation conditions	Automatic disconnection of supply / Electrical separation / Total insulation	
Installation environment				
Location type	3.5, 8.1.4, 8.2	Manufacturer's standard, according to application	None	
Protection against ingress of solid foreign bodies and ingress of water	8.2.2, 8.2.3	IP 44 minimum	None	
Mechanical strength Protection against mechanical impact	8.1.5, 10.2.6 8.2.1, 10.2.6	50 g 11 ms 6 J	None	
Resistance to UV radiation	10.2.4	Temperate climate	None	
Resistance to corrosion	7.1, 7.2, 10.2.2	Normal service conditions and/or Special service condition	normal service conditions special service condition	
Ambient air temperature – Lower limit	7.1.1	–25 °C	None	
Ambient air temperature – Upper limit	7.1.1	40 °C	None	
Ambient air temperature – Daily average maximum	7.1.1, 9.2	35 °C	None	
Maximum relative humidity	7.1.2	100 % at 25 °C	None	
Pollution degree (of the installation environment)	7.1.2	3	3 and 4	
Altitude	7.1.1	≤ 2 000 m	None	
EMC environment (A or B)	9.4, 10.12, Annex J	A/B	A/B	
Special service conditions (e.g. vibration, exceptional condensation, strong electric or magnetic fields, fungus, small creatures, explosion hazards, heavy vibration and shocks, earthquakes)	7.2, 8.5.4, 9.3.3 Table 7	No special service conditions	None	

Characteristics	Reference clause or subclause	Default arrangement [b]	Options listed in standard	User requirement [a]
Installation method				
Transportable (semi-fixed)/mobile	3.5.101 3.5.102	Transportable (semi-fixed), mobile	Transportable (semi-fixed), mobile	
Maximum overall dimensions and weight	5.6, 6.2.1	Manufacturer's standard, according to application	None	
External conductor type(s)	8.8	Manufacturer's standard	Cable / BUSBAR Trunking System	
Direction(s) of external conductors	8.8	Manufacturer's standard	None	
External conductor material	8.8	Copper	Copper / aluminium	
External phase conductor, cross SECTIONS, and terminations	8.8	As defined within the standard	None	
External PE, N, PEN conductor's cross SECTIONS, and terminations	8.8	As defined within the standard	None	
Special terminal identification requirements	8.8	Manufacturer's standard	None	
Storage and handling				
Maximum dimensions and weight of transport units	6.2.2, 10.2.5	Manufacturer's standard	None	
Methods of transport (e.g. forklift, crane)	6.2.2, 8.1.6	Manufacturer's standard	None	
Environmental conditions different from the service conditions	7.3	As service conditions	None	
Packing details	6.2.2	Manufacturer's standard	None	
Operating arrangements				
Access to manually operated devices	8.4.6	Ordinary persons	None	
Location of manually operated devices	8.5.5	Easily accessible	None	
Isolation of load installation equipment items	8.4.2, 8.4.3.3	Manufacturer's standard	Individual / groups / all	
Maintenance and upgrade capabilities				
Requirements related to accessibility in service by ordinary persons; requirement to operate devices or change components while the ACS is energised	8.4.6.1	Basic protection	None	
Method of functional units connection	8.5.1, 8.5.2	Manufacturer's standard	None	
Provisions for basic protection with hazardous live internal parts during maintenance or upgrade (e.g. functional units, main BUSBARS, distribution BUSBARS)	8.4	No requirements for protection during maintenance or upgrade	None	

Characteristics	Reference clause or subclause	Default arrangement [b]	Options listed in standard	User requirement [a]
Current carrying capability				
Rated current of the ACS I_{nA} (A)	3.8.9.1, 5.3, 8.4.3.2.3, 8.5.3, 8.8, 10.10.2, 10.10.3, 10.11.5, Annex E	Manufacturer's standard, according to application	None	
Rated current of circuits I_{nc} (A)	5.3.2	Manufacturer's standard, according to application	None	
Rated diversity factor	5.4, 10.10.2.3, Annex E	As defined within the standard	RDF for groups of circuits / RDF for whole ACS	
Ratio of cross SECTION of the neutral conductor to phase conductors: phase conductors up to and including 16 mm^2	8.6.1	100 %	None	
Ratio of cross SECTION of the neutral conductor to phase conductors: phase conductors above 16 mm^2	8.6.1	50 % (min. 16 mm^2)	None	

[a] For exceptionally onerous applications, more stringent requirements to those in the standard can apply.

[b] In some cases information declared by the assembly manufacturer can take the place of an agreement.

Annex D
(informative)

Design verification

Table D.1 provides a list of design verifications to be performed for various characteristics.

Table D.1 – List of design verifications to be performed

No.	Characteristic to be verified	Clauses or subclauses	Verification options available		
			Testing	Comparison with a reference design	Assessment
1	Strength of material and parts:	10.2			
	Resistance to corrosion	10.2.2	YES	NO	NO
	Properties of insulating materials:	10.2.3			
	Thermal stability	10.2.3.1	YES	NO	NO
	Resistance to abnormal heat and fire due to internal electric effects	10.2.3.2	YES	NO	NO
	Resistance to ultra-violet (UV) radiation	10.2.4	YES	NO	NO
	Lifting	10.2.5	YES	NO	NO
	Mechanical impact	10.2.6	YES	NO	NO
	Marking	10.2.7	YES	NO	NO
	Mechanical operation	10.2.8	YES	NO	NO
2	Degree of protection of enclosures	10.3	YES	NO	YES
3	Clearances	10.4	YES	NO	YES
4	Creepage distances	10.4	YES	NO	NO
5	Protection against electric shock and integrity of protective circuits:	10.5			
	Effective continuity between the exposed conductive parts of the ACS and the protective circuit	10.5.2	YES	NO	NO
	Short-circuit withstand strength of the protective circuit	10.5.3	YES	YES	YES
6	Incorporation of switching devices and components	10.6	NO	NO	YES
7	Internal electrical circuits and connections	10.7	NO	NO	YES
8	Terminals for external conductors	10.8	NO	NO	YES
9	Dielectric properties:	10.9			
	Power-frequency withstand voltage	10.9.2	YES	NO	NO
	Impulse withstand voltage	10.9.3	YES	NO	NO
	Enclosures made of insulating material	10.9.4	YES	NO	NO
	External operation handles of insulating material	10.9.5	YES	NO	NO
	Conductors covered by insulating material to provide protection against electric shock	10.9.6	YES	NO	NO
10	Temperature-rise limits	10.10	YES	YES	NO
11	Short-circuit withstand strength	10.11	YES	YES	NO
12	Electromagnetic compatibility (EMC)	10.12	YES	NO	YES

Annex E
(informative)

Rated diversity factor

E.1 General

The manufacturer may at their discretion declare a rated diversity factor for all the outgoing circuits of an assembly or groups or individual outgoing circuits within an assembly. Annex E provides some guidance on the subject.

All outgoing circuits within an assembly are individually capable of carrying their rated current I_{nc} continuously, in accordance with 5.3.2, but the current-carrying capacity of any circuit may be influenced by adjacent circuits. Thermal interaction can result in heat being imported from, or exported to, circuits in close proximity. Cooling air available to a circuit may be at a temperature well in excess of the ambient air temperature due to the influence of other circuits.

In practice, not all outgoing circuits within an assembly are normally required to carry rated currents I_{nc} continuously and simultaneously. Within a typical application, the type and nature of loads differ appreciably. Some circuits will be rated on the basis of inrush currents and intermittent or short duration loads. Several circuits may be heavily loaded while others are lightly loaded or switched off.

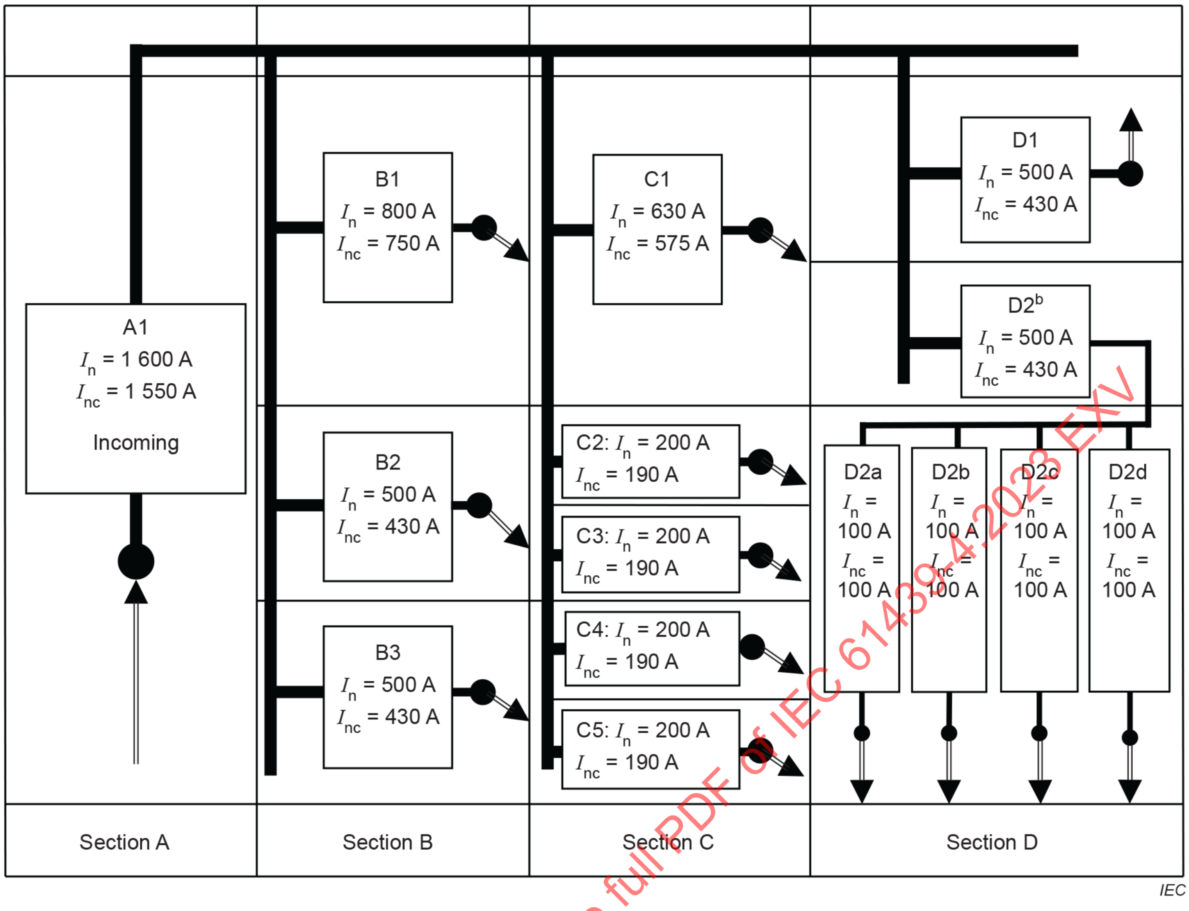
To provide assemblies in which all outgoing circuits can be operated at rated current I_{nc} continuously is therefore unnecessary and would be an inefficient use of materials and resources. This document recognizes the practical requirements of assemblies through the assignment of a rated diversity factor as defined in 3.8.11.

By stating a rated diversity factor, the assembly manufacturer is specifying the "average" loading conditions for which the assembly is designed. The rated diversity factor confirms the per unit value of rated current I_{nc} to which outgoing circuits, within the assembly can be continuously and simultaneously loaded. In assemblies where the total of the rated currents of the outgoing circuits operating at the rated diversity factor exceeds the capacity of the incoming circuit, the diversity factor only applies to any combination of outgoing circuits used to distribute the incoming current.

E.2 Rated diversity factor for outgoing circuits within an assembly

E.2.1 General

The rated diversity factor is specified in 5.4. For the typical assembly shown in Figure E.1, examples of loading arrangements for diversity factors are given in Table E.1 and shown in Figure E.2 and Figure E.3.



For each functional unit (A1, B1, etc.) the rated current of a circuit (I_{nc}) is shown. [a]

[a] The rated current of a circuit in the assembly may be less than the rated current of the device.

[b] If the rated current of D2 is less than the sum of the rated currents of the circuits D2a to D2d, inclusive, typically in line with good engineering practice, D2 is afforded appropriate overcurrent protection.

Figure E.1 – Typical assembly

Table E.1 – Examples of loading for an assembly

Functional unit	A1	B1	B2	B3	C1	C2	C3	C4	C5	D1	D2	D2a	D2b	D2c	D2d
	Current (A)														
Rating of the device, I_n	1 600	800	500	500	630	200	200	200	200	500	500	100	100	100	100
Functional unit – rated current, I_{nc} [b] (See Figure E.1)	1 550	750	430	430	575	190	190	190	190	430	430	100	100	100	100
Example 1 Figure E.2 RDF for the assembly = 0,68	1 550	510	292	292	0	129	55[a]	0	0	0	272[c]	68	68	68	68
Example 2 Figure E.3 RDF: Section B = 0,6; Section C = 0,68	1 550	450	258	258	391	129	64[a]	0	0	0	0	0	0	0	0

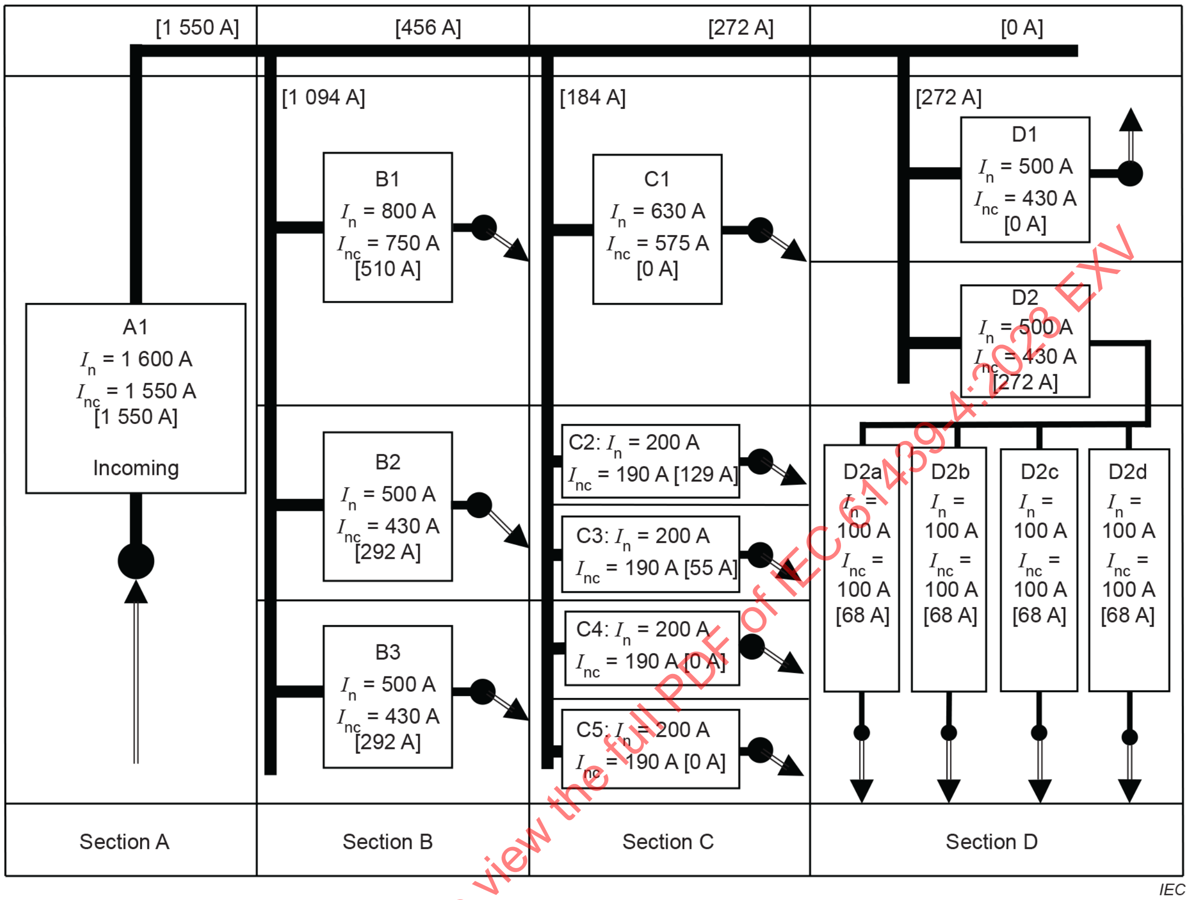
[a] Balance current to load incoming circuit to its rated current.

[b] The rated current of the functional unit (the circuit) in the assembly may be less than the rated current of the device.

[c] Maximum load from the distribution board with a diversity factor of 0,68.

E.2.2 Example of an assembly with an RDF of 0,68

Figure E.2 shows an example of the loading of an assembly with a RDF of 0,68.



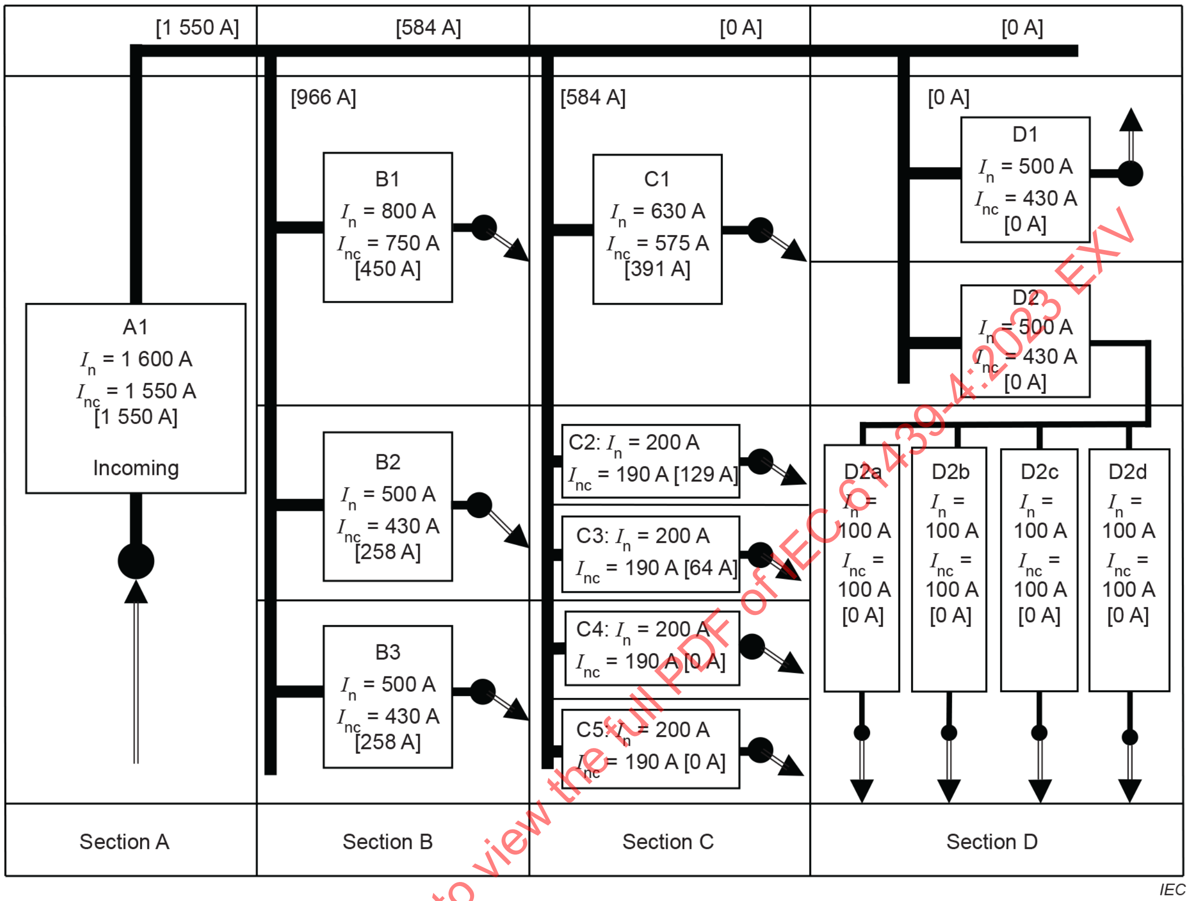
Actual loading is indicated by the figures in brackets, e.g. [292 A].

Busbar section loading is indicated by the figure in brackets, e.g. [1094 A].

Figure E.2 – Example 1: Table E.1 – Functional unit loading for an assembly with a rated diversity factor of 0,68

E.2.3 Example of an assembly with RDF declared for each section

Figure E.3 shows an example of the loading of an assembly with RDFs of 0,6 and 0,68 in different sections.



Actual loading is indicated by the figures in brackets, e.g. [450 A].

Busbar section loading is indicated by the figure in brackets, e.g. [584 A].

Figure E.3 – Example 2: Table E.1 – Functional unit loading for an assembly with a rated diversity factor of 0,6 in Section B and 0,68 in Section C

Annex F
(normative)

Measurement of clearances and creepage distances [6]

F.1 Basic principles

The width *X* of the grooves specified in examples 1 to 11 [Figure F.1 b) to l)] basically applies to all examples as a function of pollution as specified in Table F.1:

Table F.1 – Minimum width of grooves

Pollution degree	Minimum value of width *X* of grooves mm
1	0,25
2	1,0
3	1,5
4	2,5

If the associated clearance is less than 3 mm, the minimum groove width may be reduced to one-third of this clearance.

The methods of measuring clearances and creepage distances are indicated in examples 1 to 11. These examples do not differentiate between gaps and grooves or between types of insulation.

Furthermore:

– any corner is assumed to be bridged with an insulating link of *X* mm width moved into the most unfavourable position (see example 3);

– where the distance across the top of a groove is *X* mm or more, a creepage distance is measured along the contours of the grooves (see example 2);

– clearances and creepage distances measured between parts moving in relation to each other are measured when these parts are in their most unfavourable positions.

F.2 Use of ribs

Because of their influence on contamination and their improved drying-out effect, ribs considerably decrease the formation of leakage current. Creepage distances can therefore be reduced to 0,8 of the required value, provided the minimum height of the ribs is 2 mm, see Figure F.1 a).

6 Annex F is based on IEC TR 60664-2-1:2011.

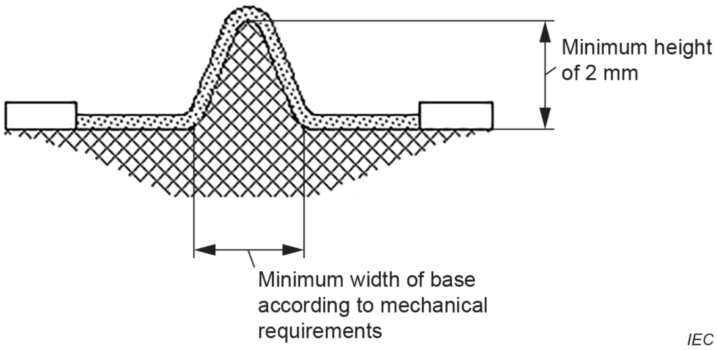
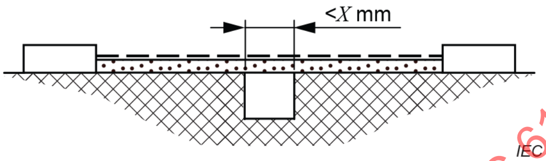


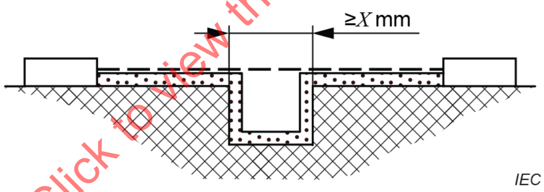
Figure F.1 a) – Measurement of ribs: examples



Condition: This creepage distance path includes a parallel- or converging-sided groove of any depth with a width less than X mm.

Rule: Creepage distance and clearances are measured directly across the groove as shown.

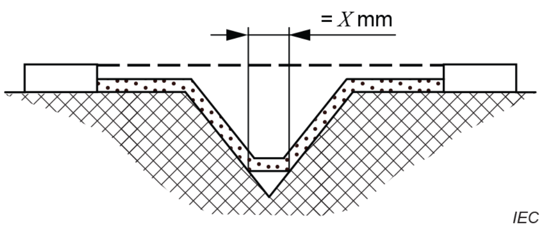
Figure F.1 b) – Example 1



Condition: This creepage distance path includes a parallel-sided groove of any depth and equal to or more than X mm.

Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the groove.

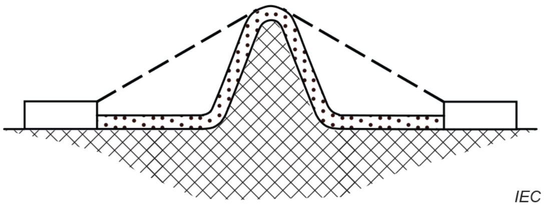
Figure F.1 c) – Example 2



Condition: This creepage distance path includes a V-shaped groove with a width greater than X mm

Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the groove but "short-circuits" the bottom of the groove by X mm link.

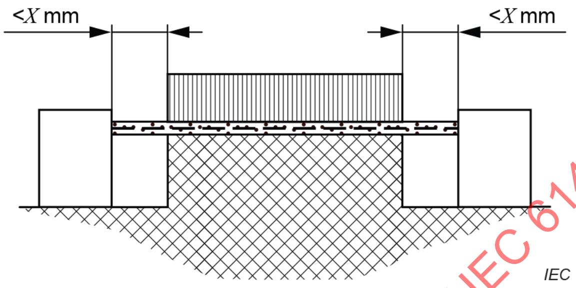
Figure F.1 d) – Example 3



Condition: This creepage distance path includes a rib.

Rule: Clearance is the shortest air path over the top of the rib. Creepage path follows the contour of the rib.

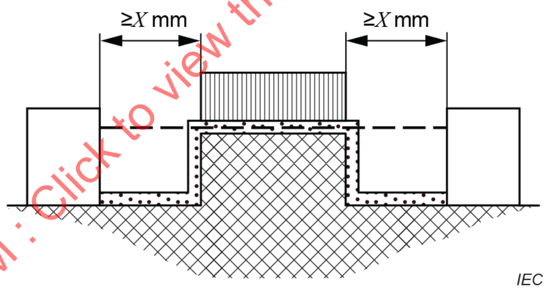
Figure F.1 e) – Example 4



Condition: This creepage distance path includes an uncemented joint with grooves less than *X* mm wide on each side.

Rule: Creepage distance and clearance paths are the "line-of-sight" distance shown.

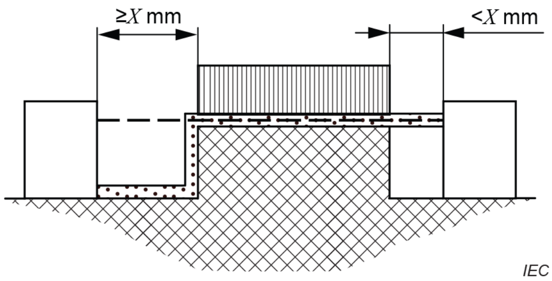
Figure F.1 f) – Example 5



Condition: This creepage distance path includes an uncemented joint with grooves equal to or more than *X* mm wide on each side.

Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the grooves.

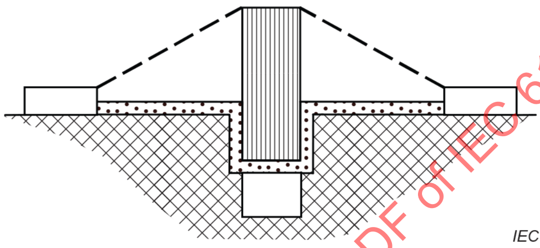
Figure F.1 g) – Example 6



Condition: This creepage distance path includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearances and creepage distance paths are as shown.

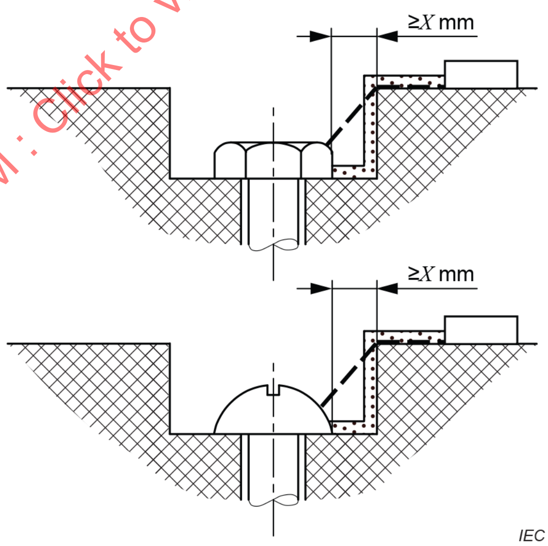
Figure F.1 h) – Example 7



Condition: Creepage distance through uncemented joint is less than creepage distance over barrier.

Rule: Clearance is the shortest direct air path over the top of the barrier.

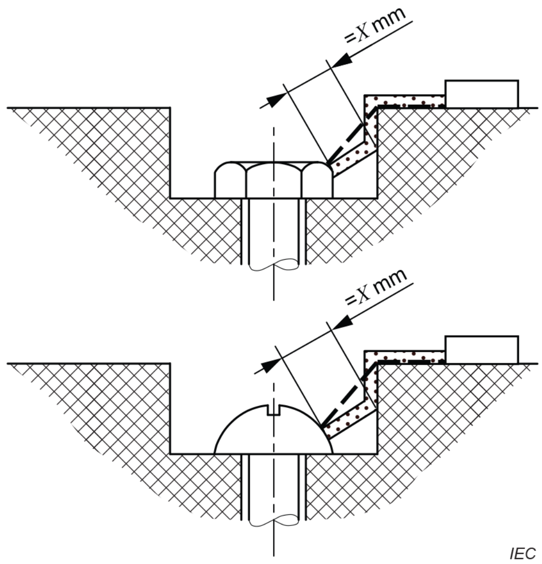
Figure F.1 i) – Example 8



Condition: Gap between head of screw and wall of recess wide enough to be taken into account.

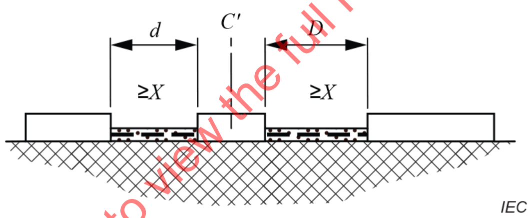
Rule: Clearances and creepage distance paths are as shown.

Figure F.1 j) – Example 9



Condition:	Gap between head of screw and wall of recess too narrow to be taken into account.	Rule:	Measurement of creepage distance is from screw to wall when the distance is equal to *X* mm.

Figure F.1 k) – Example 10



Clearance is the distance $d + D$

Creepage distance is also $d + D$

Figure F.1 l) – Example 11

Key

Figure F.1 – Measurement of clearance and creepage distances

Annex G
(normative)

Correlation between the nominal voltage of the supply system and the rated impulse withstand voltage of the equipment [7]

Annex G is intended to give the necessary information concerning the choice of equipment for use in a circuit within an electrical system or part thereof.

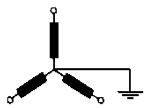
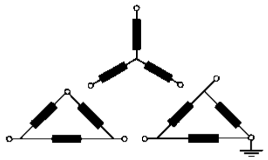
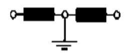
Table G.1 provides examples of the correlation between nominal supply system voltages and the corresponding rated impulse withstand voltage of the equipment.

The values of rated impulse voltage given in Table G.1 are based on 4.3.3 of IEC 60664-1:2007. Further information about criteria for the selection of an appropriate overvoltage category and overvoltage protection (if necessary) is given in IEC 60364-4-44:2007, IEC 60364-4-44:2007/AMD1:2015 and IEC 60364-4-44:2007/AMD2:2018, Clause 443.

It should be recognized that control of overvoltages with respect to the values in Table G.1 can also be achieved by conditions in the supply system such as the existence of a suitable impedance or cable feed.

[7] Annex G is based on Annex H of IEC 60947-1:2020.

Table G.1 – Correspondence between the nominal voltage of the supply system and the equipment rated impulse withstand voltage

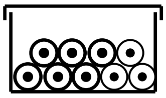
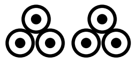
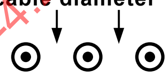
Maximum value of rated operational voltage to earth, AC RMS or DC V	Nominal voltage of the supply system (≤ rated insulation voltage of the equipment) V				Preferred values of rated impulse withstand voltage (1,2/50 µs) at 2 000 m kV			
					Overvoltage category			
					IV	III	II	I
	 AC RMS	 AC RMS	 AC RMS or DC	 AC RMS or DC	Origin of installation (service entrance) level	Distribution circuit level	Load (appliance, equipment) level	Specially protected level
50	–	–	12,5, 24, 25, 30, 42, 48		1,5	0,8	0,5	0,33
100	66/115	66	60	–	2,5	1,5	0,8	0,5
150	120/208 127/220	115, 120 127	110, 120	220-110, 240-120	4	2,5	1,5	0,8
300	220/380, 230/400 240/415, 260/440 277/480	220, 230 240, 260 277	220	440-220	6	4	2,5	1,5
600	347/600, 380/660 400/690, 415/720 480/830	347, 380, 400 415, 440, 480 500, 577, 600	480	960-480	8	6	4	2,5
1 000	–	660 690, 720 830, 1 000	1 000	–	12	8	6	4

Annex H
(informative)

Operating current and power loss of copper cables

Table H.1 and Table H.2 provide guidance values for single core copper cable operating currents and power losses under ideal conditions within an assembly. The calculation methods used to establish these values are given to enable values to be calculated for other conditions.

Table H.1 – Operating current and power loss of single-core copper cables with a permissible conductor temperature of 70 °C (ambient temperature inside the assembly: 55 °C)

Conductor arrangement						Spacing at least one cable diameter 	
		Single-core cables in a cable trunking on a wall, run horizontally and vertically. 6 of the cables (2 three-phase circuits) continuously loaded		Single-core cables, touching free in air or on a perforated tray. 6 cables[e] (2 three-phase circuits) continuously loaded		Single-core cables, spaced horizontally in free air	
Cross-sectional area of conductor mm^2	Resistance of conductor at 20°C, R_{20} [a] mΩ/m	Max. operating current, I_{max} [b] A	Power-losses per conductor, P_v W/m	Max. operating current, I_{max} [c] A	Power-losses per conductor, P_v W/m	Max. operating current, I_{max} [d] A	Power-losses per conductor, P_v W/m
0,5	36,0	3,5	0,6	-	-	-	-
0,75	24,5	5,0	0,7	-	-	-	-
1,0	18,1	6,0	0,7	-	-	-	-
1,5	12,1	7,5	0,8	9	1,3	15	3,2
2,5	7,41	10	0,9	13	1,5	21	3,7
4	4,61	14	1,0	18	1,7	28	4,2
6	3,08	18	1,1	23	2,0	36	4,7
10	1,83	24	1,3	32	2,3	50	5,4
16	1,15	33	1,5	44	2,7	67	6,2
25	0,727	43	1,6	59	3,0	89	6,9
35	0,524	54	1,8	74	3,4	110	7,7
50	0,387	65	2,0	90	3,7	134	8,3
70	0,268	83	2,2	116	4,3	171	9,4
95	0,193	101	2,4	142	4,7	208	10,0
120	0,153	117	2,5	165	5,0	242	10,7
150	0,124			191	5,4	278	11,5
185	0,099 1			220	5,7	318	12,0
240	0,075 4			260	6,1	375	12,7
300	0,060 1			301	6,6	432	13,5

a Values from IEC 60228:2004, Table 2, column 8 (stranded, plain copper conductors).

b Current carrying capacity I_{30} for one three-phase circuit from IEC 60364-5-52:2009, Table B.52.4, col. 4 (Reference method of installation: item B1 in Table B.52.1). k_2 = 0,8 (item 1 in Table B.52.17, two circuits).

c Current carrying capacity I_{30} for one three-phase circuit from IEC 60364-5-52:2009, Table B.52.10, col. 5 (Method of installation: Item F in column 1 of Table B.52.1). Values for cross-sections less than 25 mm^2 calculated following Annex D of IEC 60364-5-52:2009. k_2 = 0,88 (based on experience item 4 in Table B.52.17, two circuits, is used in preference to Table B.52.21).

d Current carrying capacity I_{30} for one three-phase circuit from IEC 60364-5-52:2009, Table B.52.10, col. 7 (Method of installation: item G in column 1 of Table B.52.1). Values for cross-sections less than 25 mm^2 calculated following Annex D of IEC 60364-5-52:2009. (k_2 = 1).

e The coefficients are based on horizontally run cables as it has negligible impact on vertically run cables within an assembly.

$$I_{max} = I_{30} \times k_1 \times k_2$$

$$P_v = I_{max}^2 \times R_{20} \times \left[1 + \alpha \times \left(T_c - 20\ °C\right)\right]$$

where

k_1 is the reduction factor for air temperature inside the enclosure around the conductors (IEC 60364-5-52:2009, Table B.52.14)

k_1 = 0,61 for conductor temperature 70 °C, ambient air temperature 55 °C

k_1 for other air temperatures: see Table H.2;

k_2 is the reduction factor for groups of more than one circuit (see further explanation in footnotes b, c and d of Table H.1);

α is the temperature coefficient of resistance, α = 0,004 K^{-1};

T_c is the conductor temperature;

I_{30} is the maximum operating current of a single conductor for air temperature around the conductor of 30 °C.

Table H.2 – Reduction factor k_1 for cables with a permissible conductor temperature of 70 °C (extract from IEC 60364-5-52:2009, Table B.52.14)

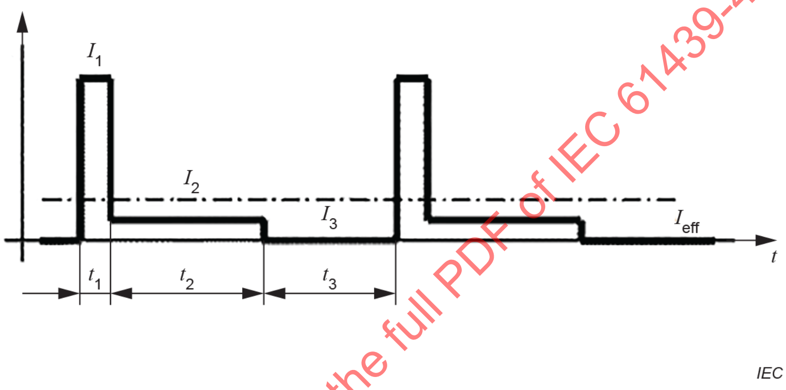
Air temperature inside the enclosure around the conductors °C	Reduction factor, k_1
20	1,12
25	1,06
30	1,00
35	0,94
40	0,87
45	0,79
50	0,71
55	0,61
60	0,50

If the operating current in Table H.1 is converted for other air temperatures using the reduction factor k_1, then also the corresponding power losses shall be calculated using the formula given above.

Annex I
(informative)

Thermal equivalent of an intermittent current

The dissipated heat of circuits built from components with Joule losses is proportional to the true RMS value of the current. An equivalent RMS current representing the thermal effect of the real intermittent current can be calculated with the formula given in Figure I.1. This enables the thermal equivalent true RMS current (I_{eff}) in the case of intermittent duty to be determined, and thus the permissible load pattern. Unless specific information is available on the thermal time constants, the ON-times should not exceed 30 min and the ON time should be less than the OFF time, since small devices could already reach their thermal equilibrium. For DC applications, the same consideration is applicable using the mean value of the current instead of the RMS value. The thermal equivalent current for predictably varying/intermittent loads should not exceed the group rated current of the circuit I_{ng} of the assembly unless precise information is available for the loading of adjacent circuits.



$$I_{eff} = \sqrt{\frac{I_1^2 \times t_1 + I_2^2 \times t_2 + I_3^2 \times t_3}{t_1 + t_2 + t_3}}$$

Key

t_1	Starting time at current I_1
t_2	Run time at current I_2
t_3	Interval time at $I_3 = 0$
$t_1 + t_2 + t_3$	Cycle time

Figure I.1 – Example of average heating effect calculation

Annex J
(normative)

Electromagnetic compatibility (EMC)

J.1 General

The subclause numbering within Annex J aligns with that of the body of the document.

J.3 Terms and definitions

For the purposes of Annex J, the following terms and definitions apply. (See Figure J.1.)

J.3.8.13.1
port
particular interface of the specified apparatus with external electromagnetic environment

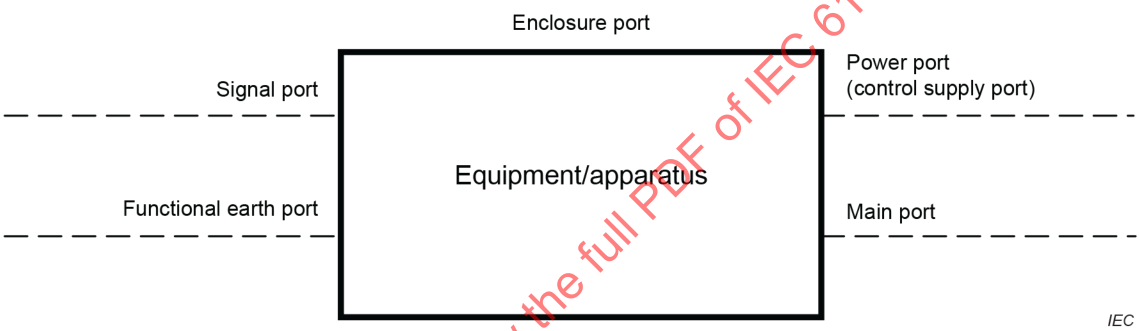


Figure J.1 – Examples of ports

J.3.8.13.2
enclosure port
physical boundary of the apparatus through which electromagnetic fields may radiate or impinge on

J.3.8.13.3
functional earth port
port other than signal, control or power port, intended for connection to earth for purposes other than electrical safety

J.3.8.13.4
signal port
port at which a conductor or cable intended to carry signals is connected to the apparatus

Note 1 to entry: Examples are analogue inputs, outputs and control lines; data buses; communication networks, etc.

J.3.8.13.5
power port
control supply port
port at which a conductor or cable carrying the primary electrical power needed for the operation (functioning) of an apparatus or associated apparatus is connected to the apparatus

[SOURCE: IEC 60947-1:2020, 3.9.3]

J.3.8.13.6
main port
port at which a conductor or cable is connected to a pole of the main circuit of the equipment

J.9.4 Performance requirements

J.9.4.1 General

For the majority of assembly applications falling within the scope of this document, two sets of environmental conditions are considered and are referred to as environment A and environment B.

a) Environment A

Environment A relates to a power network supplied from a high or medium voltage transformer dedicated to the supply of an installation feeding manufacturing or similar plant, and intended to operate in or in proximity to industrial locations, as described below. This document applies also to apparatus which is battery-operated and intended to be used in industrial locations.

The environments encompassed are industrial, both indoor and outdoor.

Industrial locations are in addition characterized by the existence of one or more of the following examples:

– industrial, scientific and medical (ISM) apparatus (as defined in CISPR 11:2015/AMD1:2016);
– heavy inductive or capacitive loads are frequently switched;
– currents and associated magnetic fields are high.

NOTE 1 The generic EMC standards for electrical and electronic equipment in industrial environments are IEC 61000-6-2:2016 regarding immunity and IEC 61000-6-4:2018 regarding emission. The EMC requirements for assemblies in industrial environments given in this document are in line with these standards.

b) Environment B

Environment B relates to low-voltage public mains networks or apparatus connected to a dedicated DC source which is intended to interface between the apparatus and the low-voltage public mains network. It applies also to apparatus which is battery-operated or is powered by a non-public, but non-industrial, low-voltage power distribution system if this apparatus is intended to be used in the locations described below.

The environments encompassed are residential, commercial and light-industrial locations, both indoors and outdoors. The following list, although not comprehensive, gives an indication of locations which are included:

– residential properties, for example houses, apartments;
– retail outlets, for example shops, supermarkets;
– business premises, for example offices, banks;
– areas of public entertainment, for example cinemas, public bars, dance halls;
– outdoor locations, for example petrol stations, car parks, amusement and sports centres;
– light-industrial locations, for example workshops, laboratories, service centres.

Locations which are characterized by being supplied directly at low-voltage from the public mains network are considered to be residential, commercial or light-industrial.

NOTE 2 The generic EMC standards for electrical and electronic equipment in residential, commercial and light-industrial environments are IEC 61000-6-1:2016 regarding immunity and IEC 61000-6-3:2006/AMD1:2010 regarding emission. The EMC requirements for assemblies in industrial environments given in this document are in line with these standards.

The environmental condition (environment A and/or environment B) for which the assembly is suitable shall be stated by the assembly manufacturer.

J.9.4.2 Requirement for testing

Assemblies are in most cases manufactured or assembled on a one-off basis, incorporating a more or less random combination of devices and components.

No EMC immunity or emission tests are required on final assemblies if the following conditions are fulfilled:

a) the incorporated devices and components are in compliance with the requirements for EMC for the stated environment (see J.9.4.1) as required by the relevant product or generic EMC standard.

b) the internal installation and wiring is carried out in accordance with the devices and components' manufacturer's instructions (arrangement with regard to mutual influences, cable, screening, earthing, etc.).

In all other cases, the EMC requirements are to be verified with tests as per J.10.12.

J.9.4.3 Immunity

J.9.4.3.1 Assemblies not incorporating electronic circuits

Under normal service conditions, assemblies not incorporating electronic circuits are not sensitive to electromagnetic disturbances and therefore no immunity tests are required.

J.9.4.3.2 Assemblies incorporating electronic circuits

Electronic equipment incorporated in assemblies shall comply with the immunity requirements of the relevant product or generic EMC standard and shall be suitable for the specified EMC environment stated by the assembly manufacturer.

In all other cases, the EMC requirements are to be verified with tests as per J.10.12.

Equipment using electronic circuits in which all components are passive (for example diodes, resistors, varistors, capacitors, surge suppressors, inductors) are not required to be tested.

The assembly manufacturer shall obtain, from the device and/or component manufacturer, the specific performance criteria of the product as given in the relevant assembly standard.

J.9.4.4 Emission

J.9.4.4.1 Assemblies not incorporating electronic circuits

For assemblies not incorporating electronic circuits, electromagnetic disturbances can only be generated by equipment during occasional switching operations. The duration of the disturbances is of the order of milliseconds. The frequency, the level and the consequences of these emissions are considered as part of the normal electromagnetic environment of low-voltage installations. Therefore, the requirements for electromagnetic emission are deemed to be satisfied, and no verification is necessary.

J.9.4.4.2 Assemblies incorporating electronic circuits

Electronic equipment incorporated in the assembly shall comply with the emission requirements of the relevant product or generic EMC standard and shall be suitable for the specific EMC environment stated by the assembly manufacturer.

Equipment utilizing electronic circuits in which all components are passive (for example diodes, resistors, varistors, capacitors, surge suppressors, inductors) are not required to be tested.

Assemblies incorporating electronic circuits (such as switched mode power supplies, circuits incorporating microprocessors with high-frequency clocks) may generate continuous electromagnetic disturbances.

For such emissions, these shall not exceed the limits specified in the relevant product standard, or the requirements of Clause 9 together with Tables 3 to 5, of IEC 61000-6-4:2018 for environment A and/or Clause 7 together with Tables 1 to 4, of IEC 61000-6-3:2006/AMD1:2010 for environment B shall apply, excluding statistical methods, if any. Tests are to be carried out as detailed in the relevant product standard, if any, otherwise according to J.10.12.

J.10.12 Tests for EMC

J.10.12.1 General

Functional units within assemblies which do not fulfil the requirements of J.9.4.2 a) and b) shall be subjected to the following tests, as applicable.

The emission and immunity tests shall be carried out in accordance with the relevant EMC standard. However, the assembly manufacturer shall specify any additional measures necessary to verify the criteria of performance for the assemblies if necessary (e.g. application of dwell times).

J.10.12.2 Immunity tests

J.10.12.2.1 Assemblies not incorporating electronic circuits

No tests are necessary; see J.9.4.3.1.

J.10.12.2.2 Assemblies incorporating electronic circuits

Tests shall be made according to the relevant environment A or B. The values are given in Table J.1 and/or Table J.2 except where a different test level is given in the relevant specific product standard.

Performance criteria shall be stated by the assembly manufacturer based on the acceptance criteria in Table J.3.

J.10.12.3 Emission tests

J.10.12.3.1 Assemblies not incorporating electronic circuits

No tests are necessary; see J.9.4.4.1.

J.10.12.3.2 Assemblies incorporating electronic circuits

The assembly manufacturer shall specify the test methods used; see J.9.4.4.2.

The emission limits for environment A are given in IEC 61000-6-4:2018, Table 3 to Table 5.

The emission limits for environment B are given in IEC 61000-6-3:2006 and IEC 61000-6-3:2006/AMD1:2010, Table 1 to Table 3.

If the assembly incorporates telecommunication ports, the emission requirements of CISPR 32:2015, relevant to that port and to the selected environment, shall apply.

Table J.1 – Tests for EMC immunity for environment A (see J.10.12.2)

Type of test	Test level required		Performance criterion [c]
Electrostatic discharge immunity test IEC 61000-4-2:2008	±4 kV contact discharge or if contact discharge not possible ±8 kV / air discharge		B
Radiated radio-frequency electromagnetic field immunity test 80 MHz to 1 GHz IEC 61000-4-3:2006, IEC 61000-4-3:2006/AMD1:2007 and IEC 61000-4-3:2006/AMD2:2010	10 V/m		A
Radiated radio-frequency electromagnetic field immunity test 1,4 GHz to 6 GHz IEC 61000-4-3:2006, IEC 61000-4-3:2006/AMD1:2007 and IEC 61000-4-3:2006/AMD2:2010	3 V/m		A
Electrical fast transient/burst immunity test IEC 61000-4-4:2012	±2 kV/ 5 kHz on power ports ±1 kV/ 5 kHz on signal ports [f]		B
1,2/50 µs and 8/20 µs surge immunity test IEC 61000-4-5 [a]	±2 kV (line to earth) on power ports ±1 kV (line to line) on power ports ±1 kV (line to earth) on signal ports		B
Conducted radio-frequency immunity test (150 kHz to 80 MHz) IEC 61000-4-6:2013	10 V (power ports) 10 V (signal ports) [f]		A
Power-frequency magnetic field immunity test [b] IEC 61000-4-8:2009	30 A/m		A
Voltage dips immunity test (50 Hz / 60 Hz) IEC 61000-4-11:2004 and IEC 61000-4-11:2004/AMD1:2017 [e]	Class 2 [c, d, e]	Class 3 [c, d, e]	
	0 % during 0,5 cycle and 1 cycle	0 % during 0,5 cycle and 1 cycle	C
	70 % during 25 / 30 cycles	40 % during 10 / 12 cycles	C
		70 % during 25 / 30 cycles	B
		80 % during 250 / 300 cycles	B
Short interruptions immunity test IEC 61000-4-11:2004 and IEC 61000-4-11:2004/AMD1:2017	Class 2 [c, d, e] 0 % during 250 / 300 cycles	Class 3 [c, d, e] 0 % during 250 / 300 cycles	C

NOTE For performance criteria, see Table J.3.

[a] Regarding applicability, see 7.2 and 8.2 of IEC 61000-4-5:2014 (not applicable for low-voltage DC input/output ports (≤ 60 V), when secondary circuits (isolated from the AC mains) are not subject to transient overvoltages).

[b] Applicable only to apparatus containing devices susceptible to power magnetic fields.

[c] The given percentage means percentage of the rated operational voltage, e.g. 0 % means 0 V.

[d] Class 2 applies to points of common coupling and in-plant points of common coupling in the industrial environment in general. Class 3 applies to in-plant couplings in industrial environment only. This class should be considered when a major part of the load is fed through converters, welding machines are present, large motors are frequently started or loads vary rapidly. The product standard shall state the applicable cases.

[e] The value before the slash mark (/) is for 50 Hz and the value after for 60 Hz tests.

[f] Applicable only to ports interfacing with cables whose total length according to the manufacturer's functional specification may exceed 3 m.

Table J.2 – Tests for EMC immunity for environment B (see J.10.12.2)

Type of test	Test level required	Performance criterion [c]
Electrostatic discharge immunity test IEC 61000-4-2:2008	±4 kV / contact discharge or if contact discharge not possible ±8 kV / air discharge	B
Radiated radio-frequency electromagnetic field immunity test 80 MHz to 1 GHz IEC 61000-4-3:2006, IEC 61000-4-3:2006/AMD1:2007 and IEC 61000-4-3:2006/ AMD2:2010	3 V/m	A
Radiated radio-frequency electromagnetic field immunity test IEC 61000-4-3:2006, IEC 61000-4-3:2006/AMD1:2007 and IEC 61000-4-3:2006/ AMD2:2010	3 V/m	A
Electrical fast transient/burst immunity test IEC 61000-4-4:2012	±1 kV/ 5 kHz on power ports ±0,5 kV/ 5 kHz on signal ports	B
1,2/50 µs and 8/20 µs surge immunity test IEC 61000-4-5:2014 and IEC 61000-4-5:2014/AMD1:2017[a]	±2 kV (line to earth) on power ports ±1 kV (line to earth) on signal ports	B
Conducted radio-frequency immunity test (150 kHz to 80 MHz) IEC 61000-4-6:2013	3 V (signal ports and power ports)	A
Power-frequency magnetic field immunity test[b] IEC 61000-4-8:2009	3 A/m [b]	A
Voltage dips immunity test (50 Hz / 60 Hz) IEC 61000-4-11:2004 and IEC 61000-4-11:2004/AMD1:2017[d]	0 % during 0,5 cycle and 1 cycle 70 % during 25 / 30 cycles[c,d]	C C
Short interruptions immunity test IEC 61000-4-11:2004 and IEC 61000-4-11:2004/AMD1:2017	0 % during 250 / 300 cycles[c,d]	C

NOTE For performance criteria see Table J.3.

[a] Regarding applicability, see 7.2 and 8.2 of IEC 61000-4-5:2014 (not applicable for low-voltage DC input/output ports (≤ 60 V), when secondary circuits (isolated from the A mains) are not subject to transient overvoltages).

[b] Applicable only to apparatus containing devices susceptible to power magnetic fields.

[c] The given percentage means percentage of the rated operational voltage, e.g. 0 % means 0 V.

[d] The value before the slash mark (/) is for 50 Hz and the value after for 60 Hz tests.

Table J.3 – Acceptance criteria when electromagnetic disturbances are present

Item	Acceptance criteria (performance criteria during tests)		
	A	**B**	**C**
Overall performance	No noticeable changes of the operating characteristic Operating as intended	Temporary degradation or loss of performance which is self-recoverable	Temporary degradation or loss of performance which requires operator intervention or system reset [a]
Operation of power and auxiliary circuits	No unwanted operation	Temporary degradation or loss of performance which is self-recoverable [a]	Temporary degradation or loss of performance which requires operator intervention or system reset [a]
Operation of displays and control panels	No changes to visible display information Only slight light intensity fluctuation of LEDs, or slight movement of characters	Temporary visible changes or loss of information Undesired LED illumination	Shut down or permanent loss of display. Wrong information and/or unpermitted operating mode, which should be apparent or for which an indication should be provided. Not self-recoverable
Information processing and sensing functions	Undisturbed communication and data interchange to external devices	Temporarily disturbed communication, with possible error reports of the internal and external devices	Erroneous processing of information Loss of data and/or information Errors in communication Not self-recoverable

[a] Specific requirements shall be detailed in the product standard.

Annex K
(normative)

Operating current and power loss of bare copper bars

Table K.1 and Table K.2 provide values for conductor operating currents and power losses under ideal conditions within an assembly (see 10.10.2.2.3, 10.10.4.2.1 and 10.10.4.3.1). Annex K does not apply to conductors verified by testing.

The calculation methods used to establish these values are given to enable values to be calculated for other conditions.

Table K.1 – Operating current and power loss of bare copper bars with rectangular cross-section, run horizontally and arranged with their largest face vertical, frequency 50 Hz to 60 Hz (ambient air temperature inside the assembly: 55 °C, temperature of the conductor 70 °C)

Height × thickness of bars	Cross-sectional area of bar	One bar per line			Two bars per line (space between the two bars is equal to the thickness of one bar)		
		k_3	Operating current	Power-losses per line conductor, P_v	k_3	Operating current	Power-losses per line conductor, P_v
mm × mm	mm²		A	W/m		A	W/m
12 × 2	23,5	1,00	70	4,5	1,01	118	6,4
15 × 2	29,5	1,00	83	5,0	1,01	138	7,0
15 × 3	44,5	1,01	105	5,4	1,02	183	8,3
20 × 2	39,5	1,01	105	6,1	1,01	172	8,1
20 × 3	59,5	1,01	133	6,4	1,02	226	9,4
20 × 5	99,1	1,02	178	7,0	1,04	325	11,9
20 × 10	199	1,03	278	8,5	1,07	536	16,6
25 × 5	124	1,02	213	8,0	1,05	381	13,2
30 × 5	149	1,03	246	9,0	1,06	437	14,5
30 × 10	299	1,05	372	10,4	1,11	689	18,9
40 × 5	199	1,03	313	10,9	1,07	543	17,0
40 × 10	399	1,07	465	12,4	1,15	839	21,7
50 × 5	249	1,04	379	12,9	1,09	646	19,6
50 × 10	499	1,08	554	14,2	1,18	982	24,4
60 × 5	299	1,05	447	15,0	1,10	748	22,0
60 × 10	599	1,10	640	16,1	1,21	1 118	27,1
80 × 5	399	1,07	575	19,0	1,13	943	27,0
80 × 10	799	1,13	806	19,7	1,27	1 372	32,0
100 × 5	499	1,10	702	23,3	1,17	1 125	31,8
100 × 10	999	1,17	969	23,5	1,33	1 612	37,1
120 × 10	1 200	1,21	1 131	27,6	1,41	1 859	43,5

The current rating given in Table K.1 shall be de-rated by 20 % for busbars run horizontally and arranged with their largest face horizontal or run vertically for more than 2 m.

NOTE 1 The operating current values given in Table K.1 only apply for the specific bar configurations given.

$$P_{\mathrm{v}} = \frac{I^2 \times k_3}{\kappa \times A} \times \left[1 + \alpha \times (T_{\mathrm{c}} - 20\ ^\circ\mathrm{C})\right]$$

where

P_{v} is the power loss per metre;

I is the operating current;

k_3 is the current displacement factor;

κ is the conductivity of copper, $\kappa = 56 \dfrac{\mathrm{m}}{\Omega \times \mathrm{mm}^2}$;

A is the cross-sectional area of bar;

α is the temperature coefficient of resistance, α = 0,004 K^{-1};

T_{c} is the temperature of the conductor (°C).

For a conductor where the verification is by calculation, the design temperature of the conductor shall not exceed 90 °C. Higher busbar temperatures may be accepted when they have been previously tested in a reference design.

NOTE 2 The maximum design temperature is set at 90 °C in order to take into account variations that can occur in practice due to the operating temperatures of specific devices.

The operating currents may be converted for other ambient air temperatures inside the assembly and/or for a conductor temperature of 90 °C by multiplying the values of Table K.1 by the corresponding factor k_4 from Table K.2. Then the power losses shall be calculated using the formula given above accordingly.

Table K.2 – Factor k_4 for different temperatures of the air inside the assembly and/or for the conductors

Air temperature inside the enclosure around the conductors °C	Factor k_4	
	Conductor temperature of 70 °C	Conductor temperature of 90 °C
20	2,08	2,49
25	1,94	2,37
30	1,82	2,26
35	1,69	2,14
40	1,54	2,03
45	1,35	1,91
50	1,18	1,77
55	1,00	1,62
60	0,77	1,48

It shall be considered that, dependent upon the design of the assembly, quite different ambient and conductor temperatures can occur, especially with higher operating currents.

Verification of the actual temperature-rise under these conditions shall be determined by test. The power losses may then be calculated by the same method as used for Table K.2.

NOTE 3 At higher currents, additional eddy current losses can be significant. These are not included in the values of Table K.1.

NOTE 4 Example on determining a conductor section.

Parameters:

– the required current rating of the busbar circuit is 200 A;

– air temperature inside the enclosure is 60 °C;

– permissible conductor temperature of 90 °C.

From Table K.1 the minimum cross-sectional area of the busbars is based on a current of 200 A (as the busbar is not part of functional unit (circuit), a conductor with a rating of 125 % of the rated current of the circuit is not required).

To rerate to an internal temperature of 60 °C and conductor temperature of 90 °C, divide 200 A by 1,48 (from Table K.2). This gives an equivalent current rating of 135,1 A.

The closest current rating (from Table K.1) is 178 A using a single bar per line of 20 mm × 5 mm or 172 A using two spaced bars per line of 20 mm × 2 mm.

Annex L
(informative)

Guidance on verification of temperature-rise

L.1 General

L.1.1 Principles

All assemblies generate heat in service. Thermal equilibrium is established when the heat dissipation capability equals the heat produced. The temperature will stabilize at a temperature-rise above the ambient air temperature surrounding the assembly. The purpose of temperature-rise verification is to ensure temperatures stabilize at a value that will not result in:

a) significant deterioration or ageing of the assembly, or

b) excessive heat being transferred to external conductors, such that the service capability of the external conductors and any equipment to which they are connected can be impaired, or,

a) people, operators or animals in the vicinity of an assembly being burnt in normal operating circumstances.

L.1.2 Current ratings of assemblies

L.1.2.1 General

Several current ratings that are essential to the user of assemblies are confirmed during temperature-rise verification. See L.1.2.2 to L.1.2.5.

L.1.2.2 Group rated current of main circuits (I_{ng})

In normal service, most of the main circuits within an assembly are carrying load current. This leads to mutual heating between circuits and in most cases a reduction in the current carrying capability compared with the nominal rating of the devices.

This reduction in current carrying ability is defined by the group rating, but as it is not possible to anticipate every varying load pattern when designing an assembly, it can only be specified for assumed conditions, namely, continuous and simultaneous loading of circuits within a specified group within the assembly.

Group rating can be assigned to incoming circuits, main and distribution busbars and outgoing circuits. Without a full understanding of the variability of various load supplied from an assembly, the group rating of an outgoing circuit should not be less than the design current, I_B, for a circuit, as defined in the IEC 60364 series.

L.1.2.3 Current rating of an assembly (I_{nA})

The current rating of an assembly defines the maximum load current that can be supplied via the incoming circuit(s) and distributed via the main busbars. This rating can be determined by the capacity of the incoming circuit(s) or the main busbars.

The rated current of the assembly, I_{nA}, is the lower of (i) the sum of the group rated currents of the incoming circuits, and (ii) the group rated current of the main busbars.

It is essential to note that the group rating of the incoming circuit(s) may be lower than the nominal rating I_n of the devices used in the incoming circuits.

L.1.2.4 Rated current of a circuit of an assembly (I_{nc})

At their discretion, a manufacturer may declare the rated current of the outgoing circuits in an assembly, I_{nc}. This is the current that an outgoing circuit can deliver when it is the only outgoing circuit that is loaded in the assembly or assembly section. Under these conditions there are minimal heating effects from other circuits.

Generally, when there is only one outgoing circuit in a section, the I_{nc} for the circuit will be at least equal to, but it will not be much higher than I_{ng}. When there are several circuits in a section, I_{nc} can be appreciably higher than I_{ng} due to the mutual heating effects between adjacent circuits.

Knowing the loads (I_B, time, duration, etc.) allows I_{ng}, and I_{nc} to be determined. In some instances, for the design current I_B can exceed I_{ng}. However, I_B should never be greater than I_{nc}.

When a load takes a current that is cyclic or varies over a relative short period (the on time being less than the off time and the maximum on time being 30 min), the thermal equivalent steady state current can be derived as detailed in Annex I. This can be used instead of the design current I_B to determine the rating of the outgoing circuit required.

The rated current I_{nc} of an incoming circuit or busbar can be determined, but it has no practical value. Hence, it is not normally provided by manufacturers. The only useful current carrying capabilitiesy of incoming circuits and busbars are those when the assembly is operating at full load; the group rated currents I_{ng}.

L.1.2.5 Rated current of a device (I_n)

The rated current of a device I_n is the rating of the device according to its product standard. This rating applies in defined conditions, usually in free air, and with specific test conductors. Generally, a device de-rates when it is installed in an assembly. Device ratings are not proven during assembly tests in accordance with the IEC 61439 series, but the rating of a device I_n and the associated protection characteristic are vital in ensuring adequate protection for the load circuit.

L.2 Temperature-rise limits

The first paragraph of this clause of IEC 61439-1:2020 is not applicable.

All the temperature-rise limits given in this document assume that the assembly will be located in an environment where the daily average and peak ambient air temperatures do not exceed 35 °C and 40 °C, respectively.

This document also assumes that all outgoing circuits within an assembly will not be loaded to their rated current at the same time. This recognition of the practical situation is defined by a "group rating" provided for each outgoing circuit.

Temperature-rise limits within the assembly are the manufacturers’ responsibility; they are essentially determined based on operating temperature not exceeding the long-term capability of the materials used within the assembly. At interfaces between the assembly and the ‘wider world’, for example, cable terminals and operating handles, this document defines temperature-rise limits (see Table 6).

Within boundaries defined in this document, temperature-rise verification can be undertaken by testing, comparison or assessment. See Figure L.1. It is permissible to use one or a combination of the verification methods set out in this document to verify temperature-rise performance of an assembly. This allows the manufacturer to choose the most appropriate method for the assembly, or part of an assembly, being considered, taking into consideration volumes, the construction, design flexibility, current rating and size of the assembly.

In typical applications involving some adaptation of a standard design, it is highly likely more than one method will be used to cover various elements of the assembly design.

L.3 Test

L.3.1 General

In order to avoid unnecessary testing, this document provides guidance on selecting groups of comparable functional units. It then details how to select the critical variant from the group for test. Design rules are then applied to assign ratings to other circuits that are "thermally similar" to the critical variant tested.

Three options for verification by test are offered in this document.

L.3.2 Method a) – Verification of the complete assembly (10.10.2.3.5)

If several or all circuits of an assembly are loaded simultaneously, then the same circuit is only able to carry its group rated current, I_{ng}, (see 3.8.10.6), owing to the thermal influence of the other circuits. To verify the group rated current for the circuits, I_{ng}, within the assembly, tests with simultaneous loaded circuits are necessary (see L.3.3 Method b) and L.3.4 Method c), below). If a manufacturer chooses to declare rated current for the circuit, I_{nc}, separate tests are carried out on each type of outgoing circuit.

To avoid the large number of tests that may be necessary, 10.10.2.3.5 describes a verification method where only one test is made with a load applied simultaneously to all circuits. As the individual outgoing circuits are not tested, only I_{ng} can be determined for each circuit.

If the test set of functional units tested does not include one of each of the different types of outgoing circuit incorporated in the assembly, further tests are carried out taking into consideration different groups of outgoing circuits until one of each type has been tested.

L.3.3 Method b) – Verification considering individual functional units separately and the complete assembly (10.10.2.3.6)

With this arrangement of testing, each critical variant of the outgoing circuit is tested separately to confirm its rated current, and then the assembly as a whole is tested with the incoming circuit loaded to its group rated current. The test sets of outgoing circuits, as required to distribute the incoming current, are loaded to their group rated current, I_{ng}. The set tested should include one outgoing circuit of each critical variant to be incorporated in the assembly. Where this is not practical, further sets are tested until all critical variants of the outgoing circuit have been considered.

This test regime takes into account the group loading of outgoing circuits that is applicable in the majority of applications. However, as in method a) above, the result is only applicable to a specific arrangement of the assembly tested.

L.3.4 Method c) – Verification considering individual functional units and the main and distribution busbars separately as well as the complete assembly (10.10.2.3.7)

This test method enables modular systems to be temperature-rise verified without the need to test every conceivable combination of circuits. Temperature-rise tests are carried out separately to prove the rating of:

a) main busbars,

b) distribution busbars,

c) functional units (optional),

d) a complete assembly.

To verify the performance of the assembly as a whole, methods a), b) and c) above, are complemented by a test d) on a representative assembly in which the incoming and outgoing circuits are loaded to their group rated currents (I_{ng}).

Whilst this approach requires more testing than L.3.2 Method a) and L.3.3 Method b) above, it has the advantage that the modular system rather than a specific arrangement of the assembly is verified.

L.4 Verification assessment

This clause of IEC 61439-1:2020 is not applicable.

L.5 Verification by comparison with a reference design

This clause of IEC 61439-1:2020 is not applicable.

Figure L.1 – Verification of temperature-rise

This figure of IEC 61439-1:2020 is not applicable.

Annex M
(normative)

Verification of the short-circuit withstand strength of busbar structures by comparison with a reference design by calculation

This annex of IEC 61439-1:2020 is not applicable.

Annex N
(informative)

List of notes concerning certain countries

Subclause	Text
6.1	Add the following note after the last paragraph: NOTE In Norway, assemblies are additional marked with the minimum ambient temperature applicable for the ACS.
7.1.1	Add the following note after the last paragraph: NOTE In Norway, assemblies suitable for normal operation at a lower ambient temperature than -25 °C also comply with the requirements of this publication.
8.2.2	Add the following note after the first paragraph: NOTE 1 In the United States of America (USA), Canada and in Mexico enclosure “type” designations are used to specify “the degree of protection” provided to the ACS. For applications in the USA, the appropriate enclosure type designation should be used as specified in NEMA 250. For applications in Canada, the appropriate enclosure type designation should be used as specified in CSA standard C22.2 No. 94.1 and 94.2. For applications in Mexico, the appropriate enclosure Type designation should be used as specified in NMX-J-235/1-ANCE and NMX-J-235/2-ANCE. Add the following note after the third paragraph of this subclause: NOTE 2 In Spain wiring rules (RD 842/2002) require a minimum degree of protection of IP 45 for enclosures, switchgear and controlgear, socket-outlets and other installation elements intended for outdoor construction sites.
8.8	Add the following note after the last paragraph: NOTE In Australia and New Zealand socket outlets for industrial use with lower current are used.
10.2.6.1	Add the following notes at the end of this subclause: NOTE 1 In Sweden National codes and regulations require a minimum operating temperature of -25 °C. NOTE 2 In Norway, the test is carried out at an ambient temperature (20±5) °C immediately after the assembly has been kept at a temperature corresponding to the minimum ambient temperature specified for the ACS, for a period of not less than 12 h.

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9 This publication was withdrawn.

IEC 61439-4

Edition 2.0 2023-10

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Low-voltage switchgear and controlgear assemblies –
Part 4: Particular requirements for assemblies for construction sites (ACS)

Ensembles d'appareillage à basse tension –
Partie 4: Exigences particulières pour ensembles de chantiers (EC)

IEC 61439-4:2023-10(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES –

Part 4: Particular requirements for assemblies for construction sites (ACS)

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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IEC 61439-4 has been prepared by subcommittee 121B: Low-voltage switchgear and controlgear assemblies, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low voltage. It is an International Standard.

This second edition of IEC 61439-4 cancels and replaces the first edition published in 2012. This edition constitutes a technical revision.

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

a) alignment with IEC 61439-1:2020 regarding the structure and technical content, as applicable.

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

Draft	Report on voting
121B/183/FDIS	121B/188/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

This document is to be read in conjunction with IEC 61439-1:2020. The provisions of the general rules dealt with in IEC 61439-1:2020 are only applicable to this document insofar as they are specifically cited. When this document states “addition”, “modification” or “replacement”, the relevant text in IEC 61439-1:2020 is to be adapted accordingly.

Subclauses that are numbered with a 101 (102, 103, etc.) suffix are additional to the same subclause in IEC 61439-1:2020.

Tables and figures in this document that are new are numbered starting with 101.

New annexes in this document are lettered AA, BB, etc.

In this document, terms written in small capitals are defined in Clause 3.

The reader’s attention is drawn to the fact that Annex N lists all of the “in-some-country” clauses on differing practices of a less permanent nature relating to the subject of this document.

A list of all parts of the IEC 61439 series, under the general title *Low-voltage switchgear and controlgear assemblies,* 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 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.

LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES –

Part 4: Particular requirements for assemblies for construction sites (ACS)

1 Scope

NOTE Throughout this document, the abbreviation ACS (assembly for construction site, see 3.1.101) is used for a low-voltage switchgear and controlgear assembly intended for use on construction and similar sites.

This document defines the specific requirements of ACS as follows:

– assemblies for which the rated voltage does not exceed 1 000 V in case of AC or 1 500 V in case of DC;
– assemblies where the nominal primary voltage and the nominal secondary voltage of transformers incorporated in ACS are within the limits specified above;
– assemblies intended for use on construction sites, both indoors and outdoors, i.e. temporary places of work to which the public do not generally have access and where building construction, installation, repairs, alteration or demolition of property (buildings) or civil engineering (public works) or excavation or any other similar operations are carried out;
– transportable (semi-fixed) or MOBILE assemblies with enclosure.

The manufacture and/or assembly can be carried out by an entity other than by the original manufacturer (see 3.10.1 of IEC 61439-1:2020).

This document does not apply to individual devices and self-contained components, such as motor starters, fuse switches, electronic equipment, etc. which will comply with the relevant product standards.

This document does not apply to assemblies for use in the administrative centres of construction sites (offices, cloakrooms, meeting rooms, canteens, restaurants, dormitories, toilets, etc.).

Requirements for electrical protection provided by equipment manufactured according to this document are given in IEC 60364-7-704.

2 Normative references

This clause of IEC 61439-1:2020 is applicable except as follows:

Addition:

IEC 60068-2-27, *Environmental testing – Part 2-27: Tests – Test Ea and guidance: Shock*

IEC 60068-2-42, *Environmental testing – Part 2-42: Tests – Test Kc: Sulphur dioxide test for contacts and connections*

IEC 60364-7-704:2017, *Low-voltage electrical installations – Part 7-704: Requirements for special installations or locations – Construction and demolition site installations*

IEC 61439-1:2020, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

IEC 61558-2-23, *Safety of transformers, reactors, power supply units and combinations thereof – Part 2-23: Particular requirements and tests for transformers and power supply units for construction sites*

3 Terms and definitions

This clause of IEC 61439-1:2020 applicable except as follows:

Additional terms and definitions:

3.1 General terms

3.1.101
low-voltage switchgear and controlgear assembly for construction sites
ACS
combination of one or several transforming or low voltage switching devices with associated control, measuring, signalling, protective and regulating equipment complete with all their internal electrical and mechanical connections and structural parts, designed and built for use on all construction sites, indoors and outdoors

3.2 Constructional units of assemblies

3.2.101
metering unit
functional unit equipped with apparatus for metering electrical energy

3.2.102
transformer unit
functional unit consisting mainly of one or several transformers

Modifications:

3.3 External design of assemblies

3.3.1
open-type assembly

This term of IEC 61439-1:2020 does not apply.

3.3.2
dead-front assembly

This term of IEC 61439-1:2020 does not apply.

Replacement:

3.3.3
enclosed ACS
ACS which is enclosed on all sides with the possible exception of its mounting surface in such a manner as to provide a defined degree of protection

3.3.7
box-type ACS
ENCLOSED ACS intended:

– either to be mounted on a vertical surface;

– or to stand on a horizontal surface supported by feet or legs (articulated or not) or by a mounting not forming part of the ACS (see 3.4.2 of IEC 61439-1:2020)

Modification:

3.5 Conditions of installation of assemblies

3.5.1
assembly for indoor installation

This term of IEC 61439-1:2020 does not apply (see 3.1.101).

3.5.2
assembly for outdoor installation

This term of IEC 61439-1:2020 does not apply (see 3.1.101).

3.5.3
stationary assembly

This term of IEC 61439-1:2020 does not apply.

3.5.4
movable assembly

This term of IEC 61439-1:2020 does not apply.

Additional terms and definitions:

3.5.101
transportable ACS
semi-fixed ACS
ACS intended for use in a place where it is not permanently fixed

Note 1 to entry: The location of a TRANSPORTABLE ACS can vary during work on the same site. When the equipment is moved to another place, it is first disconnected from the supply.

3.5.102
mobile ACS
ACS capable of being moved as work advances on the site, without being disconnected from the supply

Additional terms and definitions:

3.101 Function of the ACS

3.101.1
incoming supply function
suitability for connection of the ACS either to electricity public supply network or to the transformer substation or to on site generator

3.101.2
metering function
suitability for the metering of electrical energy consumed on the site

3.101.3
distribution function
suitability to provide the distribution and protection of electrical supply on the construction site by means of terminal connection or socket-outlets

3.101.4
transformer function
suitability to provide means for transformer voltages or to provide measures of electrical protection

Note 1 to entry: Details for their requirements are given in 101.1.

4 Symbols and abbreviations

This clause of IEC 61439-1:2020 is applicable.

5 Interface characteristics

This clause of IEC 61439-1:2020 is applicable, except as follows.

5.3.1 Rated current of an assembly (I_{nA})

Replacement of title and text:

5.3.1 Rated current of an ACS (I_{nA})

The rated current of an ACS is **group rated current** I_{ng} of its incoming circuit.

This current shall be carried without the temperature rise of the individual parts exceeding the limits specified in 9.2 of IEC 61439-1:2020.

5.4 Rated diversity factor (RDF)

Addition:

The assumed loading of the outgoing circuits of the ACS or group of outgoing circuits shall be declared by the assembly manufacturer and can be based on the values in Table 101.

When the manufacturer does not declare any RDF, the values of Table 101 apply.

5.6 Other characteristics

Replacement:

The following characteristics shall be declared:

a) the function(s) assigned by the manufacturer (see 3.101);
b) the external design (see 3.3);
c) the mobility (see 3.5.101 and 3.5.102);
d) the degree of protection (see 8.2);
e) the method of mounting, for example fixed or removable parts (see 8.5.1 and 8.5.2);
f) protection against electric shock (see 8.4);
g) the resistance to corrosion (see 10.2.2.101);
h) special service conditions, if applicable (see 7.2);
i) electromagnetic compatibility (EMC) classification (see Annex J of IEC 61439-1:2020).

6 Information

This clause of IEC 61439-1:2020 is applicable except as follows.

6.1 Assembly designation marking

Replacement of title and text:

6.1 ACS designation marking

The assembly manufacturer shall provide each ACS with one or more labels, marked in a durable manner and located in a place such that they are visible and legible when the ACS is installed and in operation.

Compliance is checked according to the test of 10.2.7 and by inspection.

The following information regarding the ACS shall be provided on the label(s):

a) assembly manufacturer's name or trade mark (see 3.10.2);
b) type designation or identification number or any other means of identification, making it possible to obtain relevant information from the assembly manufacturer;
c) means of identifying date of manufacture;
d) IEC 61439-4;
e) type of current (and the frequency in the case of AC);
f) rated voltage (U_n) (of the ACS) (see 5.2.1);
g) rated current of the ACS (I_{nA}) (see 5.3.1);
h) degree of protection (see 8.2);
i) the weight where this exceeds 30 kg.

If the indication of the name or trademark of the manufacturer appears on the ACS, it shall not be given on the nameplate.

6.2.1 Information relating to the assembly

Replacement of title and text:

6.2.1 Information relating to the ACS

The following additional information, where applicable, shall be provided in the assembly manufacturer's technical documentation supplied with the ACS:

a) rated operational voltage (U_e) (of a circuit) (see 5.2.2);
b) rated impulse withstand voltage (U_{imp}) (see 5.2.4);
c) rated insulation voltage (U_i) (see 5.2.3);
d) rated current of each circuit (I_{nc}) (see 5.3.2);
e) rated peak withstand current (I_{pk}) (see 5.3.4);
f) rated short-time withstand current (I_{cw}) together with its duration (see 5.3.4);
g) rated conditional short-circuit current (I_{cc}) (see 5.3.5);
h) rated frequency (f_n) (see 5.5);
i) rated diversity factor(s) (RDF) (see 5.4);
j) functions (see 3.101);

k) all necessary information relating to the other declared classifications and characteristics (see 5.6);

l) the short-circuit withstand strength and characteristics of short-circuit protective device(s) (see 9.3.2);

m) overall dimensions (including projections e.g handles, covers, doors).

6.2.2 Instructions for handling, installation, operation and maintenance

Addition:

The manufacturer of the ACS should specify in its technical documentation supplied with the ACS the other types of assemblies which can be connected to it. This information should indicate whether the compatibility is based upon the type of system earthing employed and/or on the need for co-ordination of the electrical protection within the complete installation.

The manufacturer should furnish the appropriate documentation for the purpose to maintain the protective measures and the co-ordination of the protective devices within the complete installation.

7 Service conditions

This clause of IEC 61439-1:2020 is applicable except as follows.

Modifications:

7.1.2 Pollution degree

Replacement of the last paragraph with:

Only pollution degrees 3 and 4 are applicable.

The microenvironment can be reduced to pollution degree 2 if the degree of protection of the enclosure is at least IP5X and care is taken to avoid condensation.

7.2 Special service conditions

Addition of the following new item:

n) heavily polluted atmosphere.

8 Constructional requirements

This clause of IEC 61439-1:2020 is applicable except as follows.

8.1.1 General

Addition:

All the apparatus shall be placed inside the enclosure fitted with such removable panels, cover plates or doors as applicable for connection or maintenance with the possible exception of the items mentioned in 8.101 provided that they withstand the service conditions of Clause 7 and the requirements of 8.1.2 and 8.1.6.

8.1.2 Protection against corrosion

Replacement:

Protection against corrosion shall be ensured by the use of suitable materials or by protective coatings to the exposed surface taking account of the normal service conditions (see 7.1) and/or special service condition (see 7.2). Compliance to this requirement is checked by the test of 10.2.2.

8.1.4 Resistance to ultra-violet (UV) radiation

Replacement:

For enclosures and external parts made of insulating materials, resistance to ultra-violet radiation shall be verified according to 10.2.4.

For external parts made of insulating material of components covered by other IEC standard (for examples socket-outlets, handles of switch, push buttons, etc.), this test is not required.

8.1.5 Mechanical strength

Addition:

The ACS shall be constructed to withstand mechanical shocks having an acceleration of 500 m/s^2, a pulse shape of a half-sine wave of 11 ms duration (commensurate with equipment being carried loose in normal road or rail vehicles for long periods).

Compliance is verified according to 10.2.6.

8.1.6 Lifting provision

Replacement:

Lifting rings and/or handles (or any other equivalent system) shall be provided on the ACS and be firmly attached to the enclosure or supporting framework.

Compliance is checked according to the test of 10.2.5.

8.2.1 Protection against mechanical impact (IK code)

Additional paragraph:

The ACS shall also withstand impacts of 6 joules energy representing collisions with site construction mechanical handling equipment (see IEC 60068-2-27).

For protection against mechanical impact refer to 10.2.6.

NOTE In addition to 8.2.1, It is possible to make reference also to the IK code in case the enclosure has been tested according to other IEC 61439 parts.

8.2.2 Protection against contact with live parts, ingress of solid foreign bodies and water (IP code)

Replacement:

The degree of protection provided by an ACS against contact with live parts, ingress of solid foreign bodies and water is indicated by the IP code according to IEC 60529 and verified according to 10.3.

The degree of protection of the ACS shall be at least IP 44, with all doors closed and all removable panels and cover plates fitted.

Ventilation and drainage holes shall not reduce this degree of protection.

The degree of protection for an operating face inside a door shall be not less than IP 21 provided that the door can be closed under all conditions of use. Where the door cannot be closed the degree of protection for the operating face shall be at least IP 44.

Unless otherwise specified, the degree of protection indicated by the original manufacturer applies to the complete ACS, when it is installed in accordance with the original manufacturer's instructions.

Socket-outlets not protected by the enclosure of the ACS shall have a degree of protection at least equivalent to IP 44, both when the plug is removed or fully inserted.

Where the ACS does not have the same IP rating throughout, the original manufacturer shall declare in its technical documentation supplied with the ACS the IP rating for the separate parts. Example: IP 44, operating face IP 21.

No IP codes can be given unless the appropriate verifications have been made according to 10.3.

8.4.3.1 Installation conditions

Replacement of the first two paragraphs:

The ACS shall include protective measures and be suitable for installations designed to be in accordance with IEC 60364-7-704:2017.

8.4.4 Additional requirements for class II assemblies

e) This item of IEC 61439-1:2020 is not applicable.

8.4.6.2 Requirements related to accessibility in service by authorized persons

This subclause of IEC 61439-1:2020 is not applicable.

8.5.3 Selection of switching devices and components

Additional paragraphs:

Plugs of different rated currents or voltages shall not be interchangeable, so as to avoid errors in connecting (see IEC 60309-1 and IEC 60309-2).

Connections for three-phase socket-outlets shall be made in such a way as to retain the same order of phases.

Additional subclause:

8.5.101 Accessible parts of ACS

Only the socket-outlets, operating handles and control buttons can be accessible without the use of a key or tool. The actuator of the main switch shall be easily accessible (see 704.536.2.2 of IEC 60364-7-704:2017).

8.8 Terminals for external cables

Addition after the third paragraph:

All connections for external cables shall be re-wireable or shall be socket-outlets. Socket-outlets shall conform with the relevant standards and have a current rating of at least 16 A.

Additional subclauses:

8.101 Supports and securing devices of ACS

Every ACS shall be fitted with supports enabling it to stand on a horizontal surface (e.g. feet or legs, articulated or not) and/or a system for fixing it to a vertical wall, attached to the enclosure or supporting framework.

These various supports or securing devices shall be external to the enclosure but firmly attached to it. They shall be appropriate to the constructional features (weight, environment, etc.) and service characteristics of the ACS and shall be tested together with the ACS (Clause 10).

8.102 Cable outlet

The cable outlet shall be at a minimum distance from the ground compatible with the bending radius of the largest cable that can be connected to the ACS.

Compliance is checked by inspection.

9 Performance requirements

This clause of IEC 61439-1:2020 is applicable except as follows.

9.3.2 Information concerning short-circuit withstand strength

The last two paragraphs of this subclause of IEC 61439-1:2020 are not applicable.

10 Design verification

This clause of IEC 61439-1:2020 is applicable except as follows.

10.2.1 General

Replacement of the second paragraph:

Where an empty enclosure in accordance with IEC 62208 is used, and it has not been modified so as to degrade the performance of the enclosure, no repetition of the enclosure testing to 10.2, with the exception of 10.2.6, is required unless the ACS is declared for heavily polluted atmosphere (see 7.2 item m).

Additional subclause:

10.2.2.101 Verification of the resistance to corrosion in a heavily polluted atmosphere

a) Principle

This test is intended to assess the corrosive effects of an industrial atmosphere, i.e. an atmosphere polluted with sulphur dioxide.

The complete and fully equipped ACS shall be continuously exposed to this atmosphere for ten days.

b) Method of test and test atmosphere

The complete and fully equipped ACS shall be tested in accordance with IEC 60068-2-42.

c) Results to be obtained

The ACS is declared satisfactory, if

– no trace of corrosion is found either inside or outside (except for the sharp edges) and;

– no damaging effect appears in the ACS, verified by applying the tests of 10.9.1 of IEC 61439-1:2020, between 24 h and 36 h after the ACS has been removed from the test chamber.

10.2.6 Verification of protection against mechanical impact (IK code)

Replacement of title and text:

10.2.6 Verification of mechanical strength

10.2.6.1 General

a) These tests shall be applied to the ACS, the test sample being in working order but disconnected from the sample supply.

The test sample shall be completely unpackaged.

b) The tests include two distinct procedures:

– impact test;

– shock test.

Tests shall be carried out at an ambient air temperature of (20 ± 5) °C after the ACS has been kept at this temperature for at least 12 h.

10.2.6.2 Impact test

a) Principle

The complete ACS (with all components mounted inside and fitted on suitable supports and securing devices (see 8.101) if these form part of the ACS) shall be subjected to a series of impacts of 6 J applied to the enclosure (not to the components inside it) (see 8.1.6).

b) Method of test

The equipment to be tested shall be fixed on a support of adequate rigidity to restrict movement of the ACS to 0,1 mm under the effect of the prescribed impact. Three successive impacts shall be applied to each face of the ACS under test by means of either:

1) a solid smooth steel sphere approximately 50 mm in diameter and with a mass of (500 ± 25) g, which shall be allowed to fall freely from rest through a vertical height of 1,2 m onto the enclosure surface held in a horizontal plane. The hardness of the sphere shall be not less than 50 HR and not more than 58 HR, or

2) a similar steel sphere, shall be suspended by a cord and swing as a pendulum in order to apply a horizontal impact, falling through a vertical distance of 1,2 m.

See Figure 101 for the test setup.

Sloping surfaces can be tested using the pendulum but if this is not convenient the surface will be aligned in the horizontal plane by turning the unit on the support and the test 1) is used. Before each test an inspection of the sphere shall be made to ensure that it is free from burrs and defects.

The test shall be so arranged that the impacts are applied at positions where weaknesses are most likely to be revealed. A total of 18 impacts shall be applied to the ACS.

The test is not applicable to components such as socket-outlets, operating handles, illuminating lights, pushbuttons, actuators, etc., when these components are mounted in recesses with respect to the main surfaces, so that the distance between the most exposed parts of these components and the said surfaces is at least 1 cm.

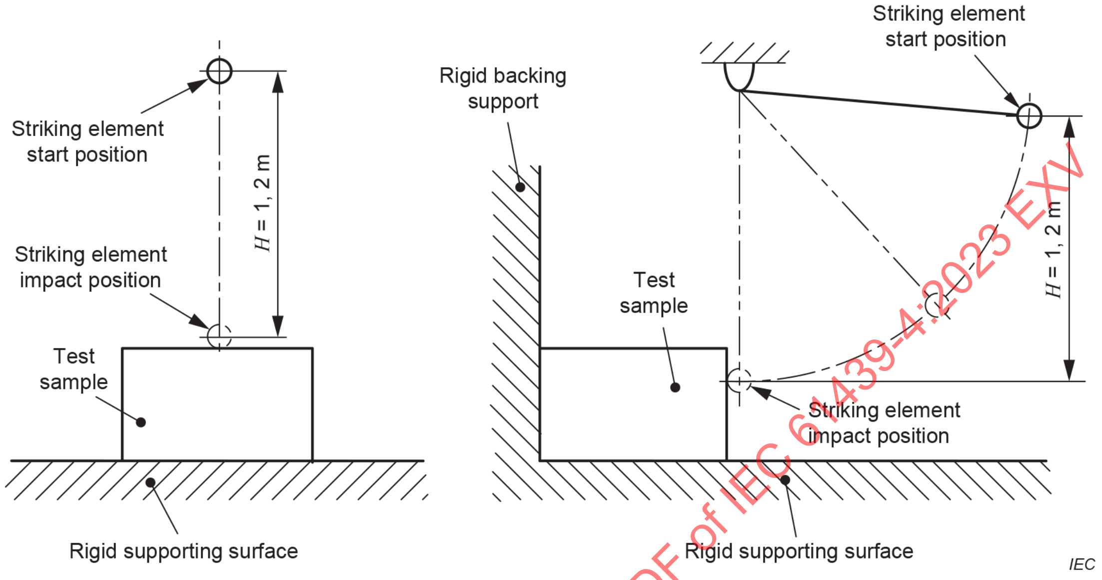

Figure 101 – Impact test using striking element

10.2.6.3 Shock test

a) Principle

The ACS shall be subjected to a single pulse half-sine wave, the shock test having a severity of 500 m/s^2 (50 g) peak acceleration and a duration of 11 ms.

b) Method of test

The ACS in working order shall be tested according to IEC 60068-2-27. Subject to agreement between manufacturer and user, the test can be carried out at separate SECTIONS of the ACS.

10.2.6.4 Results to be obtained

After the test, the enclosure shall continue to provide the degrees of protection specified in 8.2.2; any distortions or deformations of the enclosure and components shall neither be detrimental to the proper functioning of the ACS nor decrease creepage distances and clearances to below the required values; actuators, handles, etc., shall still be operable.

Distortion or deformation of plastic parts that can return in correct position by simple action (such as opening and reclosing of the cover) are not considered to be detrimental to the proper functioning of the ACS.

Superficial damage, paint removals, small indentations, cracks not visible with normal or corrected vision without further magnification, or surface cracks shall not constitute failure of the test.

10.9.3.1 General

Replacement of the first paragraph:

Verification shall be made by test.

10.10.1 General

Modification:

Item c) of this subclause of IEC 61439-1:2020 is not applicable.

10.10.4 Verification assessment

This subclause of IEC 61439-1:2020 is not applicable.

11 Routine verification

This clause of IEC 61439-1:2020 is applicable.

Additional clause:

101 Particular features of ACS

101.1 General requirements and functions

An ACS consists of one incoming unit and one or more outgoing units and can incorporate METERING UNIT(s) and TRANSFORMER UNIT(s).

Outgoing unit(s) can provide different functions such as: supply other ACS, lighting, machines or electric tools or other construction site equipment.

An ACS can be intended to be interconnected to form an installation or part of an installation in the form of a series of ACS. Apart from all their characteristics, they are covered by the same rules for protection against electric shock and provide, if possible, selective protection by a suitable choice, for example of breaking capacity, current setting and operating time.

These various characteristics are laid down by the manufacturer or are the subject of an agreement between manufacturer and user taking into account the nature of supply and/or distribution network and relevant installation requirements.

According to the relevant installation standards IEC 60364 series SPDs should be considered to protect against overvoltages.

101.2 Incoming unit

The cable connection facilities (terminals, connecting devices, connectors or plug and socket-outlet accessory) shall be compatible with the current rating of the ACS.

An isolating device and an over-current protective device shall be provided.

There shall be means for securing the isolating device in the open position.

However, the over-current protective device can be omitted if the ACS is adequately protected by an over-current protective device located in an upstream (supplying) ACS. In this case the assembly manufacturer shall provide the relevant information to the user for the correct choice of the upstream device.

According to IEC 60364-5-53, plug and socket-outlet arrangements can be used as isolating devices.