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INTERNATIONAL STANDARD

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Low-voltage switchgear and controlgear assemblies – Part 1: General rules

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES –

Part 1: General rules

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International Standard IEC 61439-1 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.

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

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

a) clarification that power electric converter systems, switch mode power supplies, uninterruptable power supplies and adjustable speed power drive systems are tested to their particular products standard, but when they are incorporated in assemblies the incorporation is in accordance with the IEC 61439 series of standards;

b) introduction of a group rated current for circuits within a loaded assembly and the refocusing of temperature-rise verification on this new characteristic;

c) addition of requirements in respect of DC;

d) introduction of the concept of class I and class II assemblies regarding protection against electric shock.

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

FDIS	Report on voting
121B/99/FDIS	121B/103/RVD

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

The reader's attention is drawn to the fact that Annex N lists all the "in-some-countries" clauses on differing practices of a less permanent nature regarding this document.

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

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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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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 ~~(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 ~~may~~ 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 ~~new re-structured~~ IEC 61439 series, the following parts are ~~envisaged~~ 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 ~~(to supersede IEC 60439-3)~~ intended to be operated by ordinary persons (DBO)

d) IEC 61439-4: ~~ASSEMBLIES for construction sites (to supersede IEC 60439-4)~~ Particular requirements for assemblies for construction sites (ACS)

e) IEC 61439-5: Assemblies for power distribution ~~(to supersede IEC 60439-5)~~ in public networks

f) IEC 61439-6: Busbar trunking systems ~~(to supersede IEC 60439-2)~~ (busways)

f) IEC 61439-7: Assemblies for specific applications such as marinas, camping sites, market squares, electric vehicle charging stations

g) IEC TR 61439-0: Guidance to specifying assemblies.

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

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

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES –

Part 1: General rules

1 Scope

~~NOTE 1 Throughout this standard, the term ASSEMBLY (see 3.1.1) is used for a low-voltage switchgear and controlgear assembly.~~

This part of IEC 61439 lays down the general definitions and ~~states the~~ service conditions, construction requirements, technical characteristics and verification requirements for low-voltage switchgear and controlgear assemblies.

~~This standard cannot be used alone to specify an ASSEMBLY or used for a purpose of determining conformity. ASSEMBLIES shall comply with the relevant part of the IEC 61439 series, Parts 2 onwards.~~

NOTE Throughout this document, the term assembly(s) (see 3.1.1) is used for a low-voltage switchgear and controlgear assembly(s).

For the purpose of determining assembly conformity, the requirements of the relevant part of the IEC 61439 series, Part 2 onwards, apply together with the cited requirements of this document. For assemblies not covered by Part 3 onward, Part 2 applies.

This document applies to ~~low-voltage switchgear and controlgear~~ assemblies ~~(ASSEMBLIES)~~ only when required by the relevant assembly standard 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 designed for a nominal frequency of the incoming supply or supplies not exceeding 1 000 Hz;

– assemblies intended for indoor and outdoor applications;

– stationary or movable assemblies with or without an enclosure;

– assemblies intended for use in connection with the generation, transmission, distribution and conversion of electric energy, and for the control of electrical energy consuming equipment.

~~– ASSEMBLIES designed for use under special service conditions, for example in ships and in rail vehicles provided that the other relevant specific requirements are complied with;~~

~~NOTE 2 Supplementary requirements for ASSEMBLIES in ships are covered by IEC 60092-302.~~

~~– ASSEMBLIES designed for electrical equipment of machines provided that the other relevant specific requirements are complied with.~~

~~NOTE 3 Supplementary requirements for ASSEMBLIES forming part of a machine are covered by the IEC 60204 series.~~

~~This standard applies to all ASSEMBLIES whether they are designed, manufactured and verified on a one-off basis or fully standardised and manufactured in quantity.~~

~~The manufacture and/or assembly may be carried out other than by the original manufacturer (see 3.10.1).~~

This document does not apply to individual devices and self-contained components such as motor starters, fuse switches, power electronic converter systems and equipment (PECS), switch mode power supplies (SMPS), uninterruptable power supplies (UPS), basic drive

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modules (BDM), complete drive modules (CDM), adjustable speed power drives systems (PDS), and other electronic equipment~~, etc.~~ which ~~will~~ comply with their relevant product standards. This document describes the integration of devices and self-contained components into an assembly or into an empty enclosure forming an assembly.

For some applications involving, for example, explosive atmospheres, functional safety, there can be a need to comply with the requirements of other standards or legislation in addition to those specified in the IEC 61439 series.

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

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 60216 (all parts), *Electrical insulating materials – Properties of thermal endurance*~~

~~IEC 60227-3:1993, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V – Part 3: Non-sheathed cables for fixed wiring*~~

~~IEC 60245-3:1994, *Rubber insulated cables – Rated voltages up to and including 450/750 V – Part 3: Heat resistant silicone insulated cables*~~

~~IEC 60245-4:1994, *Rubber insulated cables – Rated voltages up to and including 450/750 V – Part 4: Cords and flexible cables*~~

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 60364-4-44:2007, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*~~

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*

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~~IEC 60364-5-53:2001, *Electrical installations of buildings – Part 5-53: Selection and erection of electrical equipment – Isolation, switching and control*~~

~~IEC 60364-5-54:2011, *Low-voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors*~~

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

IEC 60445:~~2010~~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~~4]
IEC 60529:1989/AMD1:1999
IEC 60529:1989/AMD2:2013

~~IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*~~

IEC 60695-2-10:~~2000~~2013, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC 60695-2-11:~~2000~~2014, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products (GWEPT)*

~~IEC 60695-11-5:2004, *Fire hazard testing – Part 11-5: Test flames – Needle-flame test method – Apparatus, confirmatory test arrangement and guidance*~~

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*

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IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio frequency, electromagnetic field immunity test* [~~5~~6]

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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 edition 1.1 (2001) that includes IEC 60529 (1989) and its amendment 1 (1999).~~

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

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IEC 61000-4-3:2006/AMD2:2010

IEC 61000-4-4:~~2004~~2012, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test*

IEC 61000-4-5:~~2005~~2014, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*[7]
IEC 61000-4-5:2014/AMD1:2017

IEC 61000-4-6:~~2008~~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*

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~~IEC 61000-4-13:2002, *Electromagnetic compatibility (EMC) – Part 4-13: Testing and measurement techniques – Harmonics and interharmonics including mains signalling at a.c. power port, low-frequency immunity tests*[8]~~

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~~5 There is a consolidated edition 3.2 (2010) that includes IEC 61000-4-3 (2006) and amendment 1 (2007) and amendment 2 (2010).~~

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

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

~~8 There is a consolidated edition 1.1 (2009) that includes IEC 61000-4-13 (2002) and its amendment 1 (2009).~~

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CISPR 11:~~2009~~2015, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*~~10~~
CISPR 11:2015/AMD1:2016
CISPR 11:2015/AMD2:2019

~~CISPR 22, *Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement*~~

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

ISO 178:~~2001~~2010, *Plastics – Determination of flexural properties*
ISO 178:2010/AMD1:2013

~~ISO 179 (all parts) *Plastics – Determination of Charpy impact strength*~~

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

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ISO 179-2:1997/AMD1:2011

ISO 2409:~~2007~~2013, *Paints and varnishes – Cross-cut test*

ISO 4628-3:~~2003~~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:~~2006~~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:

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~~10 There is a consolidated edition 5.1 (2010) that includes CISPR 11 (2009) and its amendment 1 (2010).~~

- 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 ~~(of an ASSEMBLY)~~
all the conductive parts of an assembly included in a circuit which is intended to transmit electrical energy

[SOURCE: IEC 60050-441:~~1984~~2000, 441-13-02]

3.1.4
auxiliary circuit ~~(of an ASSEMBLY)~~
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:~~1984~~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 ~~separately~~ 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.]

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3.1.6
main busbar
busbar to which one or several distribution busbars and/or incoming and outgoing units ~~can be~~ 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 ~~to~~ 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

~~[2.2.21 of IEC 60947-1:2007]~~

[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

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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).

3.2 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 ~~is~~ 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

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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:~~1984~~2000, 441-13-07, modified – The text has been editorially reformatted into two bullet points.]

3.3 External design of assemblies

3.3.1
open-type assembly
assembly consisting of a supporting structure which supports the electrical equipment, the live parts of the electrical equipment being accessible

3.3.2
dead-front assembly
open-type assembly with a front cover, the live parts ~~may be~~ possibly being accessible from directions other than the front

3.3.3
enclosed assembly
assembly 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 assembly
enclosed assembly intended to be mounted on a vertical plane

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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

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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 ~~the enclosure of~~ an assembly separating one compartment ~~separating it~~ 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
~~enclosed~~ 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
assembly that is designed for use in locations where the normal service conditions for indoor use as specified in 7.1 ~~are fulfilled~~ apply

3.5.2
assembly for outdoor installation
assembly that is designed for use in locations where the normal service conditions for outdoor use as specified in 7.1 ~~are fulfilled~~ apply

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3.5.3
stationary assembly
assembly that is designed to be fixed at its place of installation, for instance to the floor or to a wall, and to be used at this place

3.5.4
movable assembly
assembly which is designed so that it can readily be moved from one place of use to another

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.

~~[IEC 60050-441:1984, 441-17-31]~~

[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
~~any~~ 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 ~~relatively long duration (~~ several seconds~~)~~ duration

~~[definition 3.7.1 of IEC 60664-1:2007, modified]~~

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

~~[IEC 60050-604:1987, 604-03-13]~~

[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

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~~NOTE The power-frequency withstand voltage is equivalent to the short-term temporary overvoltage in IEC 60664-1.~~

~~[definition 2.5.56 of IEC 60947-1: 2007]~~

[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

~~[definition 3.8.1 of IEC 60664-1: 2007]~~

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

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

~~[definition 3.11 of IEC 60664-1: 2007, modified]~~

[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 ~~devices or components~~ 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.

~~[definition 2.5.58 of IEC 60947-1: 2007]~~

[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 ~~(of a clearance or creepage distance)~~
immediate environment of the insulation which particularly influences the dimensioning of the creepage distances

Note 1 to entry: ~~the micro-environment of the creepage distance or clearance and not the environment of the ASSEMBLY or components determines the effect on the insulation. The micro-environment may be better or worse than the environment of the ASSEMBLY or components.~~

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.

~~[definition 3.12.2 of IEC 60664-1:2007, modified]~~

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[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.

~~[definition 2.5.60 of IEC 60947-1: 2007]~~

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

3.6.12
~~**surge arrester**~~
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

~~[definition 2.2.22 of IEC 60947-1: 2007]~~

[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
~~correlation of insulating characteristics of electrical equipment with the expected overvoltages and the characteristics of overvoltage protective devices on the one hand, and with the expected micro-environment and the pollution protective means on the other hand~~

~~[definition 2.5.61 of IEC 60947-1: 2007, modified]~~

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 ~~(non-uniform)~~ field
electric field which has not an essentially constant voltage gradient between electrodes

~~[definition 2.5.63 of IEC 60947-1: 2007]~~

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

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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

~~[definition 2.5.64 of IEC 60947-1: 2007]~~

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

3.6.16
comparative tracking index
CTI
numerical value of the maximum voltage in volts ~~at~~ which a material ~~withstands 50 drops of a defined test liquid~~ 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.

~~[definition 2.5.65 of IEC 60947-1: 2007, modified]~~

[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
~~conductor or~~ conductive part intended to be energized under normal ~~operation~~ 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.

~~[IEC 60050-195:1998, 195-02-19, modified]~~

[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

~~[IEC 60050-195:1998, 195-06-05]~~

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[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 ~~may~~ can become live ~~a hazardous live part under fault conditions~~ 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.

~~[IEC 60050-826:2004, 826-12-10, modified]~~

[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

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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.

~~[IEC 60050-195:1998, 195-06-06]~~

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

3.7.10
fault protection
protection against electric shock under single-fault conditions ~~(e.g. failure of basic insulation)~~

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**~~
~~**extra-low voltage**~~
~~**ELV**~~
~~any voltage not exceeding the relevant voltage limit specified in IEC 61201~~

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.]

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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

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[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]

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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 ~~(of an electrical system)~~
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:~~1984~~2000, 441-11-07]

3.8.7
prospective short-circuit current
I_{cp}
~~r.m.s. value of the~~ 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 ~~(see 10.11.5.4)~~

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:~~1984~~2000, 441-17-12]

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3.8.9
voltage ratings

3.8.9.1
rated voltage
U_n
highest nominal voltage of the electrical system, ~~a.c. (r.m.s.) or d.c.,~~ 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 ~~phases~~ 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 ~~(of a circuit of an ASSEMBLY)~~
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 ~~phases~~ lines.

3.8.9.3
rated insulation voltage
U_i
RMS withstand voltage value, assigned by the assembly manufacturer (3.10.2) to the ~~equipment~~ assembly or to a ~~part of it~~ 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 ~~phases~~ 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, ~~declared~~ 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

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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 ~~short-circuit protective device (~~ SCPD~~)~~ under specified conditions

~~NOTE The short-circuit protective device may form an integral part of the ASSEMBLY or may be a separate unit.~~

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.

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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
~~per unit value of the rated current, assigned by the ASSEMBLY manufacturer, to which outgoing circuits of an ASSEMBLY can be continuously and simultaneously loaded taking into account the mutual thermal influences~~

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 ~~made~~ 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.

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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 ~~of~~ using strict design rules and/or calculations applied to ~~a sample of~~ 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~~/user~~

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 ~~may~~ 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

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
~~ELV~~	~~extra-low voltage~~	~~3.7.11~~
EMC	electromagnetic compatibility	3.8.13

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Symbol/Abbreviation	Term	Term number
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

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5 Interface characteristics

5.1 General

The characteristics of the assembly shall ensure compatibility with the ratings of the circuits to which ~~it is~~ they are connected ~~and~~ 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.

~~NOTE~~ For single-phase circuits derived from IT systems (see IEC 60364-5-52:2009), the rated insulation voltage ~~should~~ shall be at least equal to the voltage between ~~phases~~ 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.

~~NOTE~~ 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 assembly (I_{nA})

The rated current of an assembly is the ~~smaller~~ lowest value of:

~~– the sum of the rated currents of the incoming circuits within the ASSEMBLY operated in parallel;~~

– the total group rated current I_{ng} of the incoming circuit(s), which is either the group rated current of the single incoming circuit or the sum of the group rated currents of the incoming circuits operated in parallel and simultaneously within the assembly;

– the total current that the main busbar ~~is capable of distributing~~ can distribute in the particular assembly arrangement.

This current shall be carried without the temperature-rise of the individual parts exceeding the limits specified in 9.2.

NOTE 1 The group rated current of an incoming circuit ~~may~~ can be lower than the rated current of the incoming device (according to the respective device standard) installed in the assembly.

NOTE 2 The main busbar in this context is a single busbar or a combination of single busbars that are normally connected in service e.g. by means of a bus-coupler.

~~NOTE 3 The rated current of the ASSEMBLY is the maximum permissible load current which can be distributed by the ASSEMBLY and which cannot be exceeded by adding further outgoing units.~~

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

~~The rated current of a circuit is the value of the current that can be carried by this circuit loaded alone, under normal service conditions. This current shall be carried without the temperature rise of the various parts of the ASSEMBLY exceeding the limits specified in 9.2.~~

~~NOTE 1 The rated current of a circuit may be lower than the rated currents of the devices (according to the respective device standard) installed in this circuit.~~

~~NOTE 2 Due to the complex factors determining the rated currents, no standard values can be given.~~

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 $I_{nc} \times$ 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).

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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 ~~r.m.s.~~ 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 shall be equal to or higher than the prospective r.m.s. value of short-circuit current (I_{cp}) for a duration limited by the operation of the short-circuit protective device that protects the ASSEMBLY.~~

~~The breaking capacity and current limitation characteristic (I^2t, I_{pk}) of the specified short-circuit protective device shall be stated by the ASSEMBLY manufacturer, taking into consideration the data given by the device manufacturer.~~

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)

~~The rated diversity factor is the per unit value of the rated current, assigned by the ASSEMBLY manufacturer, to which outgoing circuits of an ASSEMBLY can be continuously and simultaneously loaded taking into account the mutual thermal influences.~~

~~Rated diversity factor can be stated:~~

- ~~for groups of circuits;~~
- ~~for the whole ASSEMBLY.~~

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~~The rated diversity factor multiplied by the rated current of the circuits shall be equal to or higher than the assumed loading of the outgoing circuits. The assumed loading of outgoing circuits shall be addressed by the relevant ASSEMBLY standard.~~

~~NOTE 1 The assumed loading of the outgoing circuits can be a steady continuous current or the thermal equivalent of a varying current (See Annex E).~~

~~The rated diversity factor is applicable with the ASSEMBLY operating at rated current (I_{nA}).~~

~~NOTE 2 The rated diversity factor recognizes that multiple functional units are in practice not fully loaded simultaneously or are intermittently loaded.~~

~~See Annex E for further details.~~

~~NOTE 3 In Norway, the overload protection of conductors shall not solely be based on the use of diversity factors of the downstream circuits.~~

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).

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.

~~NOTE~~ 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) additional requirements depending on the ~~specific service conditions~~ use of a functional unit (e.g. type of coordination, overload characteristics);

b) pollution degree of the macro-environment (see 3.6.10.2);

c) types of earthing system for which the assembly is designed;

d) indoor and/or outdoor installation (see 3.5.1 and 3.5.2);

e) stationary or movable (see 3.5.3 and 3.5.4);

f) degree of protection against contact with hazardous live parts, ingress of solid foreign bodies and water, IP code (see 8.2.2);

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g) intended for use by ~~skilled or~~ ordinary or authorized persons (see 3.7.16 and 3.7.17);

h) electromagnetic compatibility (EMC) classification (see Annex J);

i) special service conditions, if applicable (see 7.2);

j) external design (see 3.3);

k) degree of protection against mechanical impact ~~protection~~, IK code, if applicable (see 8.2.1);

l) type of construction – fixed or removable parts (see 8.5.1 and 8.5.2);

m) ~~the nature~~ type of short-circuit protective device(s) (see 9.3.2);

n) measures for protection against electric shock;

o) overall dimensions (including projections e.g. handles, covers, doors), if required;

p) weight, if required.

6 Information

6.1 Assembly designation marking

The assembly manufacturer shall provide each assembly with one or more labels, marked in a durable manner and located in a place such that they are visible and legible when the assembly is installed and in operation. Compliance is checked according to the test of 10.2.7 and by inspection.

The following information regarding the assembly shall be provided on the designation 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) rated current of the assembly I_{nA} (see 3.8.10.7 and 5.3.1);

e) rated voltage of the assembly U_n (see 3.8.9.1 and 5.2.1);

f) rated frequency of the assembly f_n (see 3.8.12 and 5.5);

g) IEC 61439-X (the specific part “X” shall be identified).

NOTE The relevant assembly standard ~~may~~ can specify where additional information is to be provided on the designation label.

6.2 Documentation

6.2.1 Information relating to the assembly

All interface characteristics according to Clause 5, where applicable, shall be provided in the assembly manufacturer’s technical documentation supplied with the assembly.

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 ~~ASSEMBLIES~~ transport units. In addition, installation instructions shall provide sufficient details for the installer to adequately secure the assembly in service.

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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 ~~ASSEMBLY~~ 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 ~~may~~ 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 is not obvious from the physical arrangement of the apparatus installed, suitable information shall be supplied, for example wiring diagrams or tables.~~

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.

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 ~~below~~ in Table 15.

~~NOTE~~ If components, for example relays, electronic equipment, are used which are not designed for these conditions, ~~appropriate steps should be taken to ensure proper operation~~ the environment provided within the assembly shall be suitable for the components.

~~**7.1.1 Ambient air temperature**~~

~~**7.1.1.1 Ambient air temperature for indoor installations**~~

~~The ambient air temperature does not exceed +40 °C and its average over a period of 24 h does not exceed +35 °C.~~

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~~The lower limit of the ambient air temperature is –5 °C.~~

~~**7.1.1.2 Ambient air temperature for outdoor installations**~~

~~The ambient air temperature does not exceed +40 °C and its average over a period of 24 h does not exceed +35 °C.~~

~~The lower limit of the ambient air temperature is –25 °C.~~

~~**7.1.2 Humidity conditions**~~

~~**7.1.2.1 Humidity conditions for indoor installations**~~

~~The relative humidity of the air does not exceed 50 % at a maximum temperature of +40 °C. Higher relative humidity may be permitted at lower temperatures, for example 90 % at +20 °C. Moderate condensation should be borne in mind which may occasionally occur due to variations in temperature.~~

~~**7.1.2.2 Humidity conditions for outdoor installations**~~

~~The relative humidity may temporarily be as high as 100 % at a maximum temperature of +25 °C.~~

7.1.2 Pollution degree

The pollution degree ~~(see 3.6.9) refers~~ 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.

~~Unless otherwise stated, ASSEMBLIES for industrial applications are generally for use in a pollution degree 3 environment. However, other pollution degrees may be considered to apply, depending upon particular applications or the micro-environment.~~

The micro-environment within the assembly can be different from the macro-environment outside the enclosure. The pollution degree for a particular type of assembly is given in the relevant assembly standard.

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NOTE The pollution degree of the micro-environment for the equipment ~~may~~ 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.

~~**7.1.4 Altitude**~~

~~The altitude of the site of installation does not exceed 2 000 m.~~

~~NOTE 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.~~

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 ~~temperature and/or air pressure take place at such a speed that~~ climatic conditions are likely to result in exceptional condensation ~~is liable to occur~~ 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 ~~or breaking 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).

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;

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- 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.

~~The external shape of the ASSEMBLY enclosure can vary to suit the application and use, some examples have been defined in 3.3. These enclosures may also be constructed from various materials e.g. insulating, metallic or a combination of these.~~

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.

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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). Compliance with this requirement is checked by the test in 10.2.2.

8.1.3 Properties of insulating materials

8.1.3.1 Thermal stability

~~For~~ 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 ºC. 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 ~~might~~ can be exposed to thermal stresses due to internal electrical effects, and the deterioration of which ~~might~~ 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 either by reference to the insulation temperature index (determined for example by the methods of IEC 60216) or by compliance with IEC 60085.~~

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 ~~might~~ can be exposed to thermal stresses due to internal electrical effects, of which the deterioration ~~might~~ 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.

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

8.1.4 Resistance to ultra-violet (UV) radiation

~~For enclosures and external parts~~ External surfaces made of insulating material(s) and coated metal enclosures which are intended to be used outdoor exposed to ultra-violet radiation shall not crack nor deteriorate such that it impairs the safety of the assembly. Resistance to ultra-violet radiation shall be verified according to 10.2.4.

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.

8.1.6 Lifting provision

~~Where required, ASSEMBLIES shall be provided with the appropriate provision for lifting. Compliance is checked according to the test of 10.2.5.~~

Where lifting, other than by manual means is recommended by the manufacturer, e.g. by crane or fork lift truck, transport units shall be provided with the appropriate provision for lifting. Compliance is verified according to 10.2.5.

8.2 Degree of protection provided by an assembly enclosure

8.2.1 Protection against mechanical impact (IK code)

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The minimum degree of protection provided by an assembly enclosure against mechanical impact, if necessary, shall be defined by the relevant assembly standards ~~and verified in accordance with IEC 62262 (see 10.2.6)~~.

Compliance is verified according to 10.2.6.

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

The degree of protection provided by any assembly against contact with live parts, ingress of solid foreign bodies and water is indicated by the IP code according to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013; and verified according to 10.3.

~~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 ASSEMBLY. 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 y NMX-J-235/2-ANCE~~

After installation in accordance with the assembly manufacturer's instructions, the degree of protection of an enclosed assembly shall be at least IP2X. The degree of protection provided from the front of a dead-front assembly shall be at least IPXXB.

~~For fixed ASSEMBLIES not subject to tilting in normal service IP X2 is not applicable~~

For assemblies for outdoor use having no supplementary protection, the second characteristic numeral shall be at least 3.

NOTE ~~2~~ For outdoor installation, supplementary protection ~~may~~ can be protective roofing or similar.

Unless otherwise specified, the degree of protection indicated by the assembly manufacturer applies to the complete assembly when installed in accordance with the assembly manufacturer's instructions, for example sealing of the open mounting surface of an assembly, etc.

Where the assembly does not have the same IP rating throughout, the assembly manufacturer shall declare the IP rating for the separate parts.

Different IP ratings shall not impair the intended use of the assembly.

~~NOTE 3~~ EXAMPLES:

- operating face IP20, other parts IP00;
- drain holes in the base IPXXD, other parts IP43.

~~No~~ IP codes ~~can~~ shall not be ~~given~~ declared by the assembly manufacturer unless the appropriate verifications have been made according to 10.3.

Enclosed assemblies, for outdoor and indoor installation, intended for use in locations with high humidity and temperatures varying within wide limits, shall be provided with suitable arrangements (ventilation and/or internal heating, drain holes, etc.) to prevent harmful condensation within the assembly. However, the specified degree of protection shall at the same time be maintained.

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.

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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), ~~an agreement shall be reached between the ASSEMBLY manufacturer and the user as to what measures shall be taken to ensure adequate protection~~ the assembly manufacturer shall make available covers or similar to restore the original degree of protection. ~~Information provided by the ASSEMBLY manufacturer may take the place of such an agreement.~~ 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 ~~phase to phase~~ line to line, ~~phase~~ line to neutral, and, except where a conductor is connected directly to earth, ~~phase~~ line to earth and neutral to earth.

For bare live conductors and terminations ~~(e.g. busbars, connections between equipment and cable lugs)~~, 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 ~~unless~~; if not, a design verification test and a routine impulse withstand voltage test ~~is~~ 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.

~~NOTE In the United States of America (USA) and Mexico National Electrical Codes, are used to specify minimum clearances. In the USA National Electric Code NFPA 70, Article 408.56 is applicable. In Mexico NOM-001-SEDE is applicable. For these applications, it is recommended that clearances be selected using Annex L, Table L.1 of this standard. For applications in Canada minimum electrical clearances are specified in the Canadian Electrical Code, Part 2 Product Safety Standards.~~

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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.

~~NOTE 1~~ 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.

~~NOTE 2 In the United States of America (USA) and Mexico National Electrical Codes are used to specify minimum creepage distances. In the USA National Electric Code NFPA 70, Article 408.56 is applicable. In Mexico NOM-001-SEDE is applicable. For these applications, it is recommended that creepage distances be selected using Annex L, Table L.2 of this standard. For applications in Canada minimum creepage distances are specified in the Canadian Electrical Code, Part 2 Product Safety Standards.~~

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~~, and at the same time to ensure the necessary degree of safety~~ 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 ~~prevent~~ 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 ~~personnel~~ person(s).

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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.

~~NOTE Examples are electrical components~~ 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 ~~open~~ in the isolated position and closing of the disconnector without the use of a tool is impossible while the door is open.

   ~~NOTE In Norway, the neutral conductor shall be isolated or switched.~~

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 assembly shall include protective measures and be suitable for installations designed to be in accordance with IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017. ~~Protective~~

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~~measures suitable for particular installations (e.g. railways, ships) shall be subject to agreement between the ASSEMBLY manufacturer and the user.~~

NOTE 1 Protective measure suitable for particular installations can be subject to additional or different requirements, e.g. for installation in ships as given in IEC 60092 series.

When a TT earthing system is being used in the electrical network, one of the following protective measures shall be applied in the assembly:

a) double or reinforced insulation of ~~the incoming connections~~ all conductors (incoming cables, extension terminals, etc.) upto the supply side of the first RCD(s) in the system (this is not a requirement when a Class II assembly is used); or

b) residual current device (RCD) protecting the incoming circuit.

NOTE 2 An equivalent to reinforced insulation can be provided by rigid connections, air and suitable mechanical protection.

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 ~~(e.g. failure of basic insulation)~~ within the class I assembly;

b) protection against the consequences of earth faults ~~(e.g. failure of basic insulation)~~ in external circuits supplied through the ~~ASSEMBLY~~ 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 ~~protective~~ conductor providing earth continuity.

~~NOTE~~ With metal parts of the assembly where abrasion-resistant finishes are used (e.g. gland plates with powder coatings~~, connection for protective earthing~~), 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 ~~circuit~~ conductor is given in 10.5.2.

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

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a) When a part of the assembly is removed, for example for routine maintenance, the ~~protective circuits (~~ 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 ~~of the protective circuits~~ 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 ~~exceeding the limits of extra-low voltage (ELV)~~ is attached to them except equipment which is part of a PELV or SELV system.

If ~~apparatus~~ devices with a voltage exceeding the limits of ~~extra-low voltage~~ 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 ~~apparatus~~ devices attached ~~or~~. Alternatively, if the rated operational current of the attached ~~apparatus~~ devices is less than or equal to 16 A an equivalent electrical connection ~~especially~~ 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 ~~connected to the protective circuit~~ interconnected for earthing continuity by the fixing means of the device shall be connected to the ~~protective circuit~~ 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 ~~a protective conductor~~ 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 ~~of protective circuits~~ 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 ~~ASSEMBLY~~ class I or class II assemblies

A protective conductor within the assembly shall be designed so that it ~~is capable of withstanding~~ can withstand the highest thermal and dynamic stresses arising from earth fault currents in external circuits ~~at the place of installation that are~~ 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.).

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– In the run of protective conductors, links shall be permitted which are removable by means of a tool and accessible only to authorized ~~personnel~~ 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 ~~short-circuit protective devices (~~ 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 ~~an ASSEMBLY~~ 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 ~~as PEN conductors~~.

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 ~~may be energized by a fault in~~ can become live when basic insulation of the circuit fails.

~~For this type of protection, see Annex K.~~

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

8.4.4 ~~Protection by total insulation~~ Additional requirements for class II assemblies

~~NOTE According to 412.2.1.1 of IEC 60364-4-41, "total insulation" is equivalent to Class II equipment.~~

~~For basic and fault protection, by total insulation, the following requirements shall be met.~~

~~a) The apparatus shall be completely 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.~~

~~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 which 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.~~

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~~If an actuator 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.~~

~~If an actuator 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.~~

~~c) The enclosure, when the 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 IP 2XC (see IEC 60529).~~

~~If a protective conductor, which is extended to electrical equipment connected to the load side of the ASSEMBLY, is to be passed through an ASSEMBLY whose exposed conductive parts are insulated, the necessary terminals for connecting the external protective conductors shall be provided and identified by suitable marking.~~

~~Inside the enclosure, the protective conductor and its terminal shall be insulated from the live parts and the exposed conductive parts in the same way as the live parts are insulated.~~

~~d) Exposed conductive parts within the ASSEMBLY shall not be connected to the protective circuit, i.e. they shall not be included in a protective measure involving the use of a protective circuit. This applies also to built-in apparatus, even if they have a connecting terminal for a protective conductor.~~

~~e) If doors or covers of the enclosure can be opened without the use of a key or tool, a barrier of insulating material shall be provided that will afford protection against unintentional contact not only with the accessible live parts, but also with the exposed conductive parts that are only accessible after the cover has been opened; this barrier, however, shall not be removable except with the use of a tool.~~

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.

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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) If doors or covers of the enclosure can be opened without the use of a key or tool, a barrier of insulating material shall be provided that will afford protection of at least IPXXB against unintentional contact not only with the accessible live parts, but also with the exposed-conductive-parts that are only accessible after the door or cover has been opened; this barrier, however, shall not be removable except with the use of a tool.

8.4.5 Limitation of steady-state touch currents and charge

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

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

~~NOTE~~ 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 ~~level~~ 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

8.4.6.2.1 General

~~For~~ Depending on the application and accessibility necessary in service, by authorized person(s), one or more of the following requirements in 8.4.6.2.2 to 8.4.6.2.4 shall be fulfilled ~~subject to agreement between the ASSEMBLY manufacturer and the user~~. These requirements shall be complementary to the basic protection specified in 8.4.2.

If doors or covers of the assembly can be opened by authorized persons by overriding an interlock to obtain access to live parts, then the interlock shall automatically be restored on reclosing the door(s) or replacing the cover(s).

Obstacles can be used to prevent either:

– unintentional bodily approach to live parts; or

– unintentional contact with live parts during the operation of live equipment in normal service.

Obstacles may be removed without using a key or tool but shall be so secured as to prevent unintentional removal. The distance between a conductive obstacle and the live parts they

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protect shall not be less than the values specified for the clearances and creepage distances in 8.3.

Where a conductive obstacle is separated from hazardous live parts by basic protection only, it is an exposed-conductive-part, and measures for fault protection shall also be applied.

8.4.6.2.2 Requirements related to accessibility for inspection and similar operations

The assembly shall be constructed in such a way that certain operations~~, according to agreement between the ASSEMBLY manufacturer and the user,~~ can be performed when the assembly is in service and ~~under voltage~~ energized.

Such operations may consist of:

– visual inspections of;
  - switching devices and other apparatus;
  - settings and indicators of relays and releases;
  - conductor connections and marking;
– adjusting and resetting of relays, releases and electronic devices;
– replacement of fuse-links;
– replacement of indicating lamps;
– certain fault location operations, for example voltage and current measuring with suitably designed and insulated devices.

8.4.6.2.3 Requirements related to accessibility for maintenance

To enable maintenance ~~as agreed upon between the ASSEMBLY manufacturer and the user~~ on an isolated functional unit or isolated group of functional units in the assembly, with adjacent functional units or groups still ~~under voltage~~ energized, necessary measures shall be taken. The choice depends on such factors as service conditions, frequency of maintenance, competence of the authorized person, as well as local installation rules. Such measures may include the following:

– sufficient space between the actual functional unit or group and adjacent functional units or groups. It is recommended that parts likely to be removed for maintenance have, as far as possible, retainable fastening means;
– use of barriers or obstacles designed and arranged to protect against direct contact with equipment in adjacent functional units or groups;
– use of terminal shields;
– use of compartments for each functional unit or group;
– insertion of additional protective means provided or specified by the assembly manufacturer.

8.4.6.2.4 Requirements related to accessibility for extension ~~under voltage~~ when energized

When it is required to enable future extension of an assembly with additional functional units or groups, with the rest of the assembly still ~~under voltage~~ energized, the requirements specified in 8.4.6.2.3 shall apply, subject to agreement between the assembly manufacturer and the user. These requirements also apply for the insertion and connection of additional outgoing cables when the existing cables are ~~under voltage~~ energized.

The extension of busbars and connection of additional units to their incoming supply shall not be made ~~under voltage~~ when energized, unless the assembly is designed for this purpose.

~~**8.4.6.2.5 Obstacles**~~

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~~Obstacles shall prevent either:~~

~~– unintentional bodily approach to live parts, or~~

~~– unintentional contact with live parts during the operation of live equipment in normal service.~~

~~Obstacles may be removed without using a key or tool but shall be so secured as to prevent unintentional removal. The distance between a conductive obstacle and the live parts they protect shall not be less than the values specified for the clearances and creepage distances in 8.3.~~

~~Where a conductive obstacle is separated from hazardous live parts by basic protection only, it is an exposed conductive part, and measures for fault protection shall also be applied.~~

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 ~~under voltage~~ energized. ~~In general,~~ 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.

~~NOTE Where working on live circuits is permitted, relevant safety precautions may be necessary.~~

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 ~~whilst~~ 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.

~~In order to prevent~~ If unauthorized operation, can occur, then the removable parts ~~or their associated~~ ASSEMBLY ~~location may~~ shall be provided with a ~~lockable~~ 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

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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 ~~current-limiting~~ 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, ~~account shall be taken of~~ the maximum permissible values specified by the device manufacturer~~, having~~ 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 ~~the relevant IEC standards~~ 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.

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 ~~assemblies~~ 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.

~~Unless otherwise agreed between the ASSEMBLY manufacturer and the user~~ 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-mounted~~ 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.

~~NOTE In some countries, national codes or regulations may further limit the minimum and maximum height.~~

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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.

8.6 Internal electrical circuits and connections

8.6.1 Main circuits

The busbars (bare or insulated, see 3.15) 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 ~~information~~ 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 ~~phases~~ live parts and/or between ~~phases~~ live parts and earth is not to be expected (see 8.6.4).

~~Unless otherwise agreed between the ASSEMBLY manufacturer and the user,~~ The minimum cross-sectional area of the neutral conductor within a three-phase and neutral circuit shall be:

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

– for circuits with a ~~phase~~ line conductor cross-sectional area above 16 mm^2, 50 % of that of the corresponding ~~phases~~ 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 ~~phase~~ line currents;

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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.

~~NOTE~~ For certain applications, which lead to high values of zero sequence harmonics (e.g. third order harmonics), higher cross-sections of the ~~N~~ neutral conductor ~~might~~ may be required as these harmonics of the ~~phases~~ lines are added in the ~~N~~ 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 ~~supply~~ auxiliary circuit(s) earthing ~~system~~ and ensure that an earth fault ~~or a fault between a live part and an exposed conductive part~~ 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. ~~In particular,~~ The effects of thermal expansion, electrolytic action in the case of dissimilar metals, and the ~~effects of the endurance of the materials~~ 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 ~~adapt~~ 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:

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– 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.

~~The dimensioning of solid insulation between separate circuits shall be based on the circuit of highest rated insulation voltage.~~

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 such a manner that an internal short-circuit between phases or between phase and earth is a remote possibility. Examples of conductor types and installation requirements are given~~ 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 ~~only~~ be ~~green~~

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~~and yellow (twin-coloured), which is strictly reserved for the protective conductor~~ 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).

~~NOTE In some countries (e.g. USA, Australia, South Africa) other colours for the neutral conductor are 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

~~ASSEMBLIES can be provided with natural cooling and/or active cooling (e.g. forced cooling, internal air conditioning, heat exchanger etc.).~~ 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 ~~conductors~~ 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 ~~special agreement between the ASSEMBLY manufacturer and the user,~~ 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 ~~appropriate~~ 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.

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.

~~NOTE 1 In the United States of America (USA) and Mexico National Electrical Codes should be used for determining the minimum wire bending space requirements. In the USA NFPA 70, Article 312 is applicable. In Mexico NOM-001-SEDE is applicable. In Canada, wire space and wire bending space is prescribed in the Canadian Electrical Code, Part 2 Standard, C22.2 No. 0.12, Wire Space and Wire Bending Space in Enclosures for Equipment Rated 750 V or Less.~~

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The conductors shall not be subjected to stresses which are likely to reduce their normal life expectancy.

~~Unless otherwise agreed between the~~ ASSEMBLY ~~manufacturer and the user~~ 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 ~~phase~~ line conductor, with a minimum of 16 mm^2, if the size of the ~~phase~~ line conductor exceeds 16 mm^2;

– equal to the full cross-sectional area of the ~~phase~~ line conductor, if the size of the latter is less than or equal to 16 mm^2.

~~NOTE 2~~ For conductors, other than copper conductors, the above cross-sections should be replaced by cross-sections of equivalent ~~conductivity~~ conductance, which may require larger terminals.

~~NOTE 3~~ For certain applications, which lead to high values of zero sequence harmonics (e.g. third order harmonics), higher cross-sections of the ~~N~~ neutral conductor ~~might~~ may be required as these harmonics of the ~~phases~~ lines are added in the ~~N~~ 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 ~~phase~~ line conductor terminals.

NOTE ~~4~~ 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.

~~Unless otherwise agreed between the~~ ASSEMBLY ~~manufacturer and the user~~ 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 ~~phase~~ 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.

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~~NOTE 5~~ Special precautions ~~may~~ 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.

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.

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.

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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 ~~mean~~ daily average ambient air temperature ~~up to~~ 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 ~~have to~~ 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 ~~mean~~ 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 ~~insulation~~ temperature index ~~(determined~~, for example, by the methods of IEC 60216 (all parts) or ~~by compliance~~ in accordance with IEC 60085:2007.

9.2.2 Adjustment of rated currents for alternative ambient air temperatures

~~NOTE 1~~ 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 ~~should~~ shall state the measures to be taken, if any, to ensure compliance with the temperature limits. ~~For ambient temperatures up to 50 °C this can be done by calculation, assuming that the over temperature of each component or device is proportional to the power loss generated in this component. There are devices where the power loss is substantially proportional to I^2 and others that have substantially fixed losses.~~ 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.

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~~NOTE 2 In the United States of America (USA) and Mexico National Electrical Codes, are used to specify maximum temperature rises. In the USA, NFPA 70, Article 110.14C is applicable. In Mexico NOM-001-SEDE is applicable. For these applications, temperature rises should be selected using Annex M, Table M.1 of this standard. In Canada, maximum temperature rise is prescribed in the Canadian Electrical Code, Part 2, Product Safety Standards.~~

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 ~~may~~ 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.

~~NOTE 2~~ For assemblies intended for use in IT systems ~~(see IEC 60364-5-52)~~, 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).

~~NOTE 3~~ 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 ~~personnel~~ person(s).

9.3.2 Information concerning short-circuit withstand strength

For assemblies with a ~~short-circuit protective device (~~ SCPD~~)~~ incorporated in the incoming unit, the assembly manufacturer shall ~~indicate~~ 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 ~~more~~ 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 ASSEMBLY manufacturer shall indicate the characteristics of the short-circuit protective devices necessary for the protection of the ASSEMBLY.~~

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For an assembly having several incoming units which are unlikely to be in operation simultaneously, the short-circuit withstand strength can be indicated for each of the incoming units in accordance with the above.

For an assembly having several incoming units which are likely to be in operation simultaneously, and for an assembly having one incoming unit and one or more outgoing high-power units likely to contribute to the short-circuit current, it is necessary to determine the values of the prospective short-circuit current, considering all operating modes, in each incoming unit, in each outgoing unit and in the busbars. The prospective short-circuit currents determined shall be based on data provided by the user.

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 ~~switching device~~ 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 ~~may~~ 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.

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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 ~~tested~~ 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:

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10.2 Strength of materials and parts;

10.3 Degree of protection of ~~enclosures~~ 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 ~~Verification of temperature~~ Temperature-rise;

10.11 Short-circuit withstand strength;

10.12 Electromagnetic compatibility~~;~~

~~10.13 Mechanical operation~~.

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 62208:2011 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 is required.

10.2.2 Resistance to corrosion

10.2.2.1 ~~Test procedure~~ 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.

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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:

~~6 cycles of 24 h each to damp heat cycling test according to IEC 60068-2-30 (Test Db) at (40 ± 3) °C and relative humidity of 95 %~~

~~and~~

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

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:

~~5 cycles of 24 h each to damp heat cycling test according to IEC 60068-2-30 (Test Db) at (40 ± 3) °C and relative humidity of 95 %~~

~~and~~

~~7 cycles of 24 h each to salt mist test according to IEC 60068-2-11; (Test Ka: Salt mist), at a temperature of (35 ± 2) °C.~~

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,

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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 ~~iron oxide,~~ cracking or other deterioration ~~more~~ other than ~~that~~ 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.

10.2.3 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.

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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 ~~parts~~ 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).

~~If an identical material having representative cross-sections as the parts has already satisfied the requirements of 8.1.3.2.3 then the test need not be repeated. It is the same for all parts which have been previously tested according to their own specifications.~~

For a description of the test, see Clause 8 of IEC 60695-2-11:~~2000~~2014. The apparatus to be used shall be as described in Clause 5 of IEC 60695-2-11:~~2000~~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 ~~intended for mounting~~ 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

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As an alternative, the original manufacturer shall provide data on the suitability of materials from the insulating material ~~supplier~~ manufacturer to demonstrate compliance with ~~the requirements of 8.1.3.2.3~~ 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

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

~~UV test according to ISO 4892-2 Method A, Cycle 1 providing a total test period of 500 h. For enclosures constructed of insulating materials compliance is checked by verification that the flexural strength (according to ISO 178) and Charpy impact (according to ISO 179) of insulating materials have 70 % minimum retention.~~

~~The test shall be made on six test specimens of standard size according to ISO 178 and on six test specimens of standard size according to ISO 179. The test specimens shall be made under the same conditions as those used for the manufacture of the enclosure concerned.~~

~~For the test carried out in accordance with ISO 178, the surface of the sample exposed to UV shall be turned face down and the pressure applied to the non-exposed surface.~~

~~For the test carried out in accordance with ISO 179 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.~~

~~For compliance, enclosures constructed of metals entirely coated by synthetic material, the adherence of the synthetic material shall have a minimum retention of category 3 according to ISO 2409.~~

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

~~This test need not be carried out if the original manufacturer can provide data from the material supplier to demonstrate that material of the same type and thickness or thinner complies with this requirement.~~

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.

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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

~~For ASSEMBLIES with~~ 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

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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 ~~ASSEMBLY~~ 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 ~~ASSEMBLY~~ transport unit is raised up and suspended clear of the floor for 30 min without any movement.

Following ~~this~~ the above test and using the same transport unit, the ~~ASSEMBLY~~ 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 ~~ASSEMBLY~~ 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 protection against mechanical impact (IK code)

Mechanical impact tests, where required by the specific assembly standard, are to be carried out in accordance with ~~IEC 62262~~ the test requirements of the specific assembly standard.

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 spirit is defined as a solvent hexane with a content of aromatics of maximum 0,1 % in volume, a kauributanol value of 29, an initial boiling point of 65 °C, a final boiling point of 69 °C and a density of approximately 0,68 g/cm^3.~~ 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

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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 ~~unless stated otherwise by the original manufacturer~~ (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

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not ~~impair safety~~ 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 ~~harmful amount of~~ dust is visible on ~~electrical equipment~~ 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 ~~clearances and~~ 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 ~~Effectiveness of the protective circuit~~ 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 ~~ASSEMBLY~~ 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 ~~and that the resistance of the circuit does not exceed 0,1 Ω~~.

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.

~~NOTE~~ It is recommended to limit the duration of the test where low-current equipment is used; otherwise ~~may~~ 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 ~~10.5.3.3 to~~ 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.

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10.5.3.3 Verification by comparison with ~~a~~ 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 ~~tested~~ reference design.

10.5.3.4 Verification by comparison with ~~a~~ reference designs – Using calculation

Verification by comparison with ~~a~~ 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 ~~tested~~ 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 ~~J.~~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.

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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 ~~and control~~ circuits

Main circuits and auxiliary ~~and control~~ circuits that are connected to the main circuit shall be subjected to the test voltage according to Table 8.

Auxiliary ~~and control~~ 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 ~~between 45 Hz and 65 Hz~~ equal to the rated frequency of the assembly with a tolerance of ±25 %. A DC test voltage shall have negligible ripple.

The high-voltage ~~transformer~~ 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 ~~shall be at least 200 mA~~ 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 %.

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10.9.2.3 Application of the test voltage

The ~~power frequency~~ 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^{+2}_{0} ~~5 ($^{+2}_{0}$)~~ s as follows:

a) between all live parts of the main circuit connected together (including the ~~control and~~ 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 ~~control and~~ 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 or by assessment.

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 ~~accuracy~~ 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 ~~control and~~ 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;

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c) between each ~~control and~~ 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 ~~and a~~ at the rated frequency ~~between 45 Hz and 65 Hz~~ with a tolerance of ± 25 %.

The high-voltage ~~transformer~~ 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 ~~shall be at least 200 mA~~ 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 ~~a duration sufficient for the magnitude to be ascertained, but it shall not be less than 15 ms~~ three cycles (see IEC 60664-1:2007, 6.1.2.2.2.

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 ~~shall be at least 200 mA~~ 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.

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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 ~~once~~ three times for each polarity for a duration ~~sufficient for the magnitude to be ascertained, but it shall not be less than 15 ms or greater than 100 ms~~ 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 ~~dielectric~~ 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.

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10.10 ~~Verification of~~ 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) derivation (from a tested design) of ratings for similar variants (10.10.3);~~

~~c) calculation for a single compartment ASSEMBLY not exceeding 630 A according to 10.10.4.2 or for ASSEMBLIES not exceeding 1600 A according to 10.10.4.3.~~

b) comparison with a reference design (10.10.3);

c) assessment (calculation) (10.10.4).

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 ~~capability~~ 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 ~~obtain~~ determine with reasonable accuracy the

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~~highest possible~~ 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~~2~~: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

~~For the critical variant the most onerous compartment (where applicable) and enclosure conditions (with respect to shape, size, design of partitions and enclosure ventilation) shall be tested.~~

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. ~~If a combination of devices connected in series is intended to be used at a lower current (e.g. motor starter combination), this lower current shall be used.~~

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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.

~~NOTE~~ 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~~, an explanation is provided in Annex O~~. 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~~. The power losses of the fuse-links used for the test shall be stated in the test report. Fuse-link power loss may be determined by measurement or alternatively as declared by the fuse-link 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.

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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 ~~0 % and +3 %~~ 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 testing individual functional units within a section or a complete ASSEMBLY, the adjacent 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.~~

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 ~~control~~ 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

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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 ~~800~~ 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 ~~allowed~~ 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 ~~800~~ 1 600 A but not exceeding ~~4 000~~ 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 ~~allowed~~ 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 ~~4 000~~ 7 000 A:

   The original manufacturer shall determine all relevant items of the test, such as type of supply, number of ~~phases~~ 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

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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) ~~must~~ 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

~~Incoming and outgoing circuits of the assembly shall be loaded with their rated currents (see 5.3.2) being equivalent to a rated diversity factor of 1 (see 5.4 and Annex O).~~

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 ~~groups~~ test sets corresponding to the group rated current of the incoming circuit or distribution busbar system. The ~~groups~~ test sets shall be formed in a manner so that the highest possible temperature-rise is obtained. ~~Sufficient groups~~ Enough test sets shall be formed and tests undertaken to include all different variants of functional units in at least one ~~group~~ 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.

~~NOTE 10.10.2.3.6 provides a means of testing an ASSEMBLY with diversity factor less than one and fewer tests than specified in 10.10.2.3.7.~~

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 ~~and the rated diversity factor according to 5.4~~ 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).

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– The assembly is verified by loading the incoming circuit ~~to its rated current~~ and all outgoing functional units collectively to their ~~rated current multiplied by the diversity factor~~ 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 ~~test~~ currents, I_{ng}, of all outgoing circuits ~~(i.e. the rated currents multiplied by the diversity factor)~~, then the outgoing circuits shall be split into ~~groups~~ test sets corresponding to the group rated current of the incoming circuit or distribution busbar system. The ~~groups~~ test sets shall be formed in a manner so that the highest possible temperature-rise is obtained. Sufficient ~~groups~~ test sets shall be formed and tests undertaken to include all different variants of functional units in at least one ~~group~~ 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 ~~individual~~ 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 ~~rated for a~~ 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 ~~is loaded to its rated current~~ and each outgoing functional unit are

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loaded to their group rated current I_{ng} where I_{ng} is equal to ~~its rated current~~ I_{nc} multiplied by ~~the rated diversity factor~~ 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 ~~multiplied by the diversity factor~~), then the outgoing circuits shall be split into ~~groups~~ 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 ~~groups~~ test sets shall be formed in a manner so that the highest possible temperature-rise is obtained. ~~Sufficient groups~~ Enough test sets shall be formed and tests undertaken to include all different variants of functional units in at least one ~~group~~ 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. ~~The apparatus shall operate satisfactorily within the voltage limits specified for them at the temperature inside the ASSEMBLY.~~

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 ~~Derivation of ratings for similar variants~~ 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. ~~Tests carried out at a particular frequency are applicable at the same current rating to lower frequencies including d.c.~~

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.

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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 ~~phase~~ 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 may be substituted with a similar device from another series to that used in the original verification, provided that the power loss and terminal temperature rise of the device, when tested in accordance with its product standard, is the same or lower. In addition, the physical arrangement within the functional unit and the rating of the functional unit shall be maintained.~~

~~NOTE In addition to temperature rise other requirements are considered including the short-circuit requirements, see Table 13.~~

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A device with a rated current I_n not exceeding 1600 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;

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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

10.10.4.1 General

The following calculation methods are provided, which have differing ranges of applicability:

1) single compartment assembly with natural cooling and rated current I_{nA} not exceeding 630 A (10.10.4.2);
2) assembly with natural cooling and rated current I_{nA} not exceeding 1 600 A (10.10.4.3).

These methods determine the approximate air temperature-rise inside the enclosure, which is caused by the power losses of all circuits, and compares this temperature with the limits for the installed equipment. The methods differ only in the way the relationship between the delivered power loss and the air temperature-rise inside the enclosure is ascertained.

Due to the actual local temperatures of the current-carrying parts, which cannot be calculated by these methods, some limits and safety margins are necessary and included. Verification of the temperature-rise may be made by calculation if all the following general conditions and the additional conditions for the selected calculation method are fulfilled.

a) The rated frequency is up to and including 60 Hz.
b) The power loss data for all built-in electrical components is available from the component manufacturer.
c) There is an approximately even distribution of power losses inside the enclosure.
d) The mechanical parts and the installed equipment are so arranged that air circulation is not significantly impeded.
e) The group rated current of the circuits, (I_{ng}), of the assembly to be verified shall not exceed 80 % of the rated conventional free air thermal current (I_{th}) if known, or when I_{th} is not available, 80 % of the rated current (I_n) of the switching devices and electrical components included in the circuit. Circuit-protection devices shall be selected to ensure adequate protection to outgoing circuits, e.g. thermal motor protection devices at the calculated temperature in the assembly. The limitation to 80 % of the rated current I_{th} or I_n does not apply to electronic devices which incorporate means for forced ventilation when they are installed according to the device manufacturer's instructions.

   NOTE 1 There is no common characteristic for switching devices and electrical components that describes the value of current to be used here. For the purpose of verifying the temperature-rise limits, the value of the current is used, which describes the maximum continuous operational current that can be carried without overheating. This is, for example, for contactors the rated operational current I_e AC1 and for circuit-breakers the rated current I_n.

   NOTE 2 This verification method assesses the mean air temperature inside the enclosure assuming an even distribution of the power losses. Therefore, potential local hot spots at the devices, which are the main power loss sources, cannot be detected. To prevent overheating of the devices, the safety margin of 80 % is introduced. This is based on general testing experience.

   NOTE 3 Electronic devices with forced ventilation distribute their power losses mainly via the cooling air. They do not rely on the power dissipation via the conductors and the surface of the device/enclosure. Usually they are equipped with internal temperature monitoring to prevent overheating. Therefore, a limitation to 80 % of the rated current as imposed for other devices is not appropriate.

f) All conductors directly connected to a device shall have a minimum cross-sectional area based on 125 % of the group rated current, I_{ng}, of the associated circuit. Selection of cables shall be in accordance with IEC 60364-5-52:2009. Examples of how to adapt this document for conditions inside an assembly are given in Annex H. The cross-section of

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bare copper bars shall be as tested or as given in Annex K. Where the device manufacturer specifies a conductor with a larger cross-sectional area, this shall be used.

NOTE 4 The factor of 125 % is used to ensure that the conductors will not further derate the devices.

g) Conductors carrying currents in excess of 200 A and the adjacent structural parts are so arranged that eddy-current and hysteresis losses are minimized.

The effective power losses of all circuits including interconnecting conductors shall be calculated assuming the circuits are operating at their group rated current, I_{ng}. The total power loss of the assembly is calculated by adding the power losses of the circuits taking additionally into account that the total load current is limited to the rated current of the assembly, I_{nA}. The power losses of the conductors are determined by calculation (see Annex H and Annex K).

NOTE 5 There are devices where the power loss is substantially proportional to I^2 and others that have substantially fixed losses, e.g. variable speed drive.

EXAMPLE A single compartment assembly with a rated current I_{nA} of 100 A (limited by the distribution busbars) is equipped with 20 outgoing circuits. The assumed group rated current I_{ng} for each circuit is 8 A. The total effective power loss should be calculated for 12 outgoing circuits loaded with 8 A each.

10.10.4.2 Single compartment assembly with natural cooling and rated current (I_{nA}) not exceeding 630 A

10.10.4.2.1 Verification method

~~Verification of the temperature rise of a single compartment ASSEMBLY with the total supply current not exceeding 630 A and for rated frequencies up to and including 60 Hz may be made by calculation if all the following conditions are fulfilled:~~

~~a) the power loss data for all built-in components is available from the component manufacturer;~~

~~b) there is an approximately even distribution of power losses inside the enclosure;~~

~~c) the rated current of the circuits of the ASSEMBLY to be verified (see 10.10.1) shall not exceed 80 % of the rated conventional free air thermal current (I_{th}) if any, or the rated current (I_n) of the switching devices and electrical components included in the circuit. Circuit protection devices shall be selected to ensure adequate protection to outgoing circuits, e.g. thermal motor protection devices at the calculated temperature in the ASSEMBLY;~~

~~NOTE 1 There is no common characteristic for switching devices and electrical components that describes the value of current to be used here. For the purpose of verifying the temperature rise limits the value of current is used, which describes the maximum continuous operational current that can be carried without overheating. This is e.g. for contactors the rated operational current I_e AC1 and for circuit breakers the rated current I_n.~~

~~d) the mechanical parts and the installed equipment are so arranged that air circulation is not significantly impeded;~~

~~e) conductors carrying currents in excess of 200 A, and the adjacent structural parts are so arranged that eddy-current and hysteresis losses are minimised;~~

~~f) all conductors shall have a minimum cross-sectional area based on 125 % of the permitted current rating of the associated circuit. Selection of cables shall be in accordance with IEC 60364-5-52. Examples on how to adapt this standard for conditions inside an ASSEMBLY are given in Annex H. The cross-section of bars shall be as tested or as given in Annex N. Where the device manufacturer specifies a conductor with a larger cross-sectional area this shall be used;~~

~~g) the temperature rise depending on the power loss installed in the enclosure for the different installation methods (e.g. flush mounting, surface mounting), is:~~

~~– available from the enclosure manufacturer;~~

~~– determined in accordance with 10.10.4.2.2; or~~

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– in accordance with performance and installation criteria from the cooling equipment manufacturer when active cooling (e.g. forced cooling, internal air conditioning, heat exchanger etc.) is incorporated.

The effective power losses of all circuits including interconnecting conductors shall be calculated based on rated current of the circuits. The total power loss of the ASSEMBLY is calculated by adding the power losses of the circuits taking additionally into account that the total load current is limited to the rated current of the ASSEMBLY. The power losses of the conductors are determined by calculation (see Annex H).

NOTE 2 There are devices where the power loss is substantially proportional to I^2 and others that have substantially fixed losses.

NOTE 3 Example: A single compartment ASSEMBLY with a rated current of 100 A (limited by the distribution bars) is equipped with 20 outgoing circuits. The assumed rated current for each circuit is 8 A. The total effective power loss should be calculated for 12 outgoing circuits loaded with 8 A each.

The temperature rise within the ASSEMBLY is then determined from the total power loss using the data mentioned in g).

Verification of the temperature-rise may be made by calculation if all the general conditions listed in 10.10.4.1 are fulfilled, and using the following:

a) The air temperature-rise within the enclosure at a given power loss in the enclosure, for the applicable installation method being considered (e.g. flush mounting, surface mounting) is:
   – available from the enclosure manufacturer, or
   – determined in accordance with 10.10.4.2.2.
b) The total power loss within the enclosure is calculated as detailed in 10.10.4.1.

   The maximum permissible air temperature-rise within the enclosure is determined by the device with the lowest maximum operating air temperature and is taken as the maximum operating temperature of that device minus the daily average ambient air temperature (outside the enclosure).

   When electronic devices with integral forced ventilation are incorporated, the enclosure shall be considered as having no natural ventilation, irrespective of whether or not openings exist in the enclosure.

10.10.4.2.2 Determination of the power loss capability of an enclosure by test

The power loss shall be simulated by means of heating resistors that produce heat equivalent to the intended power loss capability of the enclosure. The heating resistors shall be distributed evenly over the height of the enclosure and installed in suitable places inside the enclosure.

The cross-section of the leads to these resistors shall be such that no appreciable amount of heat is conducted away from the enclosure.

The test shall be carried out in accordance with 10.10.2.3.1 to 10.10.2.3.4 and the air temperature rise shall be measured in the top of the enclosure. Enclosure temperatures shall not exceed the values given in Table 6.

The power loss shall be simulated by means of heating resistors that produce heat equivalent to the intended power loss capability of the enclosure. The heating resistors shall be distributed evenly over the height of the enclosure and installed in suitable places inside the enclosure.

The cross-section of the leads to these resistors shall be such that no appreciable amount of heat is conducted away from the enclosure.

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The test shall be carried out in accordance with 10.10.2.3.1 to 10.10.2.3.4 and the air temperature-rise shall be measured in the top of the enclosure. Enclosure temperatures shall not exceed the values given in Table 6.

10.10.4.2.3 Results to be obtained

~~The ASSEMBLY is verified if the air temperature determined from the calculated power loss does not exceed the permissible operating air temperature as declared by the device manufacturer. This means for switching devices or electrical components in the main circuits that the continuous load does not exceed its permissible load at the calculated air temperature and not more than 80 % of its rated current (see 10.10.4.2.1 c).~~

The assembly is verified if:

– the enclosure is capable of dissipating power losses equal to or greater than those generated by the assembly at the maximum permissible air temperature-rise within the enclosure;

– all conductors within the assembly have been selected to operate at the maximum permitted air temperature within the assembly.

10.10.4.3 ASSEMBLY with natural cooling and rated current (I_{nA}) not exceeding 1 600 A

10.10.4.3.1 Verification method

~~Verification of the temperature-rise of a single or multiple compartment ASSEMBLY with the total supply current not exceeding 1 600 A and for rated frequencies up to and including 60 Hz, may be made by calculation in accordance with the method of IEC 60890 if all the following conditions are fulfilled:~~

~~a) the power loss data for all built-in components is available from the component manufacturer;~~

~~b) there is an approximately even distribution of power losses inside the enclosure;~~

~~c) the rated current of the circuits of the ASSEMBLY to be verified (see 10.10.1) shall not exceed 80 % of the rated conventional free air thermal current (I_{th}) if any, or the rated current (I_n) of the switching devices and electrical components included in the circuit. Circuit protection devices shall be selected to ensure adequate protection to outgoing circuits, e.g. thermal -motor protection devices at the calculated temperature in the ASSEMBLY;~~

~~NOTE 1 There is no common characteristic for switching devices and electrical components that describes the value of current to be used here. For the purpose of verifying the temperature rise limits the value of current is used, which describes the maximum continuous operational current that can be carried without overheating. This is e.g. for contactors the rated operational current I_e AC1 and for circuit breakers the rated current I_n.~~

~~d) the mechanical parts and the installed equipment are so arranged that air circulation is not significantly impeded;~~

~~e) conductors carrying currents in excess of 200 A, and the adjacent structural parts are so arranged that eddy-current and hysteresis losses are minimised;~~

~~f) all conductors shall have a minimum cross-sectional area based on 125 % of the permitted current rating of the associated circuit. Selection of cables shall be in accordance with IEC 60364-5-52. Examples on how to adapt this standard for conditions inside an ASSEMBLY are given in Annex H. The cross-section of bars shall be as tested or as given in Annex N. Where the device manufacturer specifies a conductor with a larger cross-sectional area this shall be used;~~

~~g) for enclosures with natural ventilation, the cross-section of the air outlet openings is at least 1,1 times the cross section of the air inlet openings;~~

~~h) there are no more than three horizontal partitions in the ASSEMBLY or a section of an ASSEMBLY;~~

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~~i) for enclosures with compartments and natural ventilation the cross section of the ventilating openings in each horizontal partition is at least 50 % of the horizontal cross section of the compartment.~~

~~The effective power losses of all circuits including interconnecting conductors shall be calculated based on rated current of the circuits. The total power loss of the ASSEMBLY is calculated by adding the power losses of the circuits taking additionally into account that the total load current is limited to the rated current of the ASSEMBLY. The power losses of the conductors are determined by calculation (see Annex H).~~

~~NOTE 2 There are devices where are the power loss is substantially proportional to I^2 and others that have substantially fixed losses.~~

~~NOTE 3 Example: A single compartment ASSEMBLY with a rated current of 100 A (limited by the distribution bars) is equipped with 20 outgoing circuits. The assumed rated current for each circuit is 8 A. The total effective power loss should be calculated for 12 outgoing circuits loaded with 8 A each.~~

~~The temperature rise within the ASSEMBLY is then determined from the total power loss using the method of IEC 60890.~~

Verification of the temperature-rise may be made by calculation in accordance with the method of IEC TR 60890:2014 providing the additional requirements of 10.10.4.1 are fulfilled.

The air temperature-rise within the assembly is then determined from the total power loss using the method of IEC TR 60890:2014.

The air temperature within the assembly is calculated by adding this air temperature-rise and the daily average ambient air temperature of the assembly. When electronic devices with integral forced ventilation are incorporated, the enclosure shall be considered as having no natural ventilation, irrespective of whether or not openings exist in the enclosure.

NOTE Natural ventilation is by means of air flow into and out of the enclosure without forced ventilation.

10.10.4.3.2 Results to be obtained

~~The ASSEMBLY is verified if the calculated air temperature at the mounting height of any device does not exceed the permissible ambient air temperature as declared by the device manufacturer.~~

~~This means for switching devices or electrical components in the main circuits that the continuous load does not exceed its permissible load at the calculated local air temperature and not more than 80 % of its rated current (see 10.10.4.3.1 c).~~

The assembly is verified if the calculated air temperature at the mounting height of any built-in component (devices, conductors, etc.) does not exceed the permissible operating air temperatures of the built-in components as declared by their manufacturers.

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

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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 ~~an already tested~~ 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 ~~recorded~~ 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.

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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 ~~– General~~

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 ~~(see also IEC 60038)~~ 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 ~~phase~~ 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 ~~± 10 %~~ ± 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 ~~may~~ 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 ~~may~~ 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.

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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:~~2007~~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 and,~~

~~a) for a time sufficiently long to enable the short-circuit protective device in the outgoing unit to operate to clear the fault and, in any case, for not less than 10 cycles (test voltage duration), or~~

~~b) in cases where the outgoing circuit does not include a SCPD, for a magnitude and duration as specified for the busbars by the original manufacturer. Testing of outgoing circuits may also result in the operation of the incoming circuit SCPD.~~

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

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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~~, if any~~, 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 ~~phase~~ line conductor of the circuit under test including any joints. ~~Phase~~ 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 ~~phase~~ 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 ~~phase~~ line current and if the neutral conductor is:

– the same shape and cross-section as the ~~phase~~ line conductors;
– supported in an identical manner as the ~~phase~~ 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 ~~phase~~ 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:

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– 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 ~~assigned~~.

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 the average of the r.m.s. values of the a.c. component in all phases. When making the tests at maximum operational voltage, the calibration current in each phase shall be equal to the rated short-circuit current within a % tolerance and the power factor shall be within a tolerance.~~

~~All tests shall be made at the rated frequency of the assembly with a tolerance of ± 25 %, and at the power factor appropriate to the short-circuit current in accordance with Table 7.~~

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

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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.

~~NOTE In South Africa (ZA) National Electrical Code SANS 10142-1, Subclause 6.8, requires that the supply voltage be equal to 1,1 times the nominal voltage where the rated operational voltage is up to and including 500 V.~~

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 case of test station difficulty of making~~ 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 ~~the protective~~ a contact arrangement (e.g. within a switching device~~, if any,~~ 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 ~~three cycles~~ 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 ~~insulator or~~ support or cable restraint ~~has~~ 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.

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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 ~~dielectric~~ 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.

~~The fusible element (see 10.11.5.2.), if any, shall not indicate a fault current.~~

In case of any doubt, it shall be checked that the ~~apparatus~~ equipment incorporated in the assembly ~~are~~ is in a condition as prescribed in the relevant ~~specifications~~ 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 ~~phase~~ 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 ~~phase~~ line current during the three-phase test of the assembly.

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~~NOTE In South Africa (ZA) National Electrical Code SANS 10142-1, Subclause 6.8, requires that the supply voltage be equal to 1,1 times the nominal voltage where the rated operational voltage is up to and including 500 V.~~

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.

~~NOTE 1~~ 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 ~~2~~ 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.

~~10.13 Mechanical operation~~

~~This verification test shall not be made on such devices (e.g. withdrawable circuit-breaker) of the ASSEMBLY which have already been type tested according to their relevant product standard unless their mechanical operation has been modified by their mounting.~~

~~For parts, which need verification by test (see 8.1.5), satisfactory mechanical operation shall be verified after installation in the ASSEMBLY. The number of operating cycles shall be 200.~~

~~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, specified degree of protection etc., have not been impaired and if the effort required for operation is practically the same as before the test.~~

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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. ~~Where appropriate,~~ Routine verification shall confirm that ~~design verification is available~~ 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 ~~the instructions of the device manufacturer~~ 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 ~~are maintained~~.

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.

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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 ~~visual~~ inspection to ascertain that the measures prescribed in ~~8.4.3~~ 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 ~~250 A~~ 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.

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In this case, the test is satisfactory if the insulation resistance between circuits and exposed-conductive-parts is at least ~~1 000 Ω/V per circuit referred to the supply voltage to earth of these circuits~~ 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.

~~NOTE~~ In some cases, it may be necessary to make or repeat this test on site before putting the installation into operation.

Table 1 – Minimum clearances in air [a] (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.	

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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	[a]
1 000	3,2	5	7,1	10	12,5	14	16	
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~~, method~~ 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

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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 mm^2
$I_e \leq 20$	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 ~~phase~~ line conductor (mm^2).	

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 ~~maximum~~ 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. ~~These conductors~~ 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.	

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Table 5 – Minimum terminal capacity for copper protective conductors (PE~~, PEN~~) (8.8)

Cross-sectional area of ~~phase~~ line conductors, S mm^2	Minimum cross-sectional area of the corresponding protective conductor (PE~~, PEN~~), S_p [a] mm^2
$S \leq 16$	S
$16 < S \leq 35$	16
$35 < S \leq 400$	$S/2$
$400 < S \leq 800$	200
$800 < S$	$S/4$

~~[a] Current in the neutral may be influenced where there are significant harmonics in the load. See 8.6.1.~~

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]

~~NOTE 1 The 105 K relates to The temperature above which annealing of copper is likely to occur. Other materials may have a different maximum temperature rise.~~

~~NOTE 2~~ The temperature rise limits given in this table apply for a ~~mean~~ 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).

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[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 ~~infrequently~~ while the assembly is in normal service, are ~~allowed~~ permitted to ~~assume~~ 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 ~~taking~~. 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 ~~bare~~ 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**
$I \leq 5$	0,7	1,5
$5 < I \leq 10$	0,5	1,7
$10 < I \leq 20$	0,3	2,0
$20 < I \leq 50$	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.

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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 [b] DC V
$U_i \leq 60$	1 000	1 415
$60 < U_i \leq 300$	1 500	2 120
$300 < U_i \leq 690$	1 890	2 670
$690 < U_i \leq 800$	2 000	2 830
$800 < U_i \leq 1\,000$	2 200	3 110
$1\,000 < U_i \leq 1\,500$[a]	2 700	3 820

[a] For DC only.

[b] ~~Test voltages based on 6.1.3.4.1, fifth paragraph, of IEC 60664-1.~~

Table 9 – Power-frequency withstand voltage for auxiliary ~~and control~~ circuits (10.9.2)

Rated insulation voltage, U_i (line to line) V	Dielectric test voltage AC RMS V	Dielectric test voltage DC V
$U_i \leq 12$	250	355
$12 < U_i \leq 60$	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

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Table 11 – Copper test conductors for rated currents up to 400 A inclusive (10.10.2.3.2)

Range of rated current[a]		Conductor cross-sectional area[b,c]	
A		mm^2	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.

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Table 12 – Copper test conductors for rated currents from 400 A to ~~4 000~~ 7 000 A (10.10.2.3.2)

Range of rated current[a] A	Test conductors[c]			
	Cables[c]		Copper bars[b]	
	Quantity	Cross-sectional area mm^2	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.

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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 ~~connections~~ 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 ~~connections~~ conductors of each circuit of the assembly to be assessed greater than or equal to those of the reference design?		
4	Are the busbar ~~supports~~ 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 ~~supports~~ 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 seriesa with the same or better limitation characteristics (I2t, Ipk) based on the device manufacturer's data, and with the same arrangement as the reference design?~~ 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. ~~breaking capacity and~~ limitation characteristics (I^2t, ~~I_{pk}~~ I_{lt}), and critical distances.			

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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.

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Annex A
(normative)

Minimum and maximum cross-section of copper ~~conductors~~ cables suitable for connection to terminals for external ~~conductors~~ 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 ~~conductors~~ cables suitable for connection to terminals for external ~~conductors~~ cables

Rated current	Solid or stranded ~~conductors~~ cables		Flexible ~~conductors~~ 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

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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 ~~conductors~~ 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 (mm^2);

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.

~~NOTE k is the factor dependent on the material of the protective conductor, the insulation and other parts and the initial and final temperatures, see Table B.1.~~

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**
~~Final temperature~~ 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.

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Annex C
(informative)

User information template

~~This annex~~ Table C.1 is intended as a template for the identification of items necessary for the assembly manufacturer which is to be provided by the user.

It is intended to be used and developed in the relevant assembly standards.

Table C.1 – User information template

Characteristics	Referencee	Default arrangement[a]	Options listed in this document[b]	User requirement ~~a~~[c]
Electrical system				
~~Earthing~~ Type of system earthing	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 1000 V AC or 1500 V DC	
Transient overvoltages	5.2.4, 8.5.3, 9.1, Annex G	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, 10.10.3.1, 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 conductor	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	
Coordination 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	
Protection ~~of persons~~ against electric shock in accordance with IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017				
Type of protection against electric shock – Basic protection (previously protection against direct contact)	8.4.2	Basic protection	According to local installation regulations	

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Characteristics	Referencee	Default arrangement[a]	Options listed in this document[b]	User requirement ~~a~~[c]
Type of protection against electric shock – Fault protection (previously protection against indirect contact)	8.4.3	According to local installation conditions	Automatic disconnection of supply / Electrical separation / ~~Total~~ Double or reinforced insulation	
Installation environment				
Location type	3.5, 8.1.4, 8.2	Manufacturer's standard, according to application	Indoor / outdoor	
Protection against ingress of solid foreign bodies and ingress of water	8.2.2, 8.2.3	Indoor (enclosed): IP2X Outdoor (min.): IP23	~~IP 00, 2X, 3X, 4X, 5X, 6X~~ After removal of removable parts: As for connected position / Reduced protection to manufacturer's standard	
External mechanical impact (IK code)	8.2.1, 10.2.6	None	None	
Resistance to UV radiation (applies for outdoor assemblies only unless specified otherwise)	10.2.4	Indoor: Not applicable. Outdoor: Temperate climate	None	
Resistance to corrosion	10.2.2	Normal Indoor/Outdoor arrangements	None	
Ambient air temperature – Lower limit	7.1.1	Indoor: −5 °C Outdoor: −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	7.1.1	Indoor: ~~50~~ 95 % at ~~40~~ −5°C to +30 °C 70 % at +35 °C 57 % at +40 °C Outdoor: 100 % at −25 °C to +27 °C 60 % at 35 °C 46 % at 40 °C	None	
Pollution degree of the macro-environment (of the installation environment)	7.1.2	Industrial: 3	1, 2, 3, 4	
Altitude	7.1.1	≤ 2000 m	None	
EMC environment (A or B)	9.4, 10.12, Annex J	A/B	A/B	

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Characteristics	Referencee	Default arrangement[a]	Options listed in this document[b]	User requirement [a]c
Special service conditions (e.g. vibration, exceptional condensation, heavy pollution, corrosive environment, 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	
Installation method				
Type	3.3, 5.6	Manufacturer's standard	Various, e.g. floor-standing / wall-mounted	
Stationary/Movable	3.5	Stationary	Stationary / movable	
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~~ line conductor, cross-sections, and terminations	8.8	As defined within the standard	None	
External ~~PE, N~~ protective, neutral, mid-point, PEL, PEM, PEN conductor 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		Authorized persons / Ordinary persons	
Location of manually operated devices	8.5.5	Easily accessible	None	
Isolation of load installation equipment items	8.4.2, 8.4.3.3, 8.4.6.2	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 assembly is energized	8.4.6.1	Basic protection	None	
Requirements related to accessibility for inspection and similar operations	8.4.6.2.2	No requirements for accessibility	None	

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Characteristics	Referencee	Default arrangement[a]	Options listed in this document[b]	User requirement ~~a~~c
Requirements related to accessibility for maintenance in service by authorized persons	8.4.6.2.3	No requirements for accessibility	None	
Requirements related to accessibility for extension in service by authorized persons	8.4.6.2.4	No requirements for accessibility	None	
Method of functional unit's connection	8.5.1, 8.5.2	Manufacturer's standard	None	
Protection against direct contact 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	
Current carrying ~~capability~~ capacity				
Maximum total load current to be supplied by the assembly (from which the rated current of the assembly I_{nA} (A) will be determined)	3.8.10.1, 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} (amps)~~	~~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 ASSEMBLY~~	
Design current I_B and nature of load for each circuit; alternatively, I_n of the devices and nature of the load (in such cases, the assumed loading factors can be used based on the relevant part of IEC 61439)	3.8.10.8	None	None	
Ratio of cross-section of the neutral conductor to ~~phase~~ line conductors: ~~phase~~ line conductors up to and including 16 mm^2	8.6.1	100 %	None	
Ratio of cross-section of the neutral conductor to ~~phase~~ line conductors: ~~phase~~ line conductors above 16 mm^2	8.6.1	50 % (min. 16 mm^2)	None	

[a] In some cases, information declared by the assembly manufacturer may take the place of an agreement.

[b] "None" in this column means that there are no options in the standard other than the default condition or value.

[c] For exceptionally onerous applications, the user may need to specify more stringent requirements to those in the document.

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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	YES
	Resistance to ultra-violet (UV) radiation	10.2.4	YES	NO	YES
	Lifting	10.2.5	YES	NO	NO
	Mechanical impact	10.2.6	YES	NO	NO
	Marking	10.2.7	YES	NO	NO
2	Degree of protection of enclosures	10.3	YES	NO	YES
3	Clearances	10.4	YES	NO	NO
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 ASSEMBLY and the protective circuit	10.5.2	YES	NO	NO
	Short-circuit withstand strength of the protective circuit	10.5.3	YES	YES	NO
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	YES
10	Temperature-rise limits	10.10	YES	YES	YES
11	Short-circuit withstand strength	10.11	YES	YES	NO
12	Electromagnetic compatibility (EMC)	10.12	YES	NO	YES

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~~13~~	~~Mechanical operation~~	~~10.13~~	~~YES~~	~~NO~~	~~NO~~

No.	Characteristic to be verified	Subclauses	Verification options available		
			Testing[a]	Comparison with a reference design	Assessment
1	Strength of material and parts:	10.2			
	Resistance to corrosion	10.2.2	YES	YES	NO
	Properties of insulating materials:	10.2.3			
	Thermal stability	10.2.3.1	YES	YES	NO
	Resistance to abnormal heat and fire due to internal electric effects	10.2.3.2	YES	YES	YES
	Resistance to ultra-violet (UV) radiation	10.2.4	YES	YES	YES
	Lifting	10.2.5	YES	YES	NO
	Mechanical impact (IK)	10.2.6	YES	YES	NO
	Marking	10.2.7	YES	YES	NO
	Mechanical operation	10.2.8	YES	YES	NO
2	Degree of protection of enclosures (IP)	10.3	YES	NO	YES
3	Clearances	10.4	YES	NO	NO
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 a class I assembly and the protective circuit	10.5.2	YES	NO	NO
	Short-circuit withstand strength of the protective circuit	10.5.3	YES	YES	NO
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	YES
	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	YES
11	Short-circuit withstand strength	10.11	YES	YES	NO
12	Electromagnetic compatibility (EMC)	10.12	YES	NO	YES

[a] Testing may be on representative sample if permitted in the appropriate test clause.

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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 ~~all the outgoing circuits, or a group of~~ 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 of an ASSEMBLY~~

~~The rated diversity factor of an ASSEMBLY is specified in 5.4. For the typical ASSEMBLY shown in Figure E.1, examples of the multitude of loading arrangements for a diversity factor of 0,8 are given in Table E.1 and shown in Figures E.2 to E.5.~~

~~E.3 Rated diversity factor of a group of outgoing circuits~~

~~In addition to stating the rated diversity factor for a complete ASSEMBLY, an ASSEMBLY manufacturer may specify a different diversity factor for a group of related circuits within an ASSEMBLY. Subclause 5.4 specifies the rated diversity factor for a group of outgoing circuits.~~

~~Tables E.2 and E.3 give examples of a diversity factor of 0,9 for a section and subdistribution board within the typical ASSEMBLY shown in Figure E.1.~~

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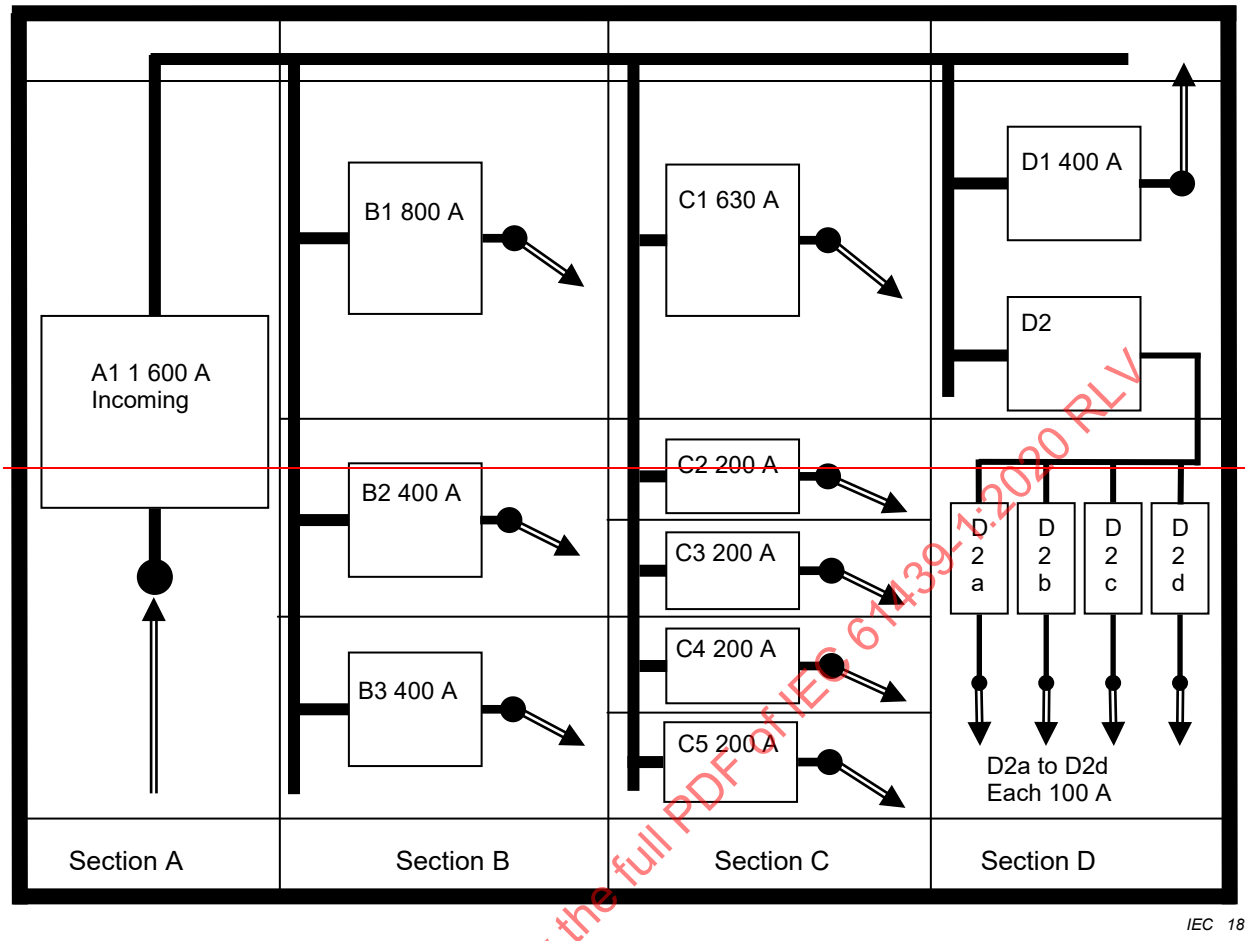

~~Functional unit – Rated current (I_n) shown~~ [a]

[a] ~~The rated current of the functional unit (the circuit) in the ASSEMBLY may be less than the rated current of the device.~~

~~Figure E.1 – Typical ASSEMBLY~~

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Table E.1 – Examples of loading for an ASSEMBLY with a rated diversity factor of 0,8

Functional unit		A1	B1	B2	B3	C1	C2	C3	C4	C5	D1	D2a	D2b	D2c	D2d
		Current (A)													
Functional unit - rated current (I_n) [b] **(See Figure E.1)**		1 600	800	400	400	630	200	200	200	200	400	100	100	100	100
Functional unit loading for an ASSEMBLY with a rated diversity factor of 0,8	Example 1 Figure E.2	1 600	640	320	320	0	160	160	0	0	0	0	0	0	0
	Example 2 Figure E.3	1 600	640	0	0	504	136[a]	0	0	0	320	0	0	0	0
	Example 3 Figure E.4	1 600	456[a]	0	0	504	160	160	160	160	0	0	0	0	0
	Example 4 Figure E.5	1 600	0	0	0	504	160	160	136[a]	0	320	80	80	80	80

[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.

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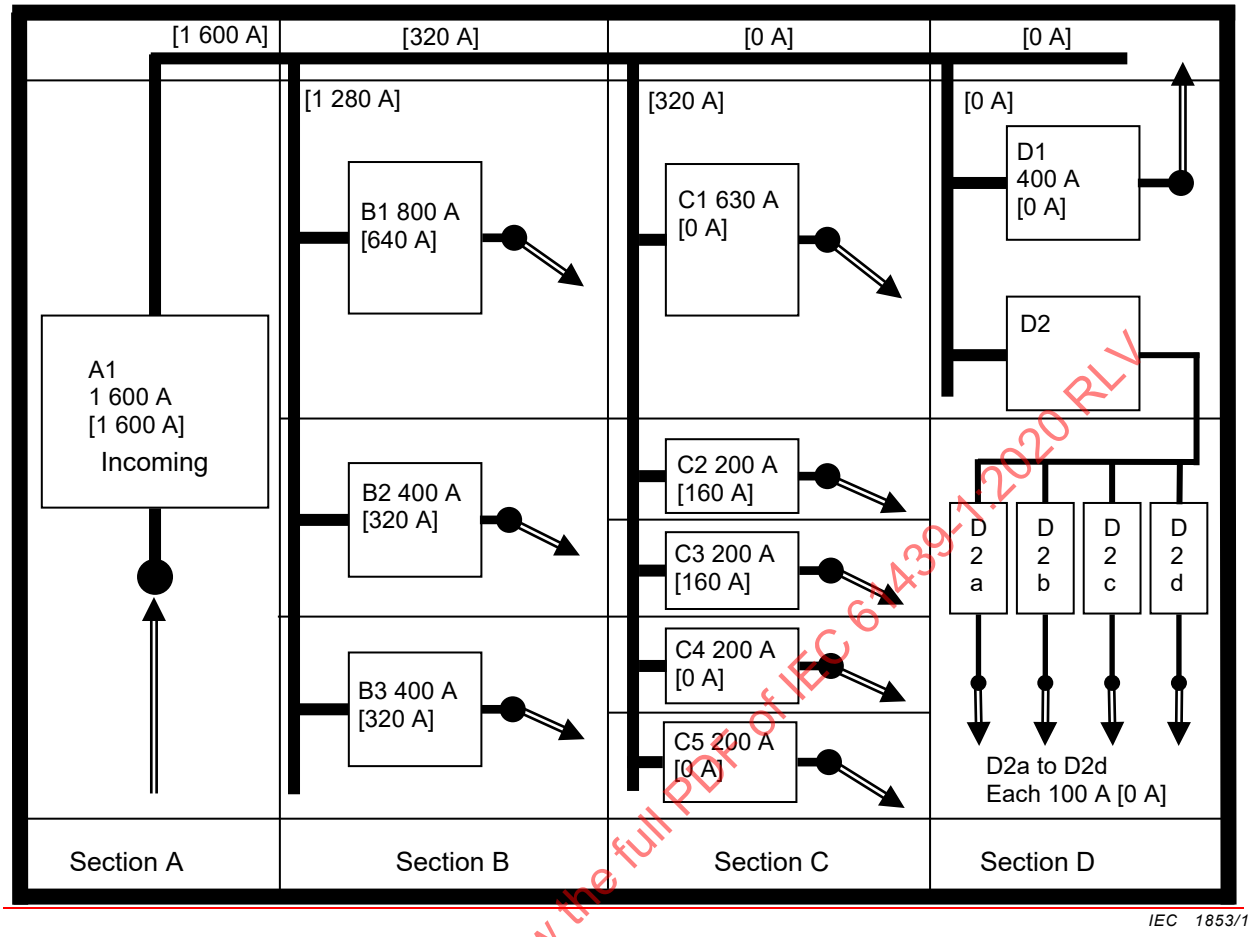

~~Actual loading is indicated by the figures in brackets e.g. [640 A].~~
~~Busbar section loading is indicated by the figure in brackets e.g. [320 A].~~

~~Figure E.2 – Example 1: Table E.1 – Functional unit loading for an ASSEMBLY with a rated diversity factor of 0,8~~

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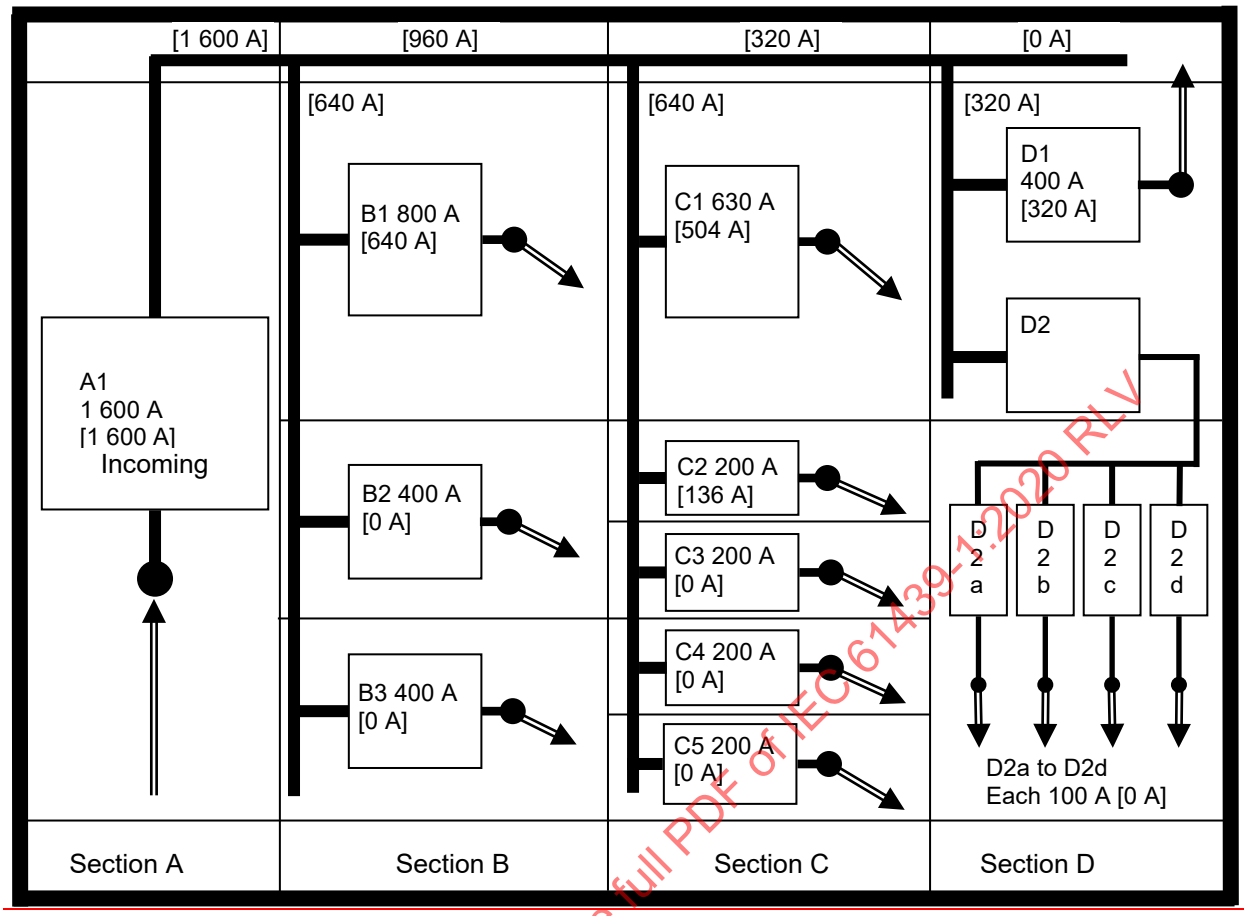

IEC 1854/11

~~Actual loading is indicated by the figures in brackets e.g. [640 A].~~
~~Busbar section loading is indicated by the figure in brackets e.g. [320 A].~~

~~Figure E.3 – Example 2: Table E.1 – Functional unit loading for an ASSEMBLY with a rated diversity factor of 0,8~~

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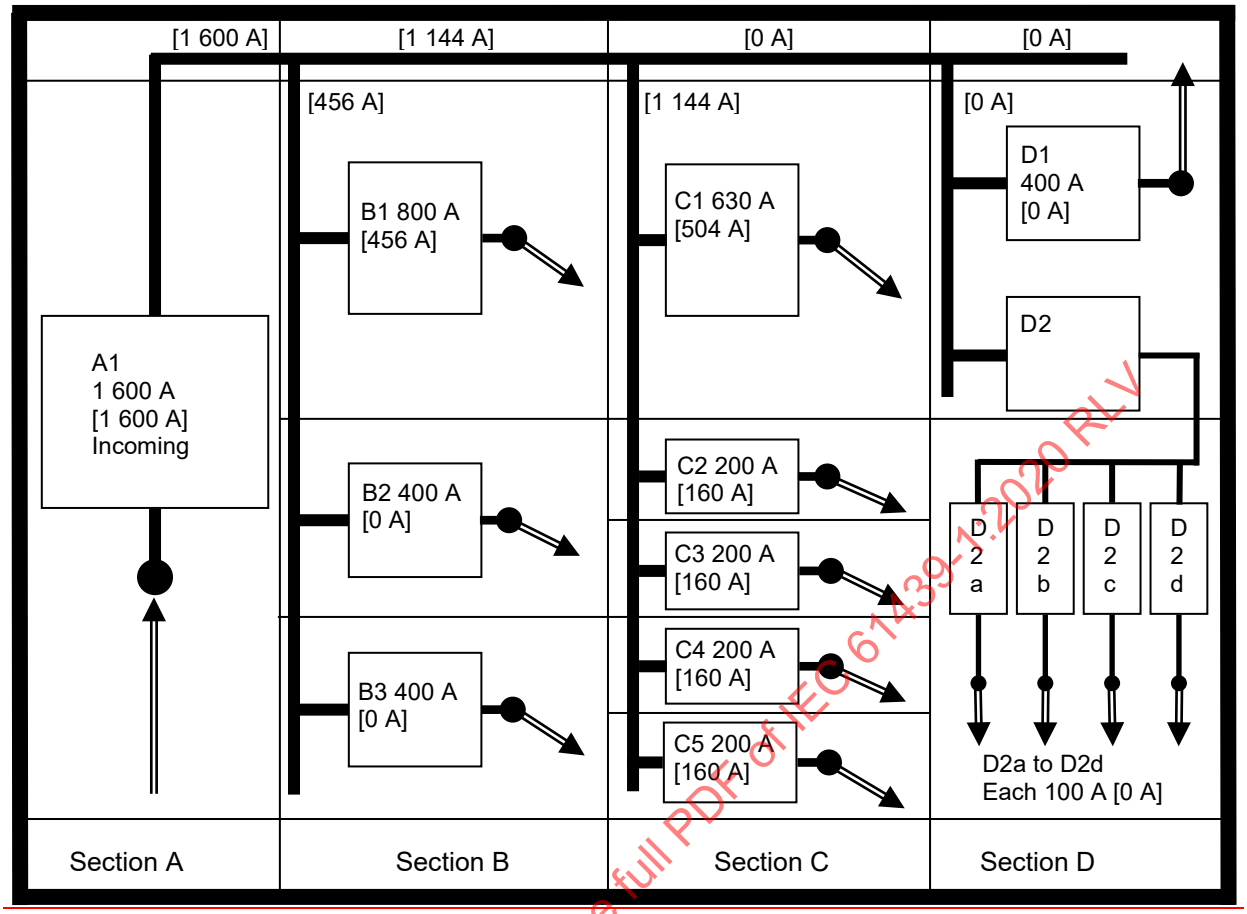

~~Actual loading is indicated by the figures in brackets e.g. [640 A].~~
~~Busbar section loading is indicated by the figure in brackets e.g. [320 A].~~

~~Figure E.4 – Example 3: Table E.1 – Functional unit loading for an ASSEMBLY with a rated diversity factor of 0,8~~

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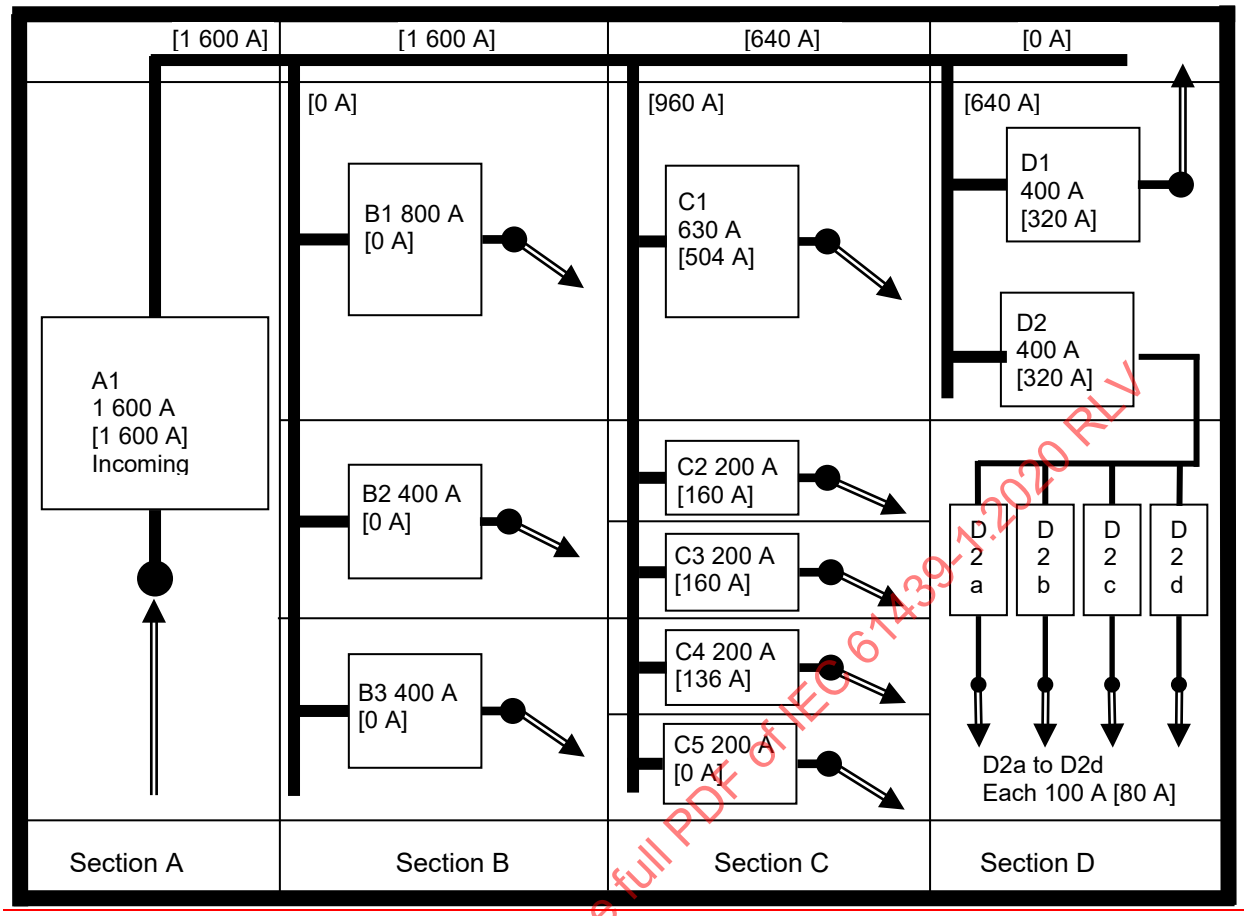

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~~Actual loading is indicated by the figures in brackets e.g. [640 A].~~
~~Busbar section loading is indicated by the figure in brackets e.g. [320 A].~~

~~Figure E.5 – Example 4: Table E.1 – Functional unit loading for an ASSEMBLY with a rated diversity factor of 0,8~~

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Table E.2 – Example of loading of a group of circuits (Section B – Figure E.1) with a rated diversity factor of 0,9

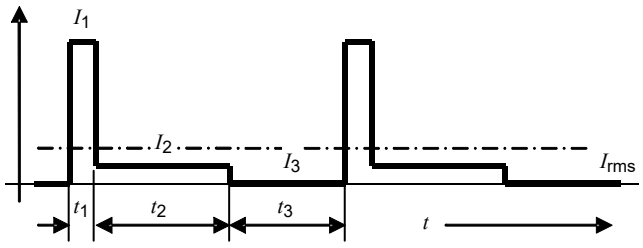
Functional unit	Distribution busbar Section B	B1	B2	B3
	Current (A)			
Functional unit – Rated current (I_n)	1 440 [a]	800	400	400
Loading – Group of circuits with a rated diversity factor of 0,9	1 440	720	360	360
[a] Minimum rated current to supply the connected functional units at the RDF (0,9).				

Table E.3 – Example of loading of a group of circuits (Sub-distribution board – Figure E.1) with a rated diversity factor of 0,9

Functional unit	D2	D2a	D2b	D2c	D2d
	Current (A)				
Functional unit – Rated current (I_n)	360 [a]	100	100	100	100
Loading – Group of circuits with a rated diversity factor of 0,9	360	90	90	90	90
[a] Minimum rated current to supply the connected functional units at the RDF (0,9).					

E.4 Rated diversity factor and intermittent duty

The dissipated heat of circuits built from components with Joule losses is proportional to the true r.m.s value of the current. An equivalent r.m.s current representing the thermal effect of the real intermittent current can be calculated by the formula given below. This enables the thermal equivalent true r.m.s current (I_{eff}) in case of intermittent duty to be determined and thus the permissible load pattern for a given RDF. Care should be taken with ON-times > 30 min since small devices could already reach the thermal equilibrium.



$$I_{rms} = \sqrt{\frac{I_1^2 \times t_1 + I_2^2 \times t_2 + I_3^2 \times t_3}{t_1 + t_2 + t_3}}$$

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

IEC 1857/11

Figure E.6 – Example of average heating effect calculation

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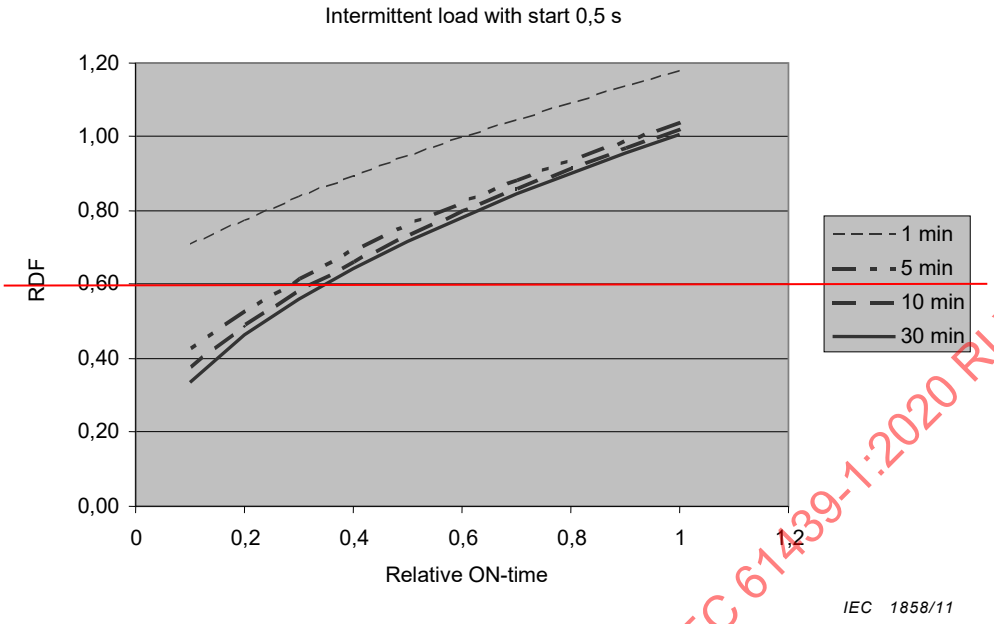
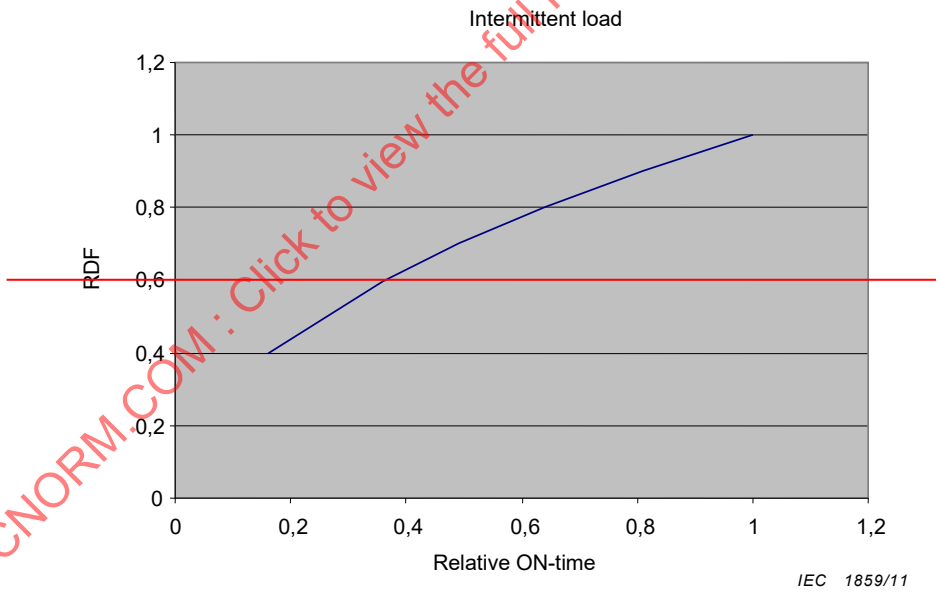


~~**Figure E.7 – Example graph for the relation between the equivalent RDF and the parameters at intermittent duty at t_1 = 0,5 s, I_1 = 7*I_2 at different cycle times**~~



~~**Figure E.8 – Example graph for the relation between the equivalent RDF and the parameters at intermittent duty at I_1 = I_2 (no starting overcurrent)**~~

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.

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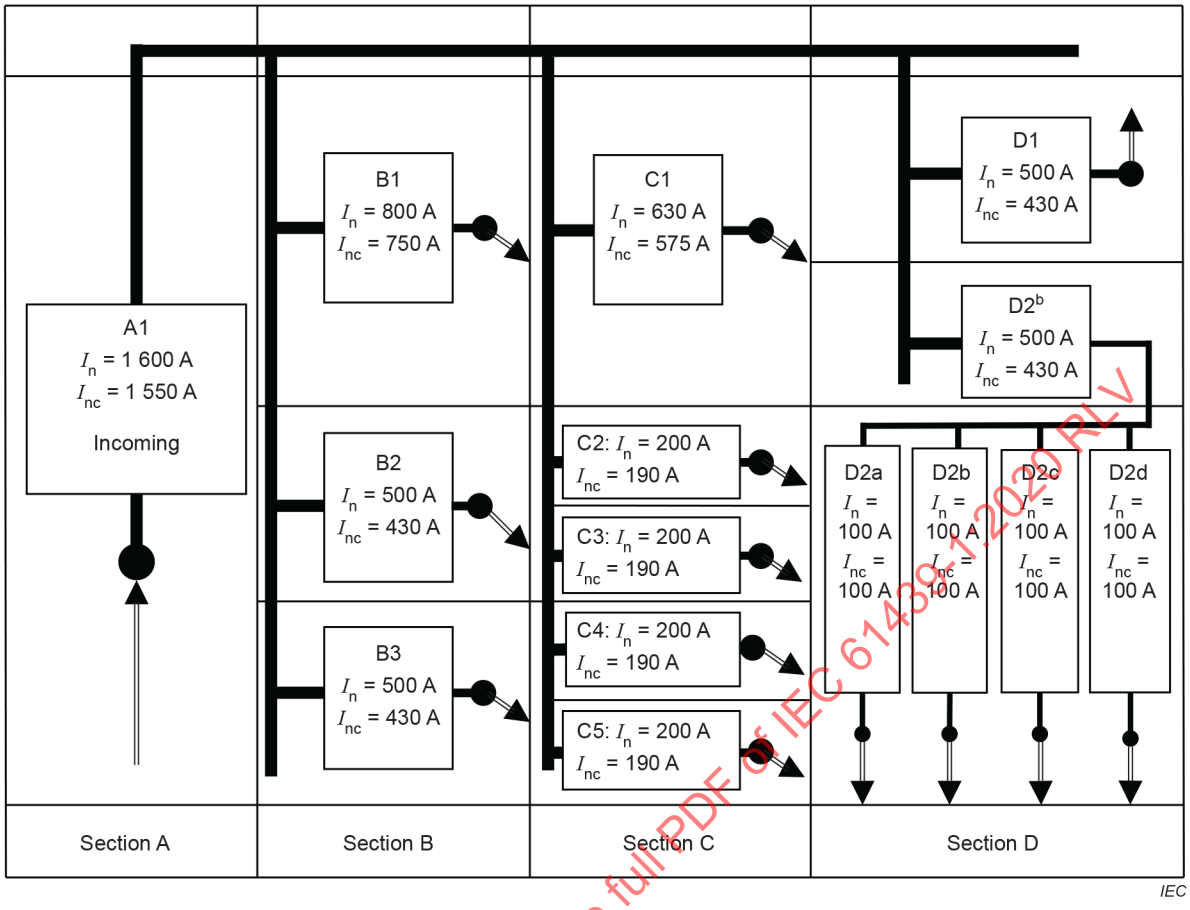

For each functional unit (A1, B1, etc.) the rated current of a circuit (I_{nc}) is shown. [a]

[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

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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.

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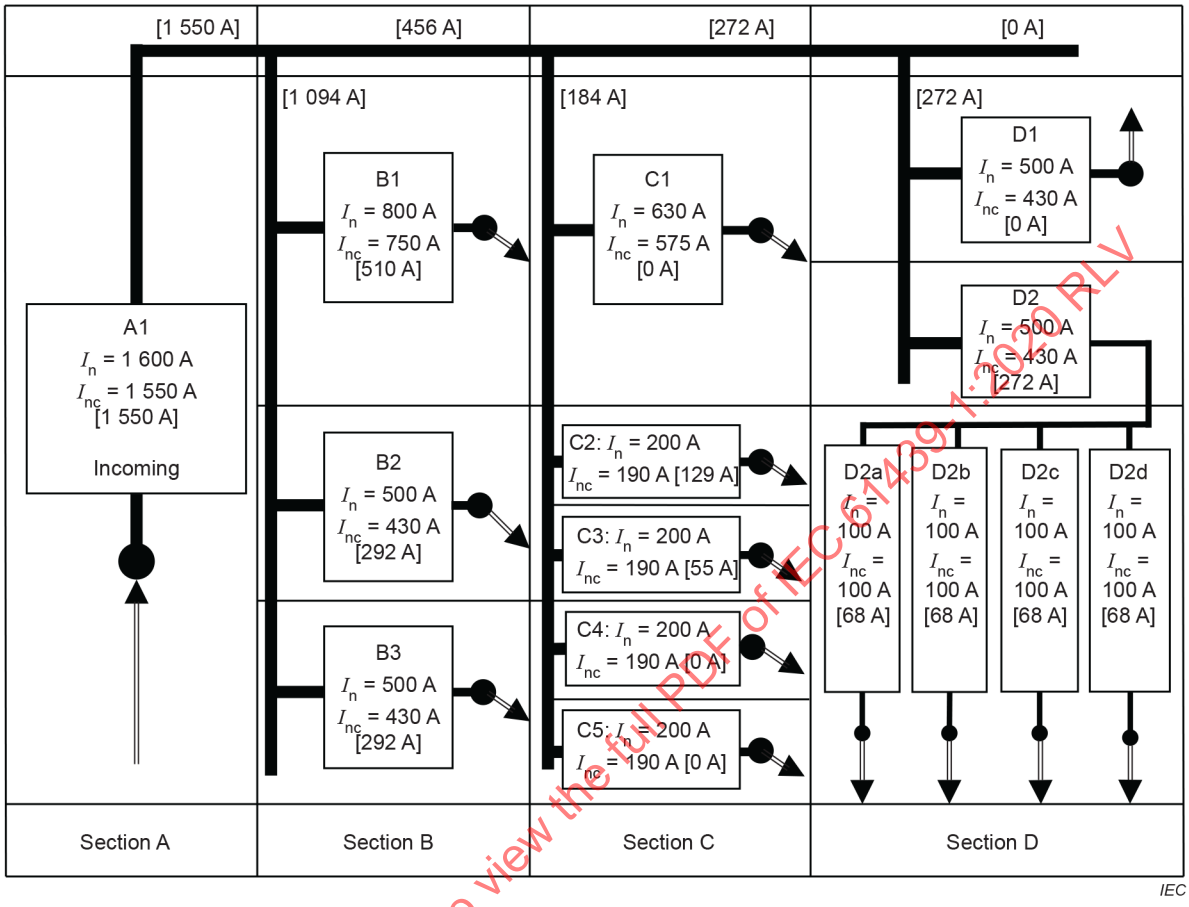
E.2.2 Example of an assembly with an RDF of 0,68

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. [1 094 A].

Figure E.2 – Example 1: Table E.1 – Functional unit loading for an assembly with a rated diversity factor of 0,68

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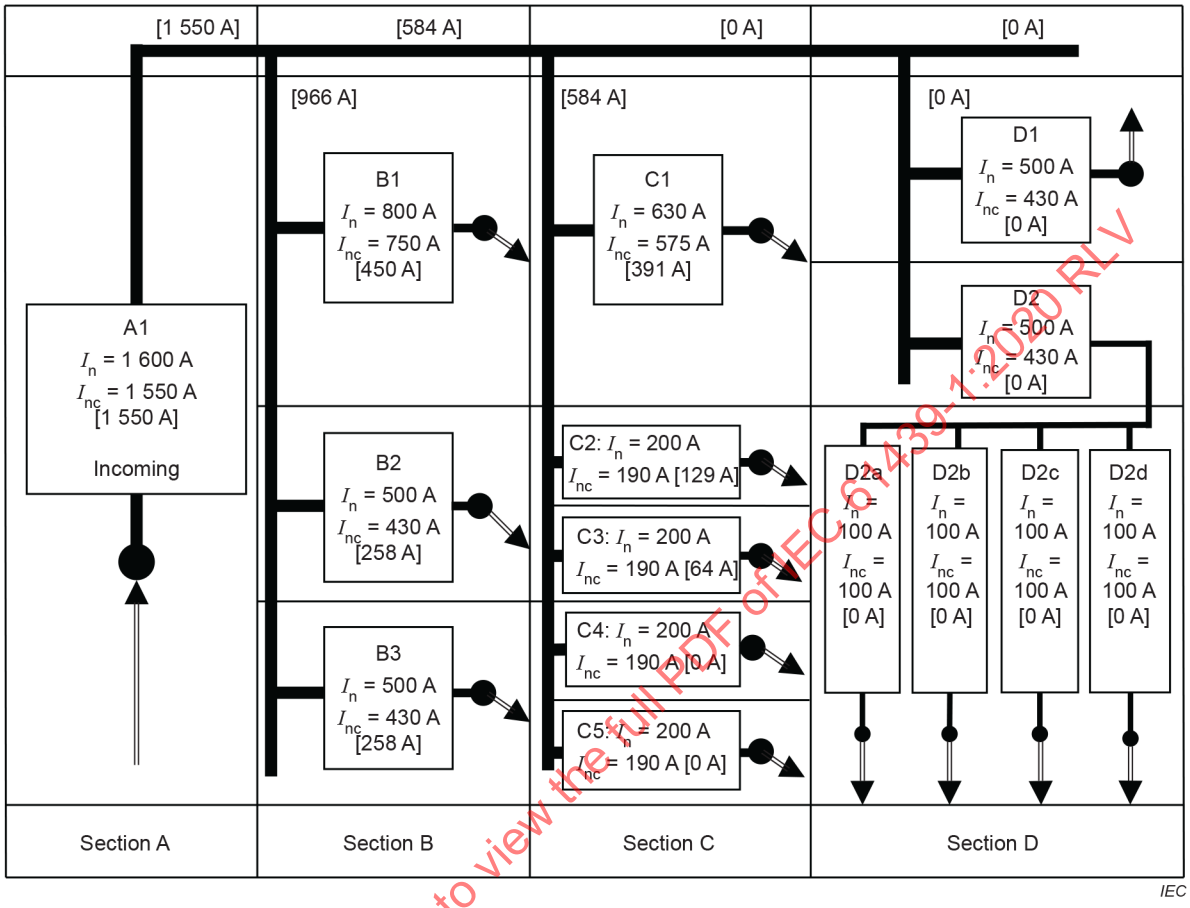
E.2.3 Example of an assembly with RDF declared for each section

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

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Annex F
(normative)

Measurement of clearances and creepage distances [11]

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).

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11 Annex F is based on IEC TR 60664-2-1:~~2007~~2011.

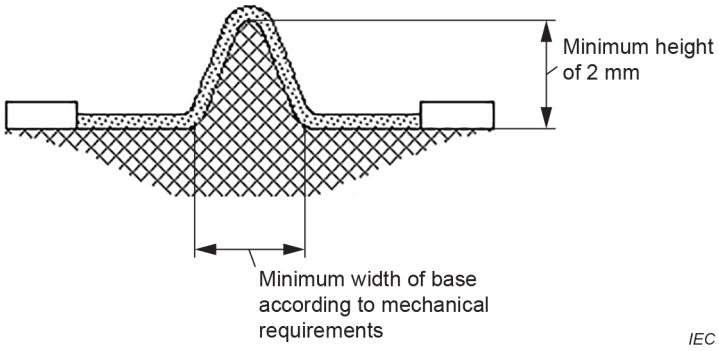
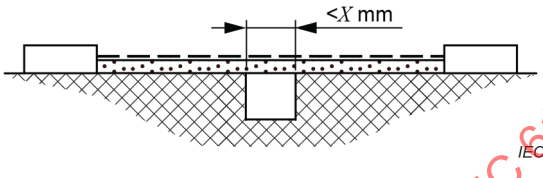
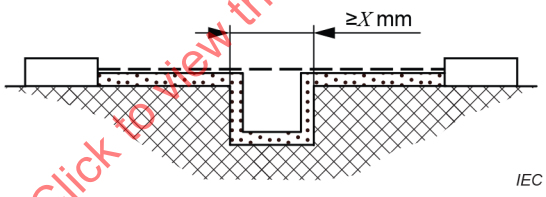


Figure F.1 a) – Measurement of ribs: examples



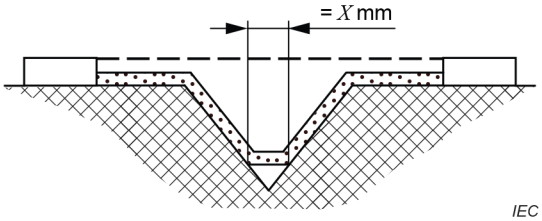
Condition:	This creepage distance path includes a parallel- or converging-sided groove of any depth with a width less than X mm.	Rule:	Creepage distance and clearances are measured directly across the groove as shown.

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

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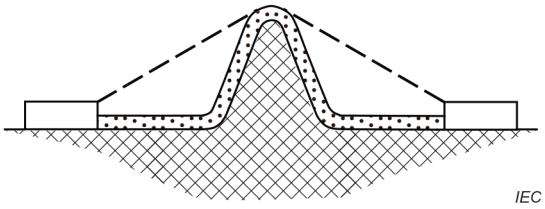
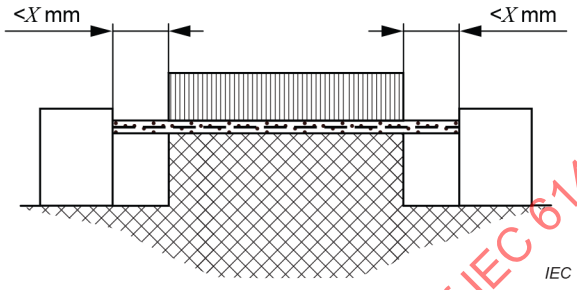


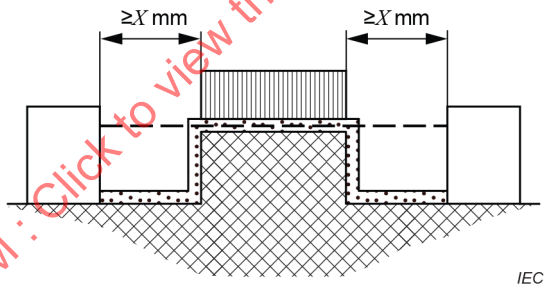
Condition: This creepage distance path includes a rib. Rule: Clearance is the shortest air path over the top of the rib. Creepage path follows the contour of the rib.

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

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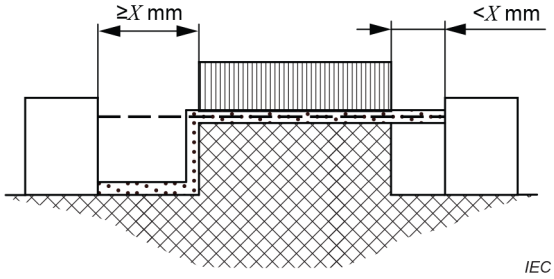
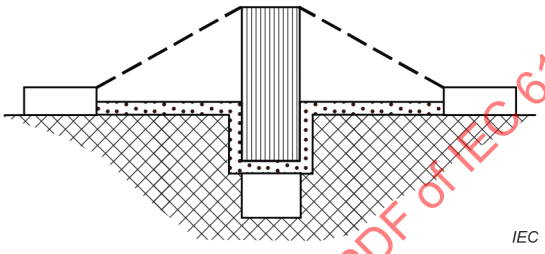


Condition: This creepage distance path includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearances and creepage distance paths are as shown.

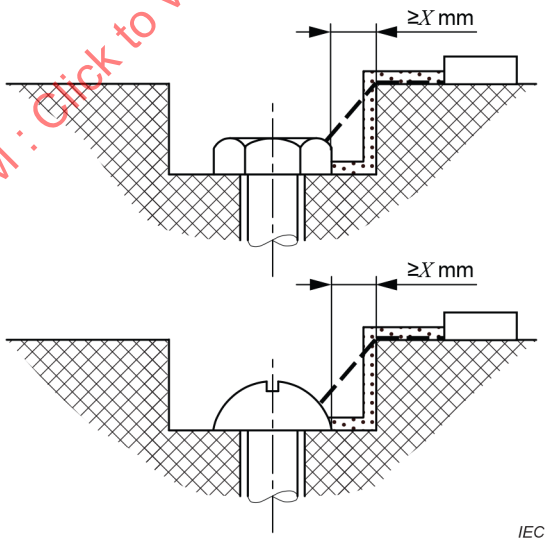
Figure F.1 h) – Example 7



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

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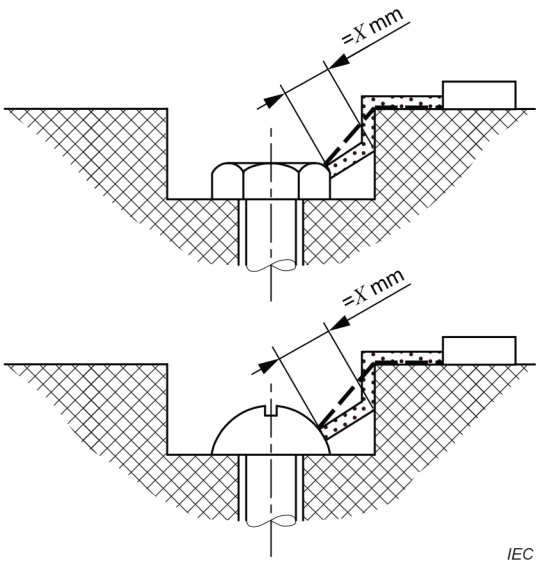
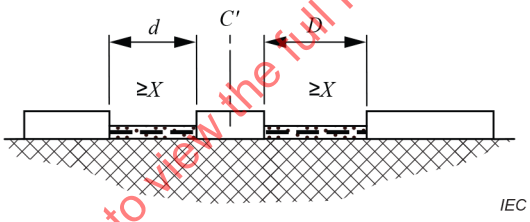


Condition: Gap between head of screw and wall of recess too narrow to be taken into account.

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

– – – – – clearance

creepage distance

Figure F.1 – Measurement of ~~ribs~~ clearance and creepage distances

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Annex G
(normative)

Correlation between the nominal voltage of the supply system and the rated impulse withstand voltage of the equipment [12]

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.

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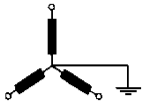
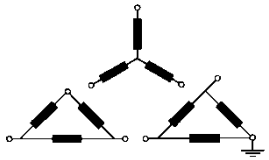
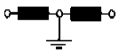
12 Annex G is based on Annex H of IEC 60947-1:~~2007~~2020.

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	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
					Origin of installation (service entrance) level	Distribution circuit level	Load (appliance, equipment) level	Specially protected level
V	AC RMS	AC RMS	AC RMS or DC	AC RMS or DC				
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

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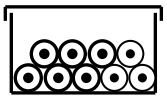
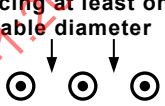
Annex H
(informative)

Operating current and power loss of copper ~~conductors~~ cables

Table H.1 and Table H.2 provide guidance values for ~~conductor~~ 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		 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[a] (2 three-phase circuits) continuously loaded		 Single-core cables, spaced horizontally in free air	
Cross-sectional area of conductor	Resistance of conductor at 20°C, R_{20} [a]	Max. operating current, I_{max} [b]	Power-losses per conductor, P_v	Max. operating current, I_{max} [c]	Power-losses per conductor, P_v	Max. operating current, I_{max} [d]	Power-losses per conductor, P_v
mm²	mΩ/m	A	W/m	A	W/m	A	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	8	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

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[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 ~~6~~ B1 in Table B.52.~~3~~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.

$$I_{max} = I_{30} \times k_1 \times k_2$$

$$P_V = I_{max}^2 \times R_{20} \times \left[1 + \alpha \times (T_c - 20\,°C)\right]$$

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 (~~IEC 60364-5-52:2009, Table B.52.17) ;~~ 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.

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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

~~NOTE~~ 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 ~~must~~ shall be calculated using the formula given above.

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~~**Annex I**~~

~~(Void)~~

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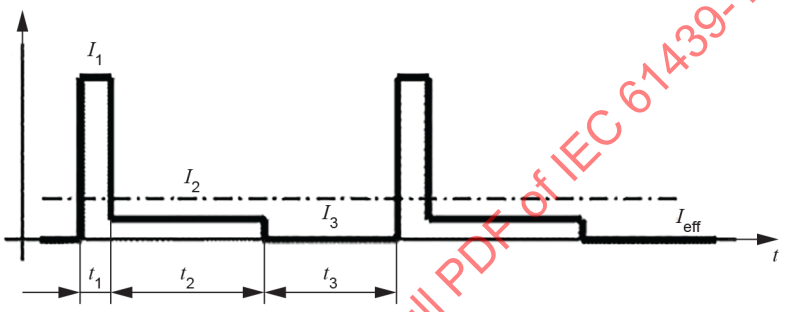
Annex I
(informative)

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

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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

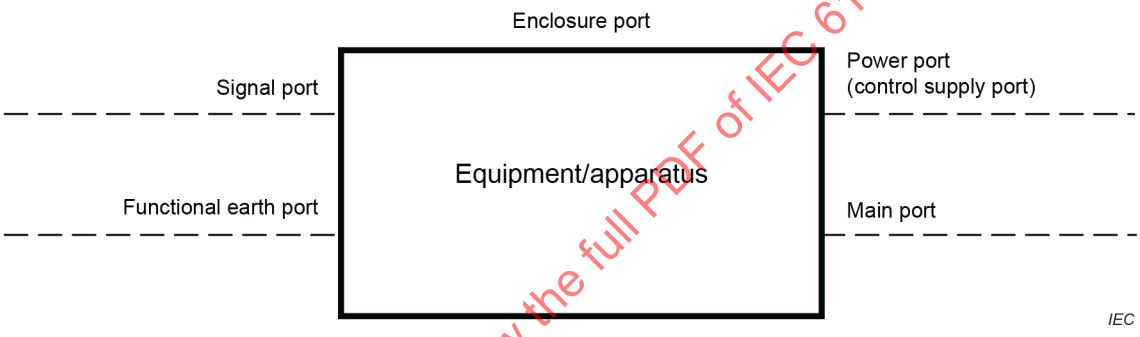

Figure J.1 – Examples of ports

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.

~~[3.4 of IEC 61000-6-1:2005]~~

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

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[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 ~~Environment A is covered by~~ 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 ~~Environment B is covered by~~ 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.

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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 ~~based on the acceptance criteria~~ as given in the relevant ~~product~~ 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.

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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 ~~and justified by the electronic components manufacturer~~.

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 61000-6-4:2006, Table 1.~~

~~The emission limits for environment B are given in IEC 61000-6-3:2006, Table 1.~~

The emission limits for environment A are given in IEC 61000-6-4:2018, Table 3 to Table 5.

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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 22~~ 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~~	~~± 8 kV / air discharge or ± 4 kV / contact discharge~~	~~B~~
~~Radiated radio-frequency electromagnetic field immunity test IEC 61000-4-3 at 80 MHz to 1 GHz and 1,4 GHz to 2 GHz~~	~~10 V/m on enclosure port~~	~~A~~
~~Electrical fast transient/burst immunity test IEC 61000-4-4~~	~~± 2 kV on power ports ± 1 kV on signal ports including auxiliary circuits and functional earth~~	~~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 IEC 61000-4-6 at 150 kHz to 80 MHz~~	~~10 V on power ports, signal ports and functional earth~~	~~A~~
~~Immunity to power-frequency magnetic fields IEC 61000-4-8~~	~~30 A/m [b] on enclosure port~~	~~A~~
~~Immunity to voltage dips and interruptions IEC 61000-4-11 [d]~~	~~30 % reduction for 0,5 cycles 60 % reduction for 5 and 50 cycles >95 % reduction for 250 cycles~~	~~B C C~~
~~Immunity to harmonics in the supply IEC 61000-4-13~~	~~No requirements~~	

~~[a] For equipment and/or input/output ports with a rated d.c. voltage of 24 V or less tests are not required.~~

~~[b] Applicable only to apparatus containing devices susceptible to magnetic fields.~~

~~[c] Performance criteria are independent of the environment. See Table J.3.~~

~~[d] Applicable only to mains input power ports.~~

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

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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] 0 % during 0,5 cycle and 1 cycle 70 % during 25 / 30 cycles	Class 3 [c, d, e] 0 % during 0,5 cycle and 1 cycle 40 % during 10 / 12 cycles 70 % during 25 / 30 cycles 80 % during 250 / 300 cycles	C C B 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.

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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~~	~~± 8 kV / air discharge or ± 4 kV / contact discharge~~	~~B~~
~~Radiated radio-frequency electromagnetic field immunity test IEC 61000-4-3 at 80 MHz to 1 GHz and 1,4 GHz to 2 GHz~~	~~3 V/m on enclosure port~~	~~A~~
~~Electrical fast transient/burst immunity test IEC 61000-4-4~~	~~± 1 kV on power ports ± 0,5 kV on signal ports including auxiliary circuits and functional earth~~	~~B~~
~~1,2/50 µs and 8/20 µs surge immunity test IEC 61000-4-5 [a]~~	~~± 0,5 kV (line to earth) for signal and power ports except for mains supply input port where ±1 kV applies (line to earth) ± 0,5 kV (line to line)~~	~~B~~
~~Conducted radio-frequency immunity test IEC 61000-4-6 at 150 kHz to 80 MHz~~	~~3 V on power ports, signal ports and functional earth~~	~~A~~

~~Immunity to power-frequency magnetic fields IEC 61000-4-8~~	~~3 A/m [b] on enclosure port~~	~~A~~
~~Immunity to voltage dips and interruptions IEC 61000-4-11 [d]~~	~~30 % reduction for 0,5 cycles~~ ~~60 % reduction for 5 cycles~~ ~~>95 % reduction for 250 cycles~~	~~B~~ ~~C~~ ~~C~~
~~Immunity to harmonics in the supply IEC 61000-4-13~~	~~No requirements~~	

~~[a] For equipment and/or input/output ports with a rated d.c. voltage of 24 V or less tests are not required.~~

~~[b] Applicable only to apparatus containing devices susceptible to magnetic fields.~~

~~[c] Performance criteria are independent of the environment. See Table J.3.~~

~~[d] Applicable only to mains input power ports.~~

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.

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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.			

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Annex K
(normative)

Protection by electrical separation

K.1 General

Electrical separation is a protective measure in which:

- basic protection (protection against direct contact) is provided by basic insulation between hazardous live parts and exposed conductive parts of a separated circuit, and
- fault protection (protection against indirect contact) is provided:
  - by simple separation of the separated circuit from other circuits and from earth;
  - by an earth-free protective equipotential bonding interconnecting exposed equipment parts of the separated circuit where more than one item of equipment is connected to the separated circuit.

Intentional connection of exposed conductive parts to a protective conductor or to an earth conductor is not permitted.

K.2 Electrical separation

K.2.1 General

Protection by electrical separation shall be ensured by compliance with all the requirements of K.2.2 to K.2.5.

K.2.2 Supply source

The circuit shall be supplied through a source that provides separation i.e.

- an isolating transformer, or
- a source of current providing a degree of safety equivalent to that of the isolating transformer specified above, for example a motor generator with windings providing equivalent isolation.

NOTE Ability to withstand a particularly high test voltage is recognized as a means of ensuring the necessary degree of isolation.

Mobile sources of supply connected to a supply system shall be selected in accordance with Clause K.3 (class II equipment or equivalent insulation).

Fixed sources of supply shall be either:

- selected in accordance with Clause K.3, or
- such that the output is separated from the input and from the enclosure by an insulation satisfying the conditions of Clause K.3; if such a source supplies several items of equipment, the exposed conductive parts of that equipment shall not be connected to the metallic enclosure of the source.

K.2.3 Selection and installation of supply source

K.2.3.1 Voltage

The voltage of the electrically separated circuit shall not exceed 500 V.

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~~**K.2.3.2 Installation**~~

~~**K.2.3.2.1** Live parts of the separated circuit shall not be connected at any point to another circuit or to earth.~~

~~To avoid the risk of a fault to earth, particular attention shall be given to the insulation of such parts from earth, especially for flexible cables and cords.~~

~~Arrangements shall ensure electrical separation not less than that between the input and output of an isolating transformer.~~

~~NOTE In particular the electrical separation is necessary between the live parts of electrical equipment such as relays, contactors, auxiliary switches and any part of another circuit.~~

~~**K.2.3.2.2** Flexible cables and cords shall be visible throughout any part of their length liable to mechanical damage.~~

~~**K.2.3.2.3** For separated circuits, the use of separate wiring systems is necessary. If the use of conductors of the same wiring system for the separated circuits and other circuits is unavoidable, multi-conductor cables without metallic covering, or insulated conductors in insulating conduit, ducting or trunking shall be used, provided that their rated voltage is not less than the highest voltage likely to occur, and that each circuit is protected against overcurrent.~~

~~**K.2.4 Supply of a single item of apparatus**~~

~~Where a single item of apparatus is supplied, the exposed conductive parts of the separated circuit shall not be connected either to the protective conductor or exposed conductive parts of other circuits.~~

~~NOTE If the exposed conductive parts of the separated circuit are liable to come into contact, either intentionally or fortuitously, with the exposed conductive parts of other circuits, protection against electric shock no longer depends solely on protection by electrical separation but on the protective measures to which the latter exposed conductive parts are subject.~~

~~**K.2.5 Supply of more than one item of apparatus**~~

~~If precautions are taken to protect the separated circuit from damage and insulation failure, a source of supply, complying with K.2.2, may supply more than one item of apparatus provided that all the following requirements are fulfilled.~~

~~a) The exposed conductive parts of the separated circuit shall be connected together by insulated non-earthed equipotential bonding conductors. Such conductors shall not be connected to the protective conductors or exposed conductive parts of other circuits or to any extraneous conductive parts.~~

~~NOTE If the exposed-conductive-parts of the separated circuit are liable to come into contact, either intentionally or fortuitously, with the exposed-conductive-parts of other circuits, protection against electric shock no longer depends solely on protection by electrical separation but on the protective measures to which the latter exposed- conductive-parts are subject.~~

~~b) All socket-outlets shall be provided with protective contacts which shall be connected to the equipotential bonding system provided in accordance with item a).~~

~~c) Except where supplying class II equipment, all flexible cables shall embody a protective conductor for use as an equipotential bonding conductor.~~

~~It shall be ensured that if two faults affecting two exposed conductive parts occur and these are fed by conductors of different polarity, a protective device shall disconnect the supply in a disconnecting time conforming to Table K.1.~~

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Table K.1 – Maximum disconnecting times for TN systems

U_0 [a] V	Disconneting time s
120	0,8
230	0,4
277	0,4
400	0,2
>400	0,1
a Values based on IEC 60038.	

For voltages which are within the tolerance band stated in IEC 60038, the disconnecting time appropriate to the nominal voltage applies.

For intermediate values of voltage, the next higher value in the above table is to be used.

K.3 Class II equipment or equivalent insulation

Protection shall be provided by electrical equipment of the following types:

- Electrical equipment having double or reinforced insulation (class II equipment)
- ASSEMBLIES having total insulation see 8.4.3.3.

This equipment is marked with the symbol .

NOTE This measure is intended to prevent the appearance of dangerous voltage on the accessible parts of electrical equipment through a fault in the basic insulation.

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Annex L
(informative)

Clearances and creepage distances for North American region

Table L.1 – Minimum clearances in air

Rated operational voltage V	Minimum clearances mm	
	Phase to phase	Phase to earth
(150) [a] 125 or less	12,7	12,7
(151) [a] 126-250	19,1	12,7
251-600	25,4	25,4
[a] Values in brackets are applicable in Mexico.		

Table L.2 – Minimum creepage distances

Rated operational voltage V	Minimum creepage distances mm	
	Phase to phase	Phase to earth
(150) [a] 125 or less	19,1	12,7
(151) [a] 126-250	31,8	12,7
251-600	50,8	25,4
[a] Values in brackets are applicable in Mexico.		

NOTE This is not a complete and exhaustive listing of all regulations that are specific to the North American marketplace.

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~~Annex M~~
~~(informative)~~

~~North American temperature rise limits~~

~~The temperature rise limitation permitted in North America are based upon the allowable rises permitted for the devices connected (wire connectors, cables, circuit breakers, etc.). In order to maintain the proper and safe performance of the entire electrical system, these must be taken into account. These requirements are mandated by the National Electrical Code, NFPA 70, Article 110.14-C, ''Temperature Limitations'. This document is published by the National Fire Protection Association, Quincy, Massachusetts, USA. In Mexico these requirements are mandated by NOM-001-SEDE.~~

~~Table M.1 – North American temperature rise limits~~

~~Parts of ASSEMBLIES~~	~~Temperature rise K~~
~~Unplated busbars~~	~~50~~
~~Plated busbars~~	~~65~~
~~Terminals except as covered below~~	~~50~~
~~Terminals for devices marked for use with 90 °C conductors, based upon 75 °C ampacity (current carrying capacity)~~	~~60~~
~~Terminals for devices rated 110 A and less, if marked for use with 75 °C conductors~~	~~65~~

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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 ~~phase~~ line I			~~Two bars per phase (spacing = thickness of bars)~~ Two bars per line (space between the two bars is equal to the thickness of one bar) II		
mm × mm	mm^2	k_3	Operating current A	Power-losses per ~~phase~~ line conductor, P_v W/m	k_3	Operating current A	Power-losses per ~~phase~~ line conductor, P_v 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

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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.

$$P_V = \frac{I^2 \times k_3}{\kappa \times A} \times \left[1 + \alpha \times (T_c - 20\,°C)\right]$$

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, $\kappa = 56 \frac{m}{\Omega \times mm^2}$;

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.

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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 ~~may~~ 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.

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Annex L
(informative)

Guidance on verification of temperature-rise

L.1 General

L.1.1 Principles

All assemblies generate heat in service. ~~Assuming~~ Thermal equilibrium is established when the heat dissipation capability ~~of the ASSEMBLY for local areas within the ASSEMBLY and for the ASSEMBLY as a whole, when operating on full load, exceeds the total~~equals the heat produced ~~then thermal equilibrium will be established;~~. 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~~, may~~ can be impaired, or,

c) 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.

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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

It is the manufacturer's responsibility to select the appropriate method for temperature-rise verification. ~~(See Figure O.1).~~

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 ~~'rated diversity factor'~~ "group rating" provided for each outgoing circuit. ~~Subject to the loading of the incoming circuit not exceeding its rated current, diversity is the proportion of the individual rated currents that any combination of outgoing circuits can carry continuously and simultaneously, without the ASSEMBLY overheating. Diversity factor (assumed loading) is usually defined for the ASSEMBLY as a whole, but a manufacturer may choose to specify it for groups of circuits, for example the circuits in a section.~~

~~Temperature rise verification confirms two criteria, as follows:~~

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a) that each type of circuit is capable of carrying its rated current when it is incorporated in the ASSEMBLY. This takes into account the way in which the circuit is connected and enclosed within the ASSEMBLY, but excludes any heating affects that may result from adjacent circuits carrying current.

b) the ASSEMBLY as a whole will not overheat when the incoming circuit is loaded to its rated current and, subject to the maximum current of the incoming circuit, any combination of outgoing circuits can be simultaneously and continuously loaded to their rated current multiplied by the rated diversity factor for the ASSEMBLY.

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, calculation, comparison or design rules 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 rated current multiplied with the rated diversity factor (see 5.4), due to the thermal influence of the other circuits. Thus to verify the rated currents of all circuits a separate test for each type of circuit is necessary. To verify the rated diversity factor one additional test with simultaneous load on all circuits has to be done (see methods b) and c)).

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 simultaneous load on all circuits. Because with only one test the rated currents and the rated diversity factor of the circuits cannot be verified separately, it is assumed that the diversity factor is one. In this case the load currents are equal to the rated currents.

This is a quick and conservative approach to achieving a result for a particular arrangement of ASSEMBLY. It proves the rating of the outgoing circuits and the ASSEMBLY in the same test. The incoming circuit and busbars are loaded to their rated current and as many outgoing circuits in a group as are necessary to distribute the incoming current, are loaded to their individual rated currents when installed in the ASSEMBLY. For most installations this is an unrealistic situation since outgoing circuits are not normally loaded to unity diversity. If the group of functional units tested does not include one of each of the different types of outgoing circuit

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~~incorporated in the ASSEMBLY, then further tests are carried out considering different groups of outgoing circuits until one of each type has been tested.~~

~~Testing in this manner requires the minimum number of temperature rise tests, but the test arrangement is more onerous than necessary and the result is not applicable to a range of ASSEMBLIES.~~

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 ~~and groups~~. The test sets of outgoing circuits, as ~~necessary~~ required to distribute the incoming current, are loaded to their group rated current ~~multiplied by the diversity factor~~, I_{ng}. The ~~group~~ set tested should include one outgoing circuit of each critical variant to be incorporated in the assembly. Where this is not practical, further ~~groups~~ sets are tested until all critical variants of the outgoing circuit have been considered.

This test regime takes into account ~~the diversity in~~ 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, ~~these tests~~ methods a), b) and c) above, are complemented by a test d) on a representative assembly in which the incoming ~~circuit is loaded to its rated current and the~~ and outgoing circuits are loaded to their ~~rated current multiplied by the diversity factor~~ group rated currents (I_{ng}).

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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 ~~Calculation~~ Verification assessment

L.4.1 General

~~Two~~ Various methods of verifying temperature-rise performance by calculation are included within this document.

L.4.2 Single compartment assembly with a rated current (I_{nA}) not exceeding 630 A

This is a very simple method of temperature-rise verification that requires confirmation that the total power loss of the components and conductors within the assembly do not exceed the known power dissipation capability of the enclosure. The scope of this approach is very limited and in order that there are no difficulties with hot spots, all components ~~must~~ should be de-rated to 80 % of their free air current rating or less.

L.4.3 Assembly with rated currents (I_{nA}) not exceeding 1 600 A

Temperature-rise verification is by calculation in accordance with IEC TR 60890:2014 with additional margins. The scope of this approach is limited to an assembly rating, I_{nA}, of 1 600 A, components are de-rated to 80 % of their free air rating or less, and any horizontal partitions ~~must~~ should have, as a minimum, a 50 % open area.

L.5 ~~Design rules~~ Verification by comparison with a reference design

This document allows, in clearly defined circumstances, for the derivation of ratings from similar variants that have been verified by test. For example, if the current rating of a double lamination busbar has been established by test, it is acceptable to assign a rating equal to 50 % of the tested arrangement to a busbar comprising a single lamination with the same width and thickness as the tested laminations, when all other considerations are the same.

~~In addition,~~ The rating of all circuits within a group of comparable functional units (all devices ~~must~~ shall be of the same frame size and belong to the same series) can be derived from a single temperature-rise test on the critical variant within the group. An example of this may be to test a nominal 250 A outgoing circuit-breaker and establish a rating for it in the assembly. Then, assuming the same frame size breaker is being considered and other specified conditions are met, verify by calculation the rating of a nominal 160 A circuit-breaker within the same enclosure.

In respect of temperature-rise, there are very strict design rules that permit the substitution of a device with a similar device from another series or even another make, without retesting. In this case, in addition to the physical arrangement being essentially the same, the power loss and terminal temperature-rise of the substitute device, when it is tested in accordance with its own product standard, ~~must~~ should not be higher than those of the original device.

~~NOTE~~ When considering device substitution, all other performance criteria, in particular that dealing with short-circuit capability, should be considered and satisfied, in accordance with this document, before an assembly is deemed to be verified.

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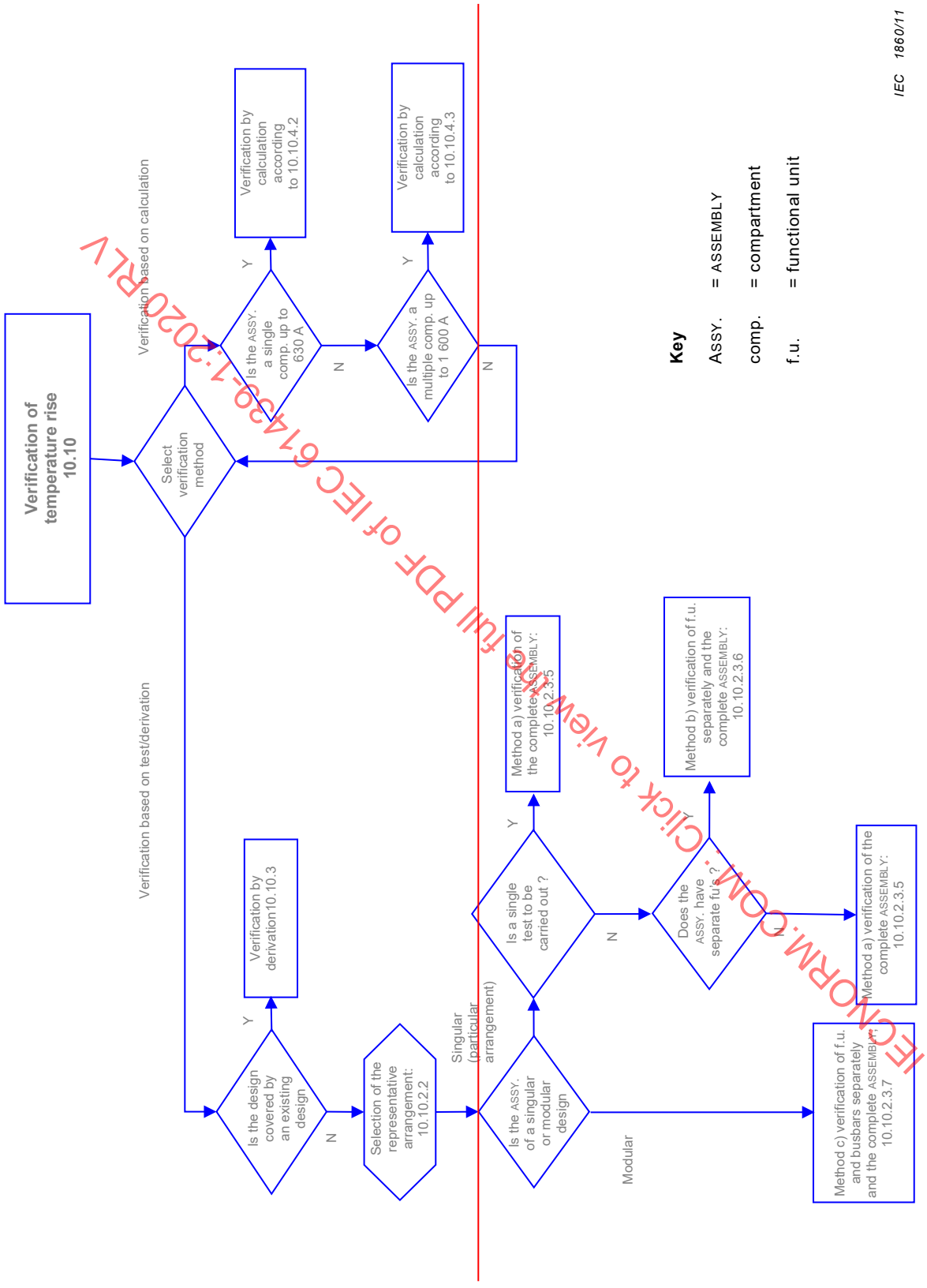

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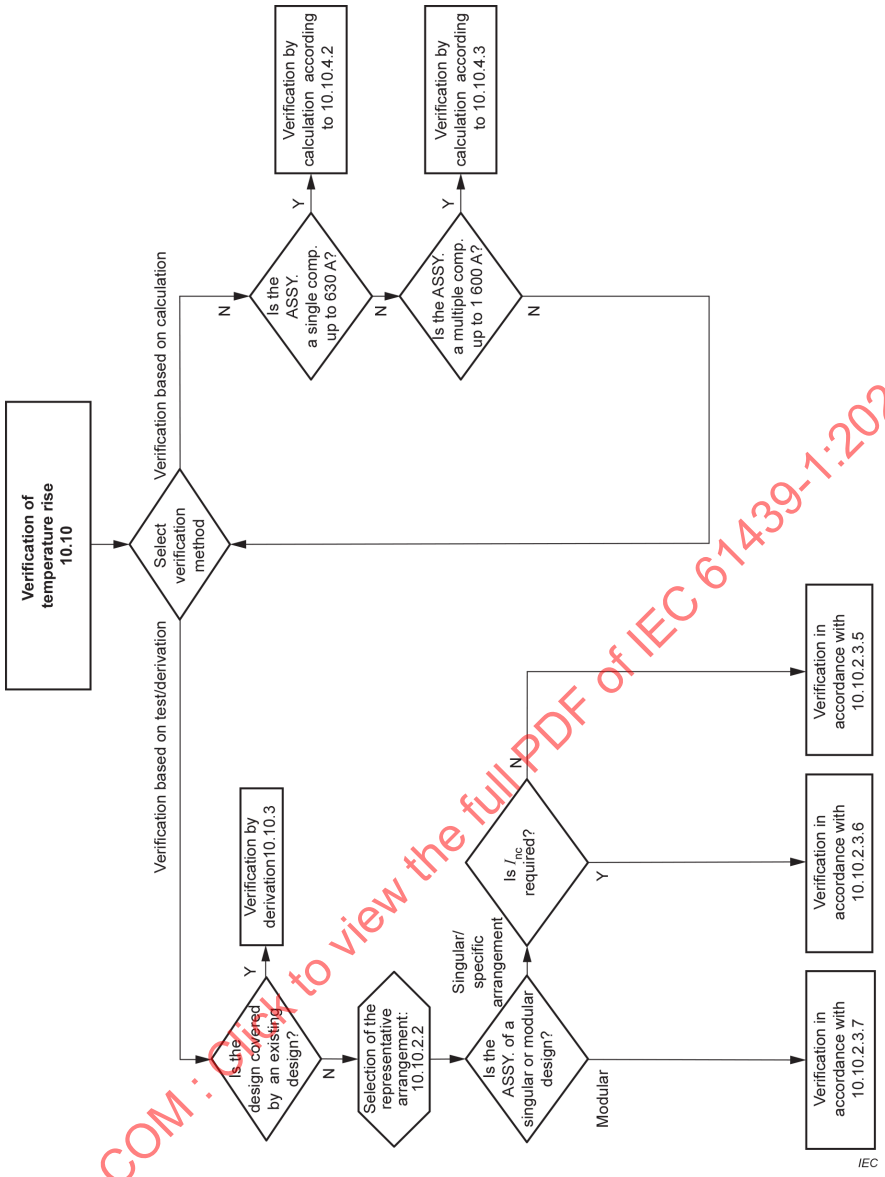

Key

ASSY. = assembly

Comp. = compartment

Figure L.1 – Verification of temperature-rise

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Annex M
(normative)

Verification of the short-circuit withstand strength of busbar structures by comparison with a ~~tested~~ reference design by calculation

M.1 General

Annex M describes a method for assessing the short-circuit withstand strength of busbar structures of an assembly by a comparison of the assembly to be assessed with an assembly already verified by test (see 10.11.5).

M.2 Terms and definitions

For the purposes of Annex M, the following terms and definitions apply.

M.2.1
tested busbar structure
TS
structure whose arrangement and equipment are documented by drawings, parts lists and descriptions in the test certificate (Figure M.1)

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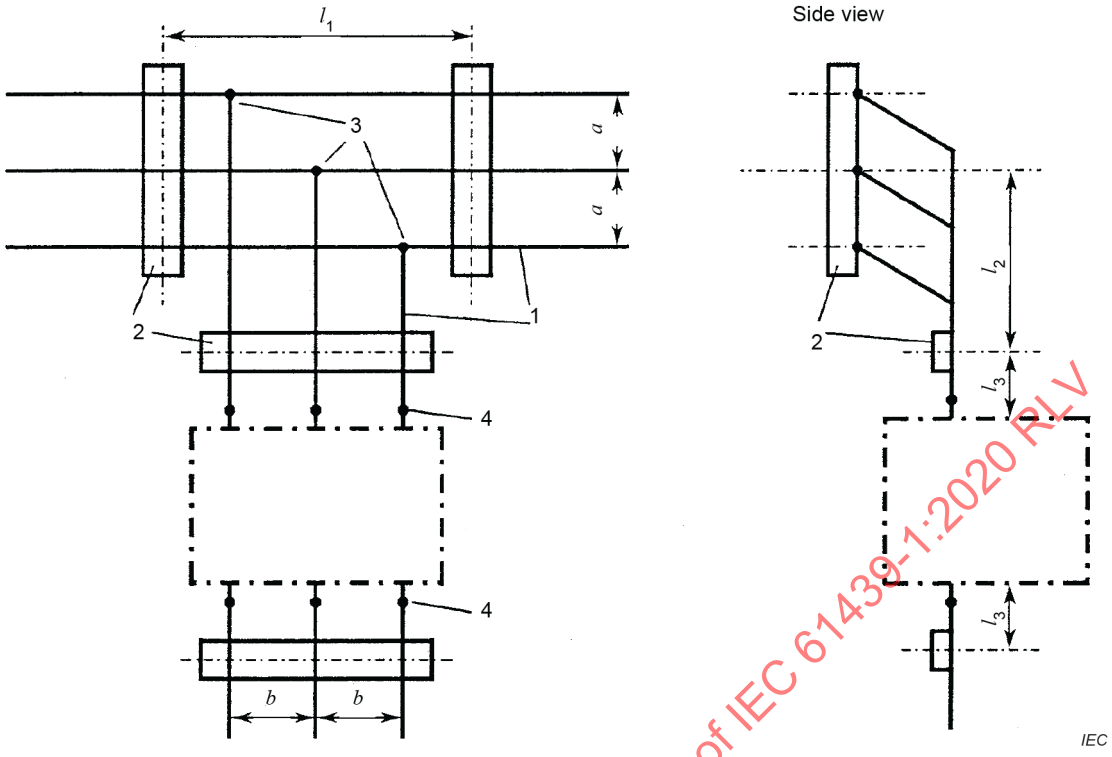

Key

1	busbar
2	support
3	busbar connection
4	equipment connection
a, b, l	distances

Figure M.1 – Tested busbar structure (TS)

M.2.2
non tested busbar structure
NTS
structure which requires verification of short-circuit withstand strength (Figure M.2)

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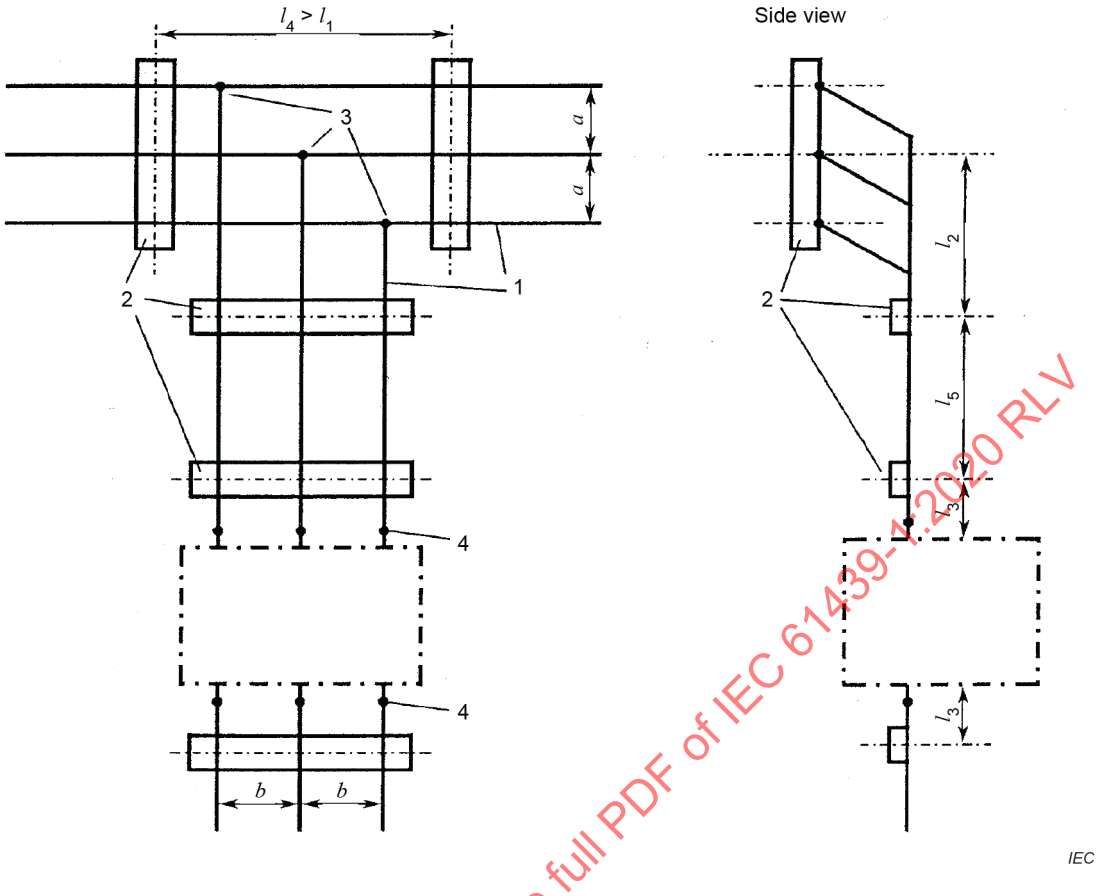

Key

1	busbar
2	support
3	busbar connection
4	equipment connection
a, *b*, *l*	distances

Figure M.2 – Non tested busbar structure (NTS)

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M.3 Method of verification

The short-circuit withstand strength of a derived busbar structure, i.e. an NTS, is verified from a tested busbar structure (TS) by applying calculations according to IEC 60865-1:2011 to both structures. The short-circuit withstand strength of the NTS is considered verified if the calculations show that the NTS does not have to withstand higher mechanical and thermal stresses than the tested structure.

M.4 Conditions for application

M.4.1 General

Changes of parameters, such as busbar clearances, ~~busbar material,~~ busbar cross-section and busbar configuration ~~shown to be necessary by the calculation in conformity with IEC 60865-1~~ are permissible only in so far as the following conditions in M.4.2 to M.4.7 are adhered to.

M.4.2 Peak short-circuit current

The short-circuit current may be changed only to lower values.

M.4.3 Thermal short-circuit strength

The thermal short-circuit strength of an NTS shall be verified by calculations according to IEC 60865-1:2011. The calculated temperature-rise of the NTS shall not be higher than that of the TS.

M.4.4 Busbar supports

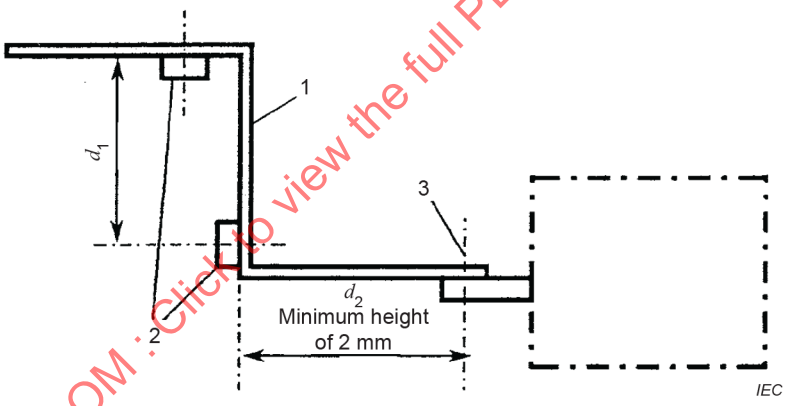
Changes of material or shape of supports taken from an assembly verified by test are not permitted. However, other supports may be used but they shall have been previously tested for the required mechanical strength with a short-circuit test in a representative arrangement.

M.4.5 Busbar connections, equipment connections

The type of busbar and equipment connections shall have been previously verified by test.

M.4.6 Angular busbar configurations

IEC 60865-1:2011 is applicable only to straight busbar configurations. Angular busbar configurations may be considered as a series of straight configurations when supports are provided at the corners (see Figure M.3).



Key

1 busbar
2 support
3 equipment connection
d support distance

Figure M.3 – Angular busbar configuration with supports at the corners

M.4.7 Calculations with special regard to conductor oscillation

For calculations in conformity with IEC 60865-1:2011 on the tested structure (TS), the following values of the factors V_σ, $V_{\sigma s}$ and V_F shall be used:

$$V_\sigma = V_{\sigma s} = V_F = 1{,}0$$

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where

V_{σ} is the ratio between dynamic and static main conductor stress;

$V_{\sigma s}$ is the ratio between dynamic and static sub-conductor stress;

V_{F} is the ratio between dynamic and static force on support.

For the NTS:

$V_{\sigma} = V_{\sigma s} = 1,0$ and

V_{F} is found from calculations in accordance with IEC 60865-1:2011, but $V_{F} < 1,0$ is to be replaced by $V_{F} = 1,0$.

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Annex N
(informative)

List of notes concerning certain countries

Subclause	Text
3.1.14	In the Russian Federation, the term "line conductor" is defined differently: **line conductor** (L) conductor which is energized under normal conditions and used for the transmission of electric energy but which is not a neutral or mid conductor
3.1.14	In the Russian Federation, the following definition applies: **earthed line conductor** (LE) line conductor which has an electrical connection with a local earth
3.1.14	In the Russian Federation, the following definition applies: **phase conductor** line conductor which is used in an AC electric circuit
3.1.14	In the Russian Federation, the following definition applies: **pole conductor** line conductor which is used in a DC electric circuit
3.4.11	In the Russian Federation, the term (electrically) protective barrier is defined differently: **(electrically) protective barrier** part providing protection against contact with hazardous-live-parts from any usual direction of access
3.4.12	In the Russian Federation, the term (electrically) protective obstacle is defined differently: (electrically) **protective obstacle** part preventing unintentional contact with hazardous-live-parts, but not preventing such contact by deliberate action
3.7	In the Russian Federation, the term current-carrying part is defined: **earth fault** occurrence of an accidental conductive path between a live part and the Earth or exposed-conductive-part, or extraneous-conductive-part, or protective conductor
3.7.1	Add the following after Note 1 to entry: Note 2 to entry: In Norway, the neutral is required to be switched for isolation, and disconnection of the neutral may also be necessary for protection against overcurrents.
3.7.3	In the Russian Federation, the term "exposed-conductive-part" is defined differently: **exposed-conductive-part** conductive part of equipment, which can be touched and which is not live under normal conditions, but which can become live when basic insulation fails
3.7.4	In the Russian Federation, the term "protective conductor" is defined differently: **protective conductor** (PE) conductor provided for purposes of electrical safety, for example protection against electric shock
3.7.5	In the Russian Federation, the term "neutral conductor" is defined differently: **neutral conductor** (N) conductor electrically connected to the neutral and used for the transmission of electric energy

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Subclause	Text
3.7.7	In the Russian Federation, the following definition applies: **earth-fault current** current flowing to the earth, exposed-conductive-part, extraneous-conductive-part or protective conductor due to an insulation fault of a live part
3.7.8	In the Russian Federation, the term "basic protection" is defined differently: **basic protection** protection against electric shock under normal conditions
3.7.9	In the Russian Federation, the term "basic insulation" is defined differently: **basic insulation** insulation of live-parts which provides basic protection
3.7.11	In the Russian Federation, the term "protective extra low-voltage system" is defined differently: **protective extra low-voltage system** (PELV system) electric system in which the voltage cannot exceed the value of extra-low-voltage: – under normal conditions and – under single fault conditions, except earth faults in other electric circuits
3.7.12	In the Russian Federation, the term "safety extra low-voltage system" is defined differently: **safety extra low-voltage system** (SELV system) electric system in which the voltage cannot exceed the value of extra-low-voltage: – under normal conditions and – under single fault conditions, including earth faults in other electric circuits
3.7.18	In the Russian Federation, the term "mid conductor" is defined differently: **mid conductor** (M) conductor electrically connected to the mid live part of the DC electrical system and used for the transmission of electric energy
3.7.24	In the Russian Federation, the term "class I equipment" is defined differently: **class I equipment** electrical equipment in which a basic insulation is used as a protective provision for a basic protection, and a protective bonding is used as a protective provision for a fault protection Note to entry: The protective bonding is electrical connection of an exposed-conductive-part of the class I electrical equipment to a protective conductor.
3.7.25	In the Russian Federation, the term "class II equipment" is defined differently: **class II equipment** electrical equipment in which a basic insulation is used as a protective provision for a basic protection, and a supplementary insulation is used as a protective provision for a fault protection, or in which the basic protection and the fault protection are provided by a reinforced insulation.
3.8.6	In the Russian Federation, the term short-circuit current is defined differently: **short-circuit current** overcurrent in an electric circuit under short-circuit
3.10.2	Add the following note to entry. Note 2 to entry: In the UK, when the party installing the assembly completes the final assembly on site by the installation of equipment strictly in accordance with the assembly manufacturer's instructions, they are not necessarily considered to be the assembly manufacturer.

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<table>
<tr><th>Subclause</th><th>Text</th></tr>
<tr><td>3.10.2</td><td>Add a note,

Note 3 to entry: Within the European Union the assembly manufacturer is defined as the manufacturer in respect of relevant Directive, e.g. Low-voltage Directive, EMC Directive.</td></tr>
<tr><td>5.4</td><td>Add the following note after the last paragraph:

NOTE 3 In Norway, the overload protection of conductors shall not solely be based on the use of diversity factors of the downstream circuits.</td></tr>
<tr><td>6.1</td><td>Add the following NOTE 2 after the note:

NOTE 2 In Norway climate conditions deviate from those specified in this document (see 7.1.1) and the assembly is not intended for a fixed location.</td></tr>
<tr><td>7.1.1</td><td>Add the following note:

NOTE In Norway, assemblies suitable for normal operation at a lower ambient air temperature than −25 °C shall also comply with the requirements of this document.</td></tr>
<tr><td>8.2.2</td><td>Add the following after the first paragraph:

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 assembly. 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</td></tr>
<tr><td>8.3.1</td><td>Add the following:

In the United States of America (USA) and Mexico National Electrical Codes are used to specify minimum creepage distances. In the USA, National Electric Code NFPA 70, Article 408.56 is applicable. In Mexico NOM-001-SEDE is applicable. For applications in Canada minimum creepage distances are specified in the Canadian Electrical Code, Part 2 Product Safety Standards.

Minimum clearance and creepage distances for North American region are given in Table 1 and Table 2, respectively.

Table 1 – Minimum clearances in air
<table>
<tr><th rowspan="2">Rated operational voltage
V</th><th colspan="2">Minimum clearances
mm</th></tr>
<tr><th>Phase to phase</th><th>Phase to earth</th></tr>
<tr><td>(150)[a] 125 or less</td><td>12,7</td><td>12,7</td></tr>
<tr><td>(151)[a] 126 to 250</td><td>19,1</td><td>12,7</td></tr>
<tr><td>251 to 600</td><td>25,4</td><td>25,4</td></tr>
<tr><td colspan="3">[a] Values in brackets are applicable in Mexico.</td></tr>
</table>
Table 2 – Minimum creepage distances
<table>
<tr><th rowspan="2">Rated operational voltage
V</th><th colspan="2">Minimum creepage distances
mm</th></tr>
<tr><th>Phase to phase</th><th>Phase to earth</th></tr>
<tr><td>(150)[a] 125 or less</td><td>19,1</td><td>12,7</td></tr>
<tr><td>(151)[a] 126 to 250</td><td>31,8</td><td>12,7</td></tr>
<tr><td>251 to 600</td><td>50,8</td><td>25,4</td></tr>
<tr><td colspan="3">[a] Values in brackets are applicable in Mexico.</td></tr>
</table>
This is not a complete and exhaustive listing of all regulations that are specific to the North American marketplace.</td></tr>
</table>

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<table>
<tr><th>Subclause</th><th>Text</th></tr>
<tr><td>8.4.2.3</td><td>Add the following note after the end of item b):

NOTE In Norway, the neutral conductor shall be isolated or switched.</td></tr>
<tr><td>8.4.3.1</td><td>Add the following note after the end of item b):

NOTE In the Netherlands, it is permitted to use overcurrent protective device for a TT system.</td></tr>
<tr><td>8.6.6</td><td>Add the following note after the last paragraph:

NOTE In the USA, Australia, South Africa, Korea, other colours for the neutral conductor are required.</td></tr>
<tr><td>8.8</td><td>Add the following note after the fifth paragraph:

NOTE 1 In the United States of America (USA) and Mexico, National Electrical Codes should be used for determining the minimum wire bending space requirements. In the USA NFPA 70, Article 312 is applicable. In Mexico, NOM-001-SEDE is applicable. In Canada, wire space and wire bending space is required in the Canadian Electrical Code, Part 2 Standard, C22.2 No. 0.12, Wire Space and Wire Bending Space in Enclosures for Equipment Rated 750 V or Less.</td></tr>
<tr><td>9.2</td><td>Add the following:

In the United States of America (USA) and Mexico, National Electrical Codes, are used to specify maximum temperature-rises. In the USA, NFPA 70, Article 110.14C is applicable. In Mexico, NOM-001-SEDE is applicable. For these applications, temperature-rises shall be selected using the values given below. In Canada, maximum temperature-rise is prescribed in the Canadian Electrical Code, Part 2, Product Safety Standards.

These values are based upon the allowable rises permitted for the devices connected (wire connectors, cables, circuit-breakers, etc.). In order to maintain the proper and safe performance of the entire electrical system, these shall be taken into account.

Table 3 – North American temperature-rise limits
<table>
<tr><th>Parts of assemblies</th><th>Temperature-rise
K</th></tr>
<tr><td>Unplated busbars</td><td>50</td></tr>
<tr><td>Plated busbars</td><td>65</td></tr>
<tr><td>Terminals except as covered below</td><td>50</td></tr>
<tr><td>Terminals for devices marked for use with 90 °C conductors, based upon 75 °C ampacity (current-carrying capacity)</td><td>60</td></tr>
<tr><td>Terminals for devices rated 110 A and less, if marked for use with 75 °C conductors</td><td>65</td></tr>
</table></td></tr>
</table>

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Subclause	Text
10.10.3.5	Add the following note after the last paragraph: NOTE In CO, AU and NZ, a similar device from another manufacturer can be substituted if the conditions of this clause are satisfied and the device rating does not exceed 3 150 A.
10.10.3.5	Add the following note after the last paragraph: NOTE In the US, a device within a circuit with a rated current I_{nc} not exceeding 1 200 A can be considered for substitution.
10.10.3.5	Add the following note after the last paragraph: NOTE In the US, no individual dimension and the overall dimension of the substitute device, height × width × depth, shall not exceed 110 % of the original device. In addition, when the substitution device is installed as intended in the assembly, the distance to adjacent devices shall not be less than 90 % of the distance for the original device.
10.10.3.5	Add the following note after the last paragraph: NOTE In Italy, the value of the devices terminals temperature-rise (when tested in accordance with the relevant product standard) is not significant to define if the substitution is possible, providing that both devices are totally fulfilling the product standards requirements.
10.11.5.4	Add the following note at the end of item b): NOTE In South Africa (ZA) the National Standard SANS 10142-1 for the *Wiring of Premises Part 1: Low-voltage installations*, requires that the supply voltage could be equal to 1,1 times the nominal voltage where the operational voltages are up to and including 525 V.
10.11.5.6.1	Add the following note at the end of the subclause: NOTE In South Africa (ZA), the allowable voltage variations require that the test voltage be equal to 1,1 times the nominal voltage.
Table 6	Add the following note to footnote b: NOTE In the United Kingdom (UK), where an installation conductor operates at a temperature exceeding 70 °C, it shall be ascertained that the equipment connected to the conductor is suitable for the resulting temperature at the connection. See IEC 60364-5-52:2009, Table 52.1. Installation circuit conductors having an in service operating temperature exceeding 70 °C shall not be connected to assemblies manufactured to a standard in this series unless; the circuit(s) in question is/are specifically agreed and recorded by the manufacture in the assembly documentation that, the above requirement has been verified by test.
Table 13	Replace the text of item 6 after the first paragraph with the following note: NOTE In Norway, if the short-circuit protective devices are not equivalent, they shall: • have a breaking capacity not less than the short-circuit rating of the assembly at the rated operational voltage of the assembly, and • 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, and • 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, and • have a heat dissipation less or equal to that of the reference design when applied for a current corresponding to the rated breaking capacity of the device, and • fulfil the requirements of coordination with upstream and downstream devices (see 9.3.4), if required, and • have the same arrangement as in the reference design.

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Subclause	Text
Table 13	Add in item 6 the following note: NOTE In Colombia (CO), South Africa (ZA), Singapore (SG), Australia (AU) and New Zealand (NZ) short-circuit protective devices from another manufacturer may be substituted if the conditions of Table 13 footnote a are satisfied and the substituting device has limitation characteristics (I^2t, I_{pk}) equal to or better than the verified substituted device.

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Low-voltage switchgear and controlgear assemblies – Part 1: General rules

Ensembles d'appareillage à basse tension – Partie 1: Règles générales

IEC 61439-1:2020-05(en-fr)

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LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES –

Part 1: General rules

FOREWORD

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International Standard IEC 61439-1 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.

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

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

a) clarification that power electric converter systems, switch mode power supplies, uninterruptable power supplies and adjustable speed power drive systems are tested to their particular products standard, but when they are incorporated in assemblies the incorporation is in accordance with the IEC 61439 series of standards;
b) introduction of a group rated current for circuits within a loaded assembly and the refocusing of temperature-rise verification on this new characteristic;

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c) addition of requirements in respect of DC;

d) introduction of the concept of class I and class II assemblies regarding protection against electric shock.

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

FDIS	Report on voting
121B/99/FDIS	121B/103/RVD

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

The reader's attention is drawn to the fact that Annex N lists all the "in-some-countries" clauses on differing practices of a less permanent nature regarding this document.

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

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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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

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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.

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[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

This part of IEC 61439 lays down the general definitions and service conditions, construction requirements, technical characteristics and verification requirements for low-voltage switchgear and controlgear assemblies.

NOTE Throughout this document, the term assembly(s) (see 3.1.1) is used for a low-voltage switchgear and controlgear assembly(s).

For the purpose of determining assembly conformity, the requirements of the relevant part of the IEC 61439 series, Part 2 onwards, apply together with the cited requirements of this document. For assemblies not covered by Part 3 onward, Part 2 applies.

This document applies to assemblies only when required by the relevant assembly standard as follows:

– assemblies for which the rated voltage does not exceed 1 000 V AC or 1 500 V DC;
– assemblies designed for a nominal frequency of the incoming supply or supplies not exceeding 1 000 Hz;
– assemblies intended for indoor and outdoor applications;
– stationary or movable assemblies with or without an enclosure;
– assemblies intended for use in connection with the generation, transmission, distribution and conversion of electric energy, and for the control of electrical energy consuming equipment.

This document does not apply to individual devices and self-contained components such as motor starters, fuse switches, power electronic converter systems and equipment (PECS), switch mode power supplies (SMPS), uninterruptable power supplies (UPS), basic drive modules (BDM), complete drive modules (CDM), adjustable speed power drives systems (PDS), and other electronic equipment which comply with their relevant product standards. This document describes the integration of devices and self-contained components into an assembly or into an empty enclosure forming an assembly.

For some applications involving, for example, explosive atmospheres, functional safety, there can be a need to comply with the requirements of other standards or legislation in addition to those specified in the IEC 61439 series.

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

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 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*

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

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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 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: Rules*

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 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*

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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).

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.

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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

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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).

3.2 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

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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.]

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3.3 External design of assemblies

3.3.1
open-type assembly
assembly consisting of a supporting structure which supports the electrical equipment, the live parts of the electrical equipment being accessible

3.3.2
dead-front assembly
open-type assembly with a front cover, the live parts possibly being accessible from directions other than the front

3.3.3
enclosed assembly
assembly 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 assembly
enclosed assembly intended to be mounted on a vertical plane

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

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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

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[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
assembly that is designed for use in locations where the normal service conditions for indoor use as specified in 7.1 apply

3.5.2
assembly for outdoor installation
assembly that is designed for use in locations where the normal service conditions for outdoor use as specified in 7.1 apply

3.5.3
stationary assembly
assembly that is designed to be fixed at its place of installation, for instance to the floor or to a wall, and to be used at this place

3.5.4
movable assembly
assembly which is designed so that it can readily be moved from one place of use to another

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.]

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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

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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’.]

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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.]

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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]

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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

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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

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[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]

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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.

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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

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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

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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} × RDF ≥ 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

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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

4 Symbols and abbreviations

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

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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

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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 $\sqrt{3}$.

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 assembly (I_{nA})

The rated current of an assembly is the lowest value of:

– the total group rated current I_{ng} of the incoming circuit(s), which is either the group rated current of the single incoming circuit or the sum of the group rated currents of the incoming circuits operated in parallel and simultaneously within the assembly;

– the total current that the main busbar can distribute in the particular assembly arrangement.

This current shall be carried without the temperature-rise of the individual parts exceeding the limits specified in 9.2.

NOTE 1 The group rated current of an incoming circuit can be lower than the rated current of the incoming device (according to the respective device standard) installed in the assembly.

NOTE 2 The main busbar in this context is a single busbar or a combination of single busbars that are normally connected in service e.g. by means of a bus-coupler.

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.

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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).

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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).

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.

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5.6 Other characteristics

The following characteristics shall be declared:

a) additional requirements depending on the use of a functional unit (e.g. type of coordination, overload characteristics);
b) pollution degree of the macro-environment (see 3.6.10.2);
c) types of earthing system for which the assembly is designed;
d) indoor and/or outdoor installation (see 3.5.1 and 3.5.2);
e) stationary or movable (see 3.5.3 and 3.5.4);
f) degree of protection against contact with hazardous live parts, ingress of solid foreign bodies and water, IP code (see 8.2.2);
g) intended for use by ordinary or authorized persons (see 3.7.16 and 3.7.17);
h) electromagnetic compatibility (EMC) classification (see Annex J);
i) special service conditions, if applicable (see 7.2);
j) external design (see 3.3);
k) degree of protection against mechanical impact, IK code, if applicable (see 8.2.1);
l) type of construction – fixed or removable parts (see 8.5.1 and 8.5.2);
m) type of short-circuit protective device(s) (see 9.3.2);
n) measures for protection against electric shock;
o) overall dimensions (including projections e.g. handles, covers, doors), if required;
p) weight, if required.

6 Information

6.1 Assembly designation marking

The assembly manufacturer shall provide each assembly with one or more labels, marked in a durable manner and located in a place such that they are visible and legible when the assembly is installed and in operation. Compliance is checked according to the test of 10.2.7 and by inspection.

The following information regarding the assembly shall be provided on the designation 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) rated current of the assembly I_{nA} (see 3.8.10.7 and 5.3.1);
e) rated voltage of the assembly U_n (see 3.8.9.1 and 5.2.1);
f) rated frequency of the assembly f_n (see 3.8.12 and 5.5);
g) IEC 61439-X (the specific part “X” shall be identified).

NOTE The relevant assembly standard can specify where additional information is to be provided on the designation label.

6.2 Documentation

6.2.1 Information relating to the assembly

All interface characteristics according to Clause 5, where applicable, shall be provided in the assembly manufacturer’s technical documentation supplied with the assembly.

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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.

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.

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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.

The micro-environment within the assembly can be different from the macro-environment outside the enclosure. The pollution degree for a particular type of assembly is given in the relevant assembly standard.

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;

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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).

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

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away from the source of the vibration, or the provision of anti-vibration mountings shall be considered.

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). Compliance with this requirement is checked by the test in 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 ºC. 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

External surfaces made of insulating material(s) and coated metal enclosures which are intended to be used outdoor exposed to ultra-violet radiation shall not crack nor deteriorate such that it impairs the safety of the assembly. Resistance to ultra-violet radiation shall be verified according to 10.2.4.

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).

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

8.1.6 Lifting provision

Where lifting, other than by manual means is recommended by the manufacturer, e.g. by crane or fork lift truck, transport units shall be provided with the appropriate provision for lifting. Compliance is verified according to 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.

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

The degree of protection provided by any assembly against contact with live parts, ingress of solid foreign bodies and water is indicated by the IP code according to IEC 60529:1989, IEC 60529:1989/AMD1:1999 and IEC 60529:1989/AMD2:2013; and verified according to 10.3.

After installation in accordance with the assembly manufacturer's instructions, the degree of protection of an enclosed assembly shall be at least IP2X. The degree of protection provided from the front of a dead-front assembly shall be at least IPXXB.

For assemblies for outdoor use having no supplementary protection, the second characteristic numeral shall be at least 3.

NOTE For outdoor installation, supplementary protection can be protective roofing or similar.

Unless otherwise specified, the degree of protection indicated by the assembly manufacturer applies to the complete assembly when installed in accordance with the assembly manufacturer's instructions, for example sealing of the open mounting surface of an assembly, etc.

Where the assembly does not have the same IP rating throughout, the assembly manufacturer shall declare the IP rating for the separate parts.

Different IP ratings shall not impair the intended use of the assembly.

EXAMPLES:

- operating face IP20, other parts IP00;
- drain holes in the base IPXXD, other parts IP43.

IP codes shall not be declared by the assembly manufacturer unless the appropriate verifications have been made according to 10.3.

Enclosed assemblies, for outdoor and indoor installation, intended for use in locations with high humidity and temperatures varying within wide limits, shall be provided with suitable arrangements (ventilation and/or internal heating, drain holes, etc.) to prevent harmful condensation within the assembly. However, the specified degree of protection shall at the same time be maintained.

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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.

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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.

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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 assembly shall include protective measures and be suitable for installations designed to be in accordance with IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017.

NOTE 1 Protective measure suitable for particular installations can be subject to additional or different requirements, e.g. for installation in ships as given in IEC 60092 series.

When a TT earthing system is being used in the electrical network, one of the following protective measures shall be applied in the assembly:

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a) double or reinforced insulation of all conductors (incoming cables, extension terminals, etc.) upto the supply side of the first RCD(s) in the system (this is not a requirement when a Class II assembly is used); or

b) residual current device (RCD) protecting the incoming circuit.

NOTE 2 An equivalent to reinforced insulation can be provided by rigid connections, air and suitable mechanical protection.

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.

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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

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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.

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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) If doors or covers of the enclosure can be opened without the use of a key or tool, a barrier of insulating material shall be provided that will afford protection of at least IPXXB against unintentional contact not only with the accessible live parts, but also with the exposed-conductive-parts that are only accessible after the door or cover has been opened; this barrier, however, shall not be removable except with the use of a tool.

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

8.4.6.2.1 General

Depending on the application and accessibility necessary in service, by authorized person(s), one or more of the following requirements in 8.4.6.2.2 to 8.4.6.2.4 shall be fulfilled. These requirements shall be complementary to the basic protection specified in 8.4.2.

If doors or covers of the assembly can be opened by authorized persons by overriding an interlock to obtain access to live parts, then the interlock shall automatically be restored on reclosing the door(s) or replacing the cover(s).

Obstacles can be used to prevent either:

– unintentional bodily approach to live parts; or

– unintentional contact with live parts during the operation of live equipment in normal service.

Obstacles may be removed without using a key or tool but shall be so secured as to prevent unintentional removal. The distance between a conductive obstacle and the live parts they protect shall not be less than the values specified for the clearances and creepage distances in 8.3.

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Where a conductive obstacle is separated from hazardous live parts by basic protection only, it is an exposed-conductive-part, and measures for fault protection shall also be applied.

8.4.6.2.2 Requirements related to accessibility for inspection and similar operations

The assembly shall be constructed in such a way that certain operations can be performed when the assembly is in service and energized.

Such operations may consist of:

– visual inspections of;
  - switching devices and other apparatus;
  - settings and indicators of relays and releases;
  - conductor connections and marking;
– adjusting and resetting of relays, releases and electronic devices;
– replacement of fuse-links;
– replacement of indicating lamps;
– certain fault location operations, for example voltage and current measuring with suitably designed and insulated devices.

8.4.6.2.3 Requirements related to accessibility for maintenance

To enable maintenance on an isolated functional unit or isolated group of functional units in the assembly, with adjacent functional units or groups still energized, necessary measures shall be taken. The choice depends on such factors as service conditions, frequency of maintenance, competence of the authorized person, as well as local installation rules. Such measures may include the following:

– sufficient space between the actual functional unit or group and adjacent functional units or groups. It is recommended that parts likely to be removed for maintenance have, as far as possible, retainable fastening means;
– use of barriers or obstacles designed and arranged to protect against direct contact with equipment in adjacent functional units or groups;
– use of terminal shields;
– use of compartments for each functional unit or group;
– insertion of additional protective means provided or specified by the assembly manufacturer.

8.4.6.2.4 Requirements related to accessibility for extension when energized

When it is required to enable future extension of an assembly with additional functional units or groups, with the rest of the assembly still energized, the requirements specified in 8.4.6.2.3 shall apply, subject to agreement between the assembly manufacturer and the user. These requirements also apply for the insertion and connection of additional outgoing cables when the existing cables are energized.

The extension of busbars and connection of additional units to their incoming supply shall not be made when energized, unless the assembly is designed for this purpose.

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.

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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.

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.

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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.

8.6 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

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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.

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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.

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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

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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.

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

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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.

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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.

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.

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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.

For an assembly having several incoming units which are unlikely to be in operation simultaneously, the short-circuit withstand strength can be indicated for each of the incoming units in accordance with the above.

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For an assembly having several incoming units which are likely to be in operation simultaneously, and for an assembly having one incoming unit and one or more outgoing high-power units likely to contribute to the short-circuit current, it is necessary to determine the values of the prospective short-circuit current, considering all operating modes, in each incoming unit, in each outgoing unit and in the busbars. The prospective short-circuit currents determined shall be based on data provided by the user.

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

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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;

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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 62208:2011 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 is required.

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.

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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.

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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.

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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.

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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.

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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 protection against mechanical impact (IK code)

Mechanical impact tests, where required by the specific assembly standard, are to be carried out in accordance with the test requirements of the specific assembly standard.

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.

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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.

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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.

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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.

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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 %.

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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^{+2}_{0} 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 or by assessment.

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;

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– 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).

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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) assessment (calculation) (10.10.4).

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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,

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– 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.

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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.

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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 1600 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.

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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 1600 A but not exceeding 7000 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 7000 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.

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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.

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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

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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.

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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.]

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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 1600 A circuit-breaker cannot be assigned a current rating of 1750 A in an ambient air temperature of 20 °C.

10.10.4 Verification assessment

10.10.4.1 General

The following calculation methods are provided, which have differing ranges of applicability:

1) single compartment assembly with natural cooling and rated current I_{nA} not exceeding 630 A (10.10.4.2);
2) assembly with natural cooling and rated current I_{nA} not exceeding 1600 A (10.10.4.3).

These methods determine the approximate air temperature-rise inside the enclosure, which is caused by the power losses of all circuits, and compares this temperature with the limits for the installed equipment. The methods differ only in the way the relationship between the delivered power loss and the air temperature-rise inside the enclosure is ascertained.

Due to the actual local temperatures of the current-carrying parts, which cannot be calculated by these methods, some limits and safety margins are necessary and included. Verification of the temperature-rise may be made by calculation if all the following general conditions and the additional conditions for the selected calculation method are fulfilled.

a) The rated frequency is up to and including 60 Hz.
b) The power loss data for all built-in electrical components is available from the component manufacturer.
c) There is an approximately even distribution of power losses inside the enclosure.
d) The mechanical parts and the installed equipment are so arranged that air circulation is not significantly impeded.
e) The group rated current of the circuits, (I_{ng}), of the assembly to be verified shall not exceed 80 % of the rated conventional free air thermal current (I_{th}) if known, or when I_{th} is not available, 80 % of the rated current (I_n) of the switching devices and electrical components included in the circuit. Circuit-protection devices shall be selected to ensure adequate protection to outgoing circuits, e.g. thermal motor protection devices at the calculated temperature in the assembly. The limitation to 80 % of the rated current I_{th} or I_n does not apply to electronic devices which incorporate means for forced ventilation when they are installed according to the device manufacturer's instructions.

NOTE 1 There is no common characteristic for switching devices and electrical components that describes the value of current to be used here. For the purpose of verifying the temperature-rise limits, the value of the current is used, which describes the maximum continuous operational current that can be carried without overheating. This is, for example, for contactors the rated operational current I_e AC1 and for circuit-breakers the rated current I_n.

NOTE 2 This verification method assesses the mean air temperature inside the enclosure assuming an even distribution of the power losses. Therefore, potential local hot spots at the devices, which are the main power loss sources, cannot be detected. To prevent overheating of the devices, the safety margin of 80 % is introduced. This is based on general testing experience.

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NOTE 3 Electronic devices with forced ventilation distribute their power losses mainly via the cooling air. They do not rely on the power dissipation via the conductors and the surface of the device/enclosure. Usually they are equipped with internal temperature monitoring to prevent overheating. Therefore, a limitation to 80 % of the rated current as imposed for other devices is not appropriate.

f) All conductors directly connected to a device shall have a minimum cross-sectional area based on 125 % of the group rated current, I_{ng}, of the associated circuit. Selection of cables shall be in accordance with IEC 60364-5-52:2009. Examples of how to adapt this document for conditions inside an assembly are given in Annex H. The cross-section of bare copper bars shall be as tested or as given in Annex K. Where the device manufacturer specifies a conductor with a larger cross-sectional area, this shall be used.

NOTE 4 The factor of 125 % is used to ensure that the conductors will not further derate the devices.

g) Conductors carrying currents in excess of 200 A and the adjacent structural parts are so arranged that eddy-current and hysteresis losses are minimized.

The effective power losses of all circuits including interconnecting conductors shall be calculated assuming the circuits are operating at their group rated current, I_{ng}. The total power loss of the assembly is calculated by adding the power losses of the circuits taking additionally into account that the total load current is limited to the rated current of the assembly, I_{nA}. The power losses of the conductors are determined by calculation (see Annex H and Annex K).

NOTE 5 There are devices where the power loss is substantially proportional to I^2 and others that have substantially fixed losses, e.g. variable speed drive.

EXAMPLE A single compartment assembly with a rated current I_{nA} of 100 A (limited by the distribution busbars) is equipped with 20 outgoing circuits. The assumed group rated current I_{ng} for each circuit is 8 A. The total effective power loss should be calculated for 12 outgoing circuits loaded with 8 A each.

10.10.4.2 Single compartment assembly with natural cooling and rated current (I_{nA}) not exceeding 630 A

10.10.4.2.1 Verification method

Verification of the temperature-rise may be made by calculation if all the general conditions listed in 10.10.4.1 are fulfilled, and using the following:

a) The air temperature-rise within the enclosure at a given power loss in the enclosure, for the applicable installation method being considered (e.g. flush mounting, surface mounting) is:
   - available from the enclosure manufacturer, or
   - determined in accordance with 10.10.4.2.2.

b) The total power loss within the enclosure is calculated as detailed in 10.10.4.1.

   The maximum permissible air temperature-rise within the enclosure is determined by the device with the lowest maximum operating air temperature and is taken as the maximum operating temperature of that device minus the daily average ambient air temperature (outside the enclosure).

   When electronic devices with integral forced ventilation are incorporated, the enclosure shall be considered as having no natural ventilation, irrespective of whether or not openings exist in the enclosure.

10.10.4.2.2 Determination of the power loss capability of an enclosure by test

The power loss shall be simulated by means of heating resistors that produce heat equivalent to the intended power loss capability of the enclosure. The heating resistors shall be distributed evenly over the height of the enclosure and installed in suitable places inside the enclosure.

The cross-section of the leads to these resistors shall be such that no appreciable amount of heat is conducted away from the enclosure.

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The test shall be carried out in accordance with 10.10.2.3.1 to 10.10.2.3.4 and the air temperature-rise shall be measured in the top of the enclosure. Enclosure temperatures shall not exceed the values given in Table 6.

10.10.4.2.3 Results to be obtained

The assembly is verified if:

– the enclosure is capable of dissipating power losses equal to or greater than those generated by the assembly at the maximum permissible air temperature-rise within the enclosure;

– all conductors within the assembly have been selected to operate at the maximum permitted air temperature within the assembly.

10.10.4.3 Assembly with natural cooling and rated current (I_{nA}) not exceeding 1 600 A

10.10.4.3.1 Verification method

Verification of the temperature-rise may be made by calculation in accordance with the method of IEC TR 60890:2014 providing the additional requirements of 10.10.4.1 are fulfilled.

The air temperature-rise within the assembly is then determined from the total power loss using the method of IEC TR 60890:2014.

The air temperature within the assembly is calculated by adding this air temperature-rise and the daily average ambient air temperature of the assembly. When electronic devices with integral forced ventilation are incorporated, the enclosure shall be considered as having no natural ventilation, irrespective of whether or not openings exist in the enclosure.

NOTE Natural ventilation is by means of air flow into and out of the enclosure without forced ventilation.

10.10.4.3.2 Results to be obtained

The assembly is verified if the calculated air temperature at the mounting height of any built-in component (devices, conductors, etc.) does not exceed the permissible operating air temperatures of the built-in components as declared by their manufacturers.

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:

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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.

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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 1500 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 1500 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 1500 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 1500 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).

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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.

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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

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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.

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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.

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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.

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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.

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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.

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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.	

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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	[a]
1 000	3,2	5	7,1	10	12,5	14	16	
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

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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 mm^2
$I_e \leq 20$	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 (mm^2).

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 mm^2	Minimum cross-sectional area of the corresponding protective conductor (PE), S_p mm^2
$S \leq 16$	S
$16 < S \leq 35$	16
$35 < S \leq 400$	$S/2$
$400 < S \leq 800$	200
$800 < S$	$S/4$

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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.

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Table 7 – Values for the factor n[a] (9.3.3)

RMS value of the short-circuit current kA	cos φ	n
$I \leq 5$	0,7	1,5
$5 < I \leq 10$	0,5	1,7
$10 < I \leq 20$	0,3	2,0
$20 < I \leq 50$	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
$U_i \leq 60$	1 000	1 415
$60 < U_i \leq 300$	1 500	2 120
$300 < U_i \leq 690$	1 890	2 670
$690 < U_i \leq 800$	2 000	2 830
$800 < U_i \leq 1\,000$	2 200	3 110
$1\,000 < U_i \leq 1\,500$[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
$U_i \leq 12$	250	355
$12 < U_i \leq 60$	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

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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]	
		mm^2	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.

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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] A	Test conductors[c]			
	Cables[c]		Copper bars[b]	
	Quantity	Cross-sectional area mm^2	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.

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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.

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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.

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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.

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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 (mm^2);

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.

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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 to be provided by the user.

It is intended to be used and developed in the relevant assembly standards.

Table C.1 – User information template

Characteristics	Referencee	Default arrangement[a]	Options listed in this document[b]	User requirement[c]
Electrical system				
Type of system earthing	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 1000 V AC or 1500 V DC	
Transient overvoltages	5.2.4, 8.5.3, 9.1, Annex G	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, 10.10.3.1, 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 conductor	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	
Coordination 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	
Protection against electric shock in accordance with IEC 60364-4-41:2005 and IEC 60364-4-41:2005/AMD1:2017				
Type of protection against electric shock – Basic protection (previously protection against direct contact)	8.4.2	Basic protection	According to local installation regulations	

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Characteristics	Referencee	Default arrangement[a]	Options listed in this document[b]	User requirement[c]
Type of protection against electric shock – Fault protection (previously protection against indirect contact)	8.4.3	According to local installation conditions	Automatic disconnection of supply / Electrical separation / Double or reinforced insulation	
Installation environment				
Location type	3.5, 8.1.4, 8.2	Manufacturer's standard, according to application	Indoor / outdoor	
Protection against ingress of solid foreign bodies and ingress of water	8.2.2, 8.2.3	Indoor (enclosed): IP2X Outdoor (min.): IP23	After removal of removable parts: As for connected position / Reduced protection to manufacturer's standard	
External mechanical impact (IK code)	8.2.1, 10.2.6	None	None	
Resistance to UV radiation (applies for outdoor assemblies only unless specified otherwise)	10.2.4	Indoor: Not applicable. Outdoor: Temperate climate	None	
Resistance to corrosion	10.2.2	Normal Indoor/Outdoor arrangements	None	
Ambient air temperature – Lower limit	7.1.1	Indoor: −5 °C Outdoor: −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	7.1.1	Indoor: 95 % at −5°C to +30 °C 70 % at +35 °C 57 % at +40 °C Outdoor: 100 % at −25 °C to +27 °C 60 % at 35 °C 46 % at 40 °C	None	
Pollution degree of the macro-environment (of the installation environment)	7.1.2	Industrial: 3	1, 2, 3, 4	
Altitude	7.1.1	≤ 2000 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, heavy pollution, corrosive environment, 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	

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Characteristics	Referencee	Default arrangement[a]	Options listed in this document[b]	User requirement[c]
Installation method				
Type	3.3, 5.6	Manufacturer's standard	Various, e.g. floor-standing / wall-mounted	
Stationary/Movable	3.5	Stationary	Stationary / movable	
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 line conductor, cross-sections, and terminations	8.8	As defined within the standard	None	
External protective, neutral, mid-point, PEL, PEM, PEN conductor 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	7.3	As service conditions	None	
Packing details	6.2.2	Manufacturer's standard	None	
Operating arrangements				
Access to manually operated devices	8.4		Authorized persons / Ordinary persons	
Location of manually operated devices	8.5.5	Easily accessible	None	
Isolation of load installation equipment items	8.4.2, 8.4.3.3, 8.4.6.2	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 assembly is energized	8.4.6.1	Basic protection	None	
Requirements related to accessibility for inspection and similar operations	8.4.6.2.2	No requirements for accessibility	None	
Requirements related to accessibility for maintenance in service by authorized persons	8.4.6.2.3	No requirements for accessibility	None	
Requirements related to accessibility for extension in service by authorized persons	8.4.6.2.4	No requirements for accessibility	None	

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Characteristics	Referencee	Default arrangement[a]	Options listed in this document[b]	User requirement[c]
Method of functional unit's connection	8.5.1, 8.5.2	Manufacturer's standard	None	
Protection against direct contact 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	
Current carrying capacity				
Maximum total load current to be supplied by the assembly (from which the rated current of the assembly I_{nA} (A) will be determined)	3.8.10.1, 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	
Design current I_B and nature of load for each circuit; alternatively, I_n of the devices and nature of the load (in such cases, the assumed loading factors can be used based on the relevant part of IEC 61439)	3.8.10.8	None	None	
Ratio of cross-section of the neutral conductor to line conductors: line conductors up to and including 16 mm^2	8.6.1	100 %	None	
Ratio of cross-section of the neutral conductor to line conductors: line conductors above 16 mm^2	8.6.1	50 % (min. 16 mm^2)	None	

[a] In some cases, information declared by the assembly manufacturer may take the place of an agreement.

[b] "None" in this column means that there are no options in the standard other than the default condition or value.

[c] For exceptionally onerous applications, the user may need to specify more stringent requirements to those in the document.

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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	Subclauses	Verification options available		
			Testing[a]	Comparison with a reference design	Assessment
1	Strength of material and parts:	10.2			
	Resistance to corrosion	10.2.2	YES	YES	NO
	Properties of insulating materials:	10.2.3			
	Thermal stability	10.2.3.1	YES	YES	NO
	Resistance to abnormal heat and fire due to internal electric effects	10.2.3.2	YES	YES	YES
	Resistance to ultra-violet (UV) radiation	10.2.4	YES	YES	YES
	Lifting	10.2.5	YES	YES	NO
	Mechanical impact (IK)	10.2.6	YES	YES	NO
	Marking	10.2.7	YES	YES	NO
	Mechanical operation	10.2.8	YES	YES	NO
2	Degree of protection of enclosures (IP)	10.3	YES	NO	YES
3	Clearances	10.4	YES	NO	NO
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 a class I assembly and the protective circuit	10.5.2	YES	NO	NO
	Short-circuit withstand strength of the protective circuit	10.5.3	YES	YES	NO
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	YES
	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	YES
11	Short-circuit withstand strength	10.11	YES	YES	NO
12	Electromagnetic compatibility (EMC)	10.12	YES	NO	YES

[a] Testing may be on representative sample if permitted in the appropriate test clause.

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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.

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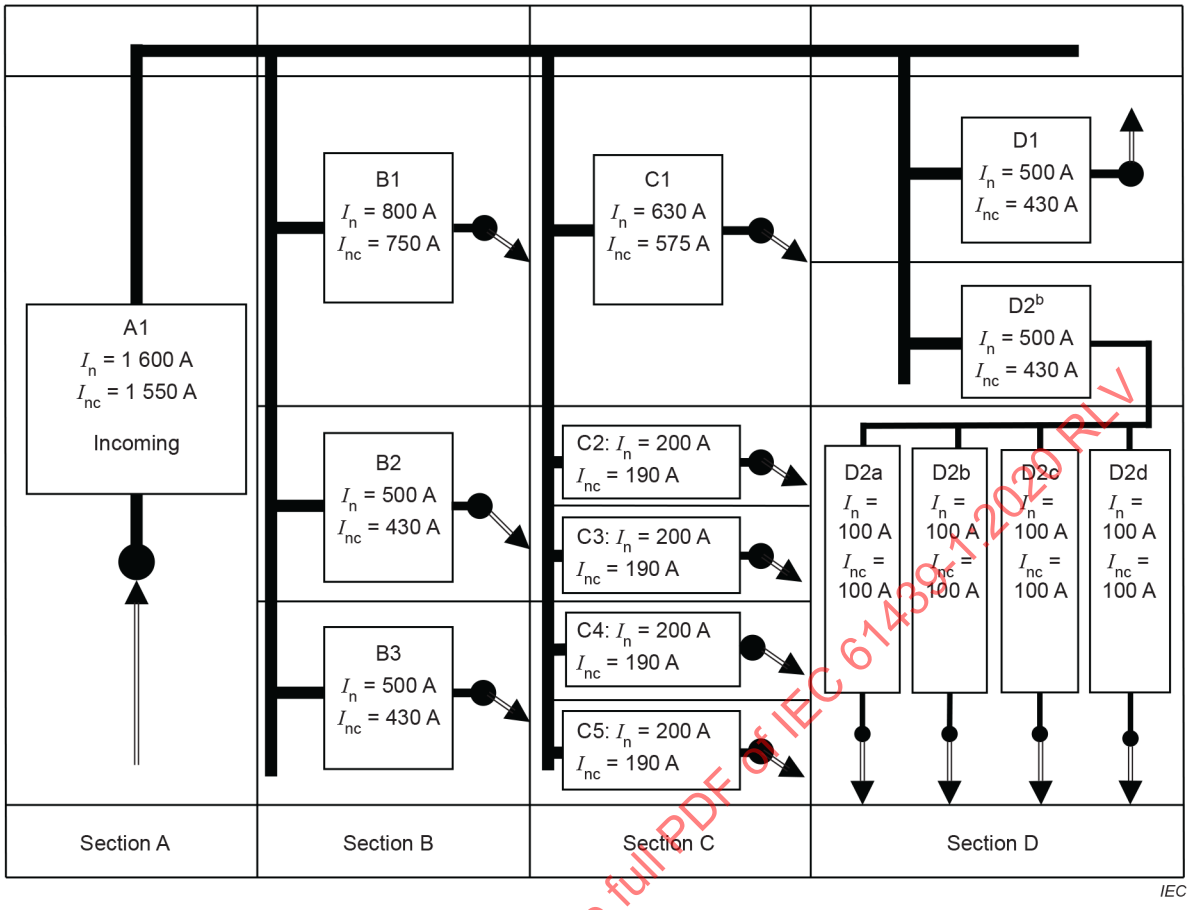

For each functional unit (A1, B1, etc.) the rated current of a circuit (I_{nc}) is shown. [a]

[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

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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.

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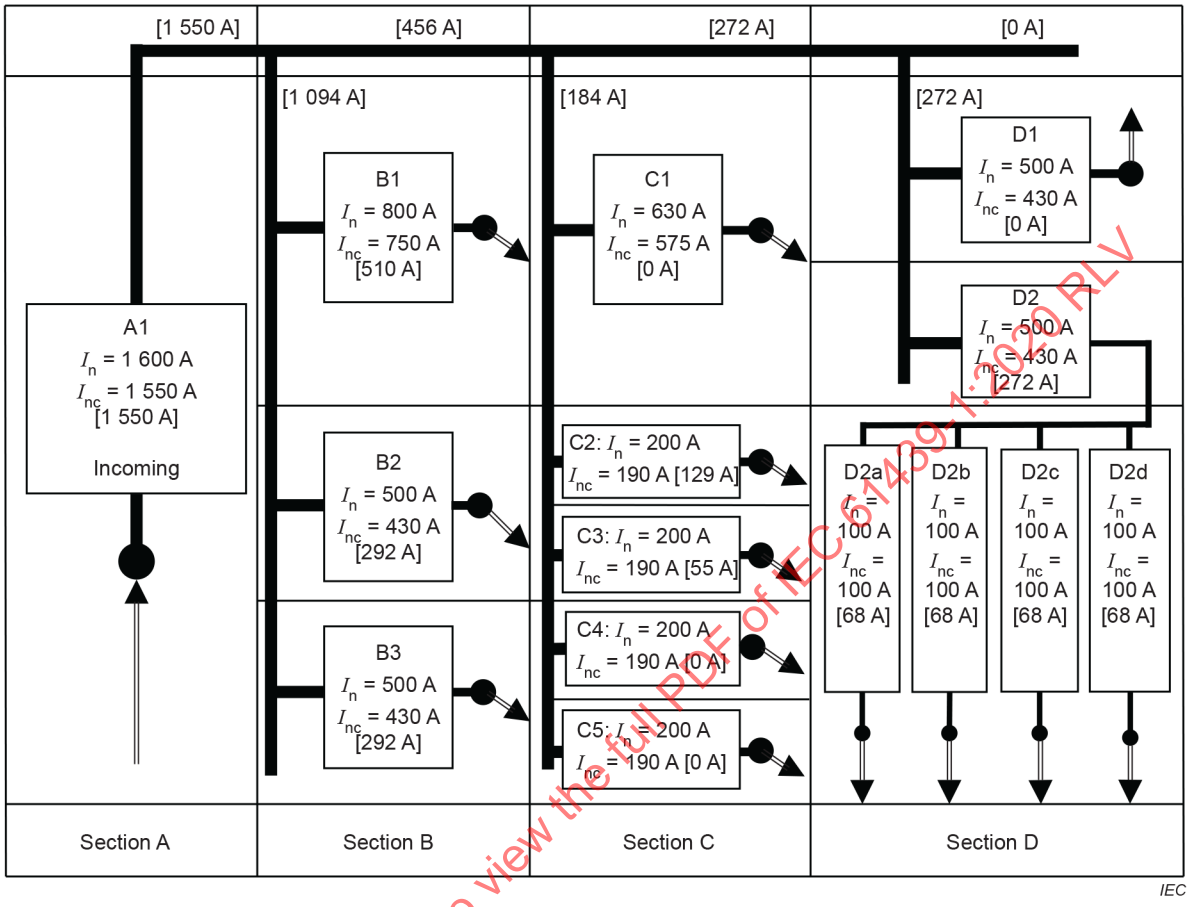
E.2.2 Example of an assembly with an RDF of 0,68

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. [1 094 A].

Figure E.2 – Example 1: Table E.1 – Functional unit loading for an assembly with a rated diversity factor of 0,68

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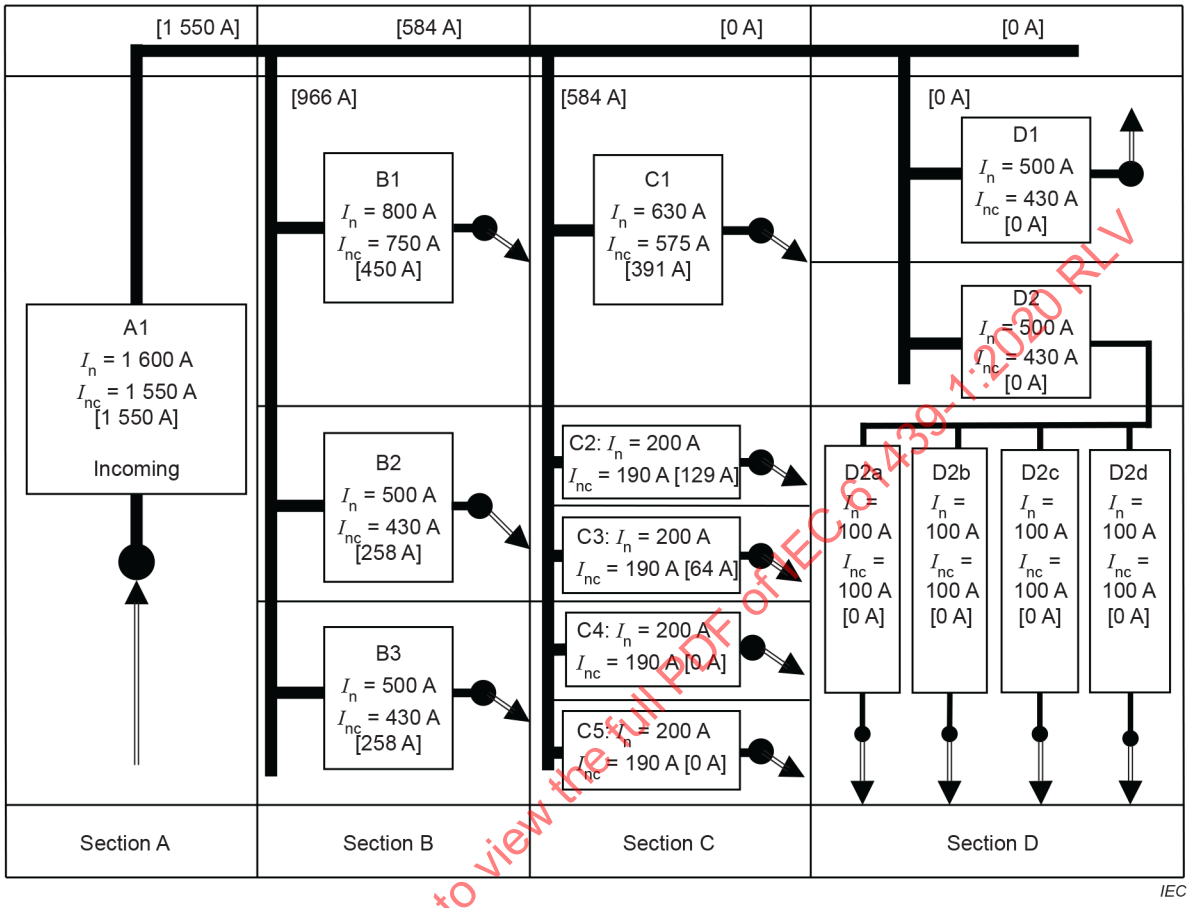
E.2.3 Example of an assembly with RDF declared for each section

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

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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).

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6 Annex F is based on IEC TR 60664-2-1:2011.

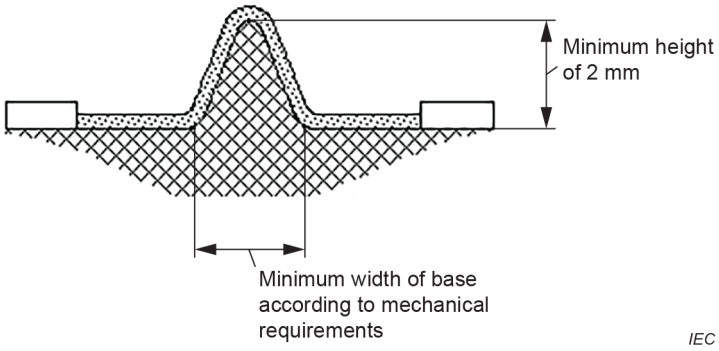
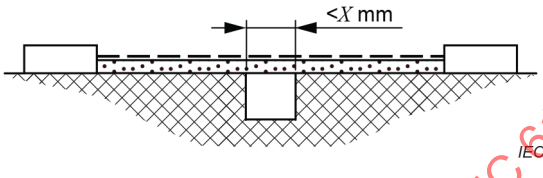
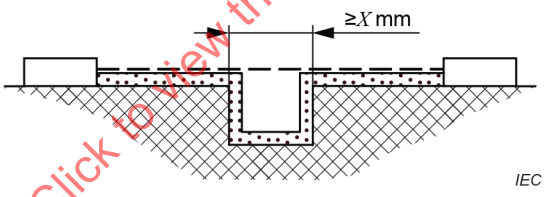


Figure F.1 a) – Measurement of ribs: examples



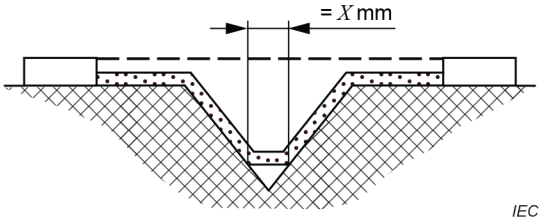
Condition:	This creepage distance path includes a parallel- or converging-sided groove of any depth with a width less than X mm.	Rule:	Creepage distance and clearances are measured directly across the groove as shown.

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

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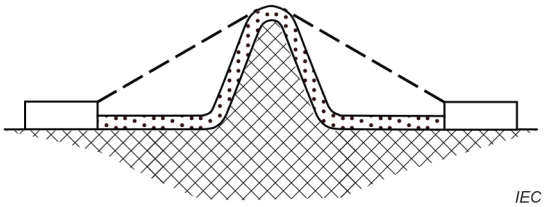
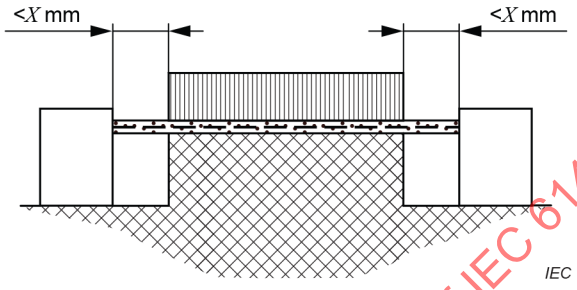


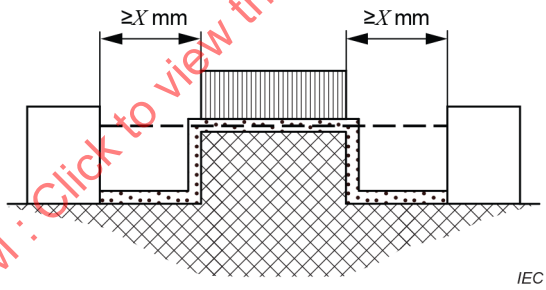
Condition: This creepage distance path includes a rib. Rule: Clearance is the shortest air path over the top of the rib. Creepage path follows the contour of the rib.

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

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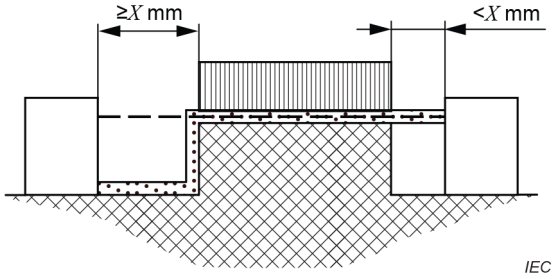
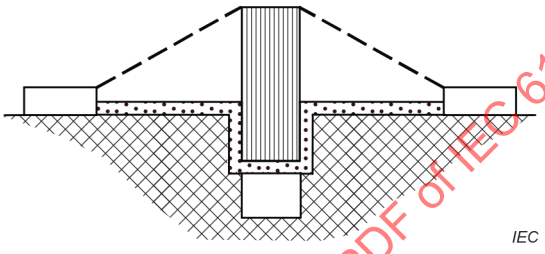


Condition: This creepage distance path includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearances and creepage distance paths are as shown.

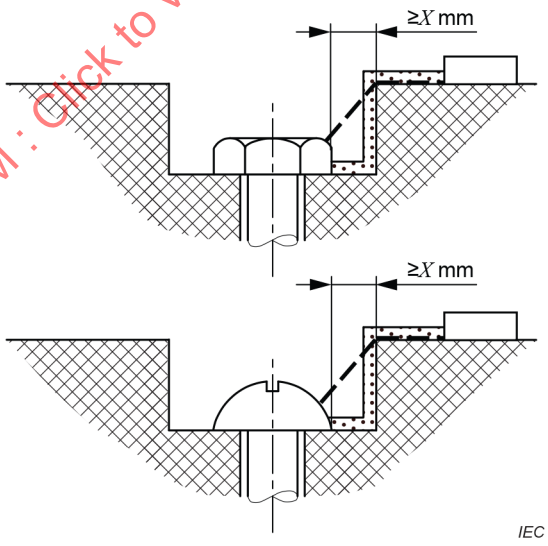
Figure F.1 h) – Example 7



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

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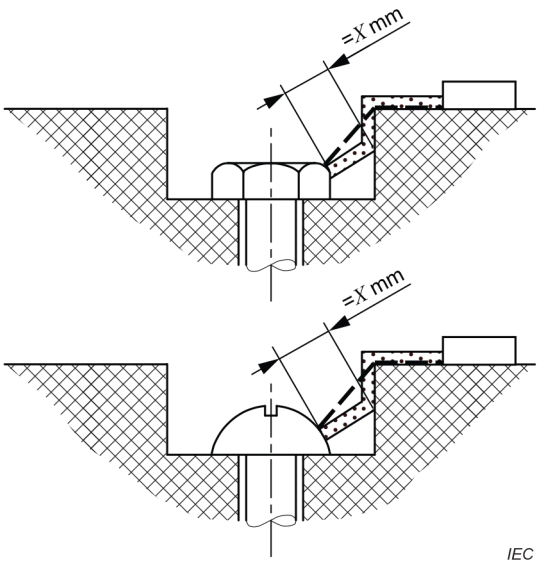
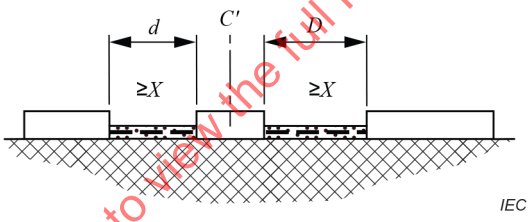


Condition: Gap between head of screw and wall of recess too narrow to be taken into account.

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

– – – – clearance

creepage distance

Figure F.1 – Measurement of clearance and creepage distances

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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.

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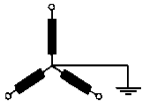
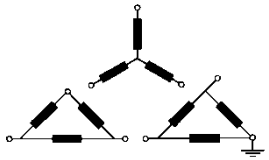
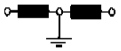
7 Annex G is based on Annex H of IEC 60947-1:2020.

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	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
					Origin of installation (service entrance) level	Distribution circuit level	Load (appliance, equipment) level	Specially protected level
V	AC RMS	AC RMS	AC RMS or DC	AC RMS or DC				
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

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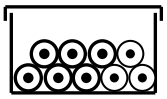
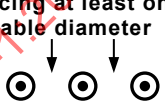
Annex H
(informative)

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		 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	Resistance of conductor at 20°C, R_{20} [a]	Max. operating current, I_{max} [b]	Power-losses per conductor, P_v	Max. operating current, I_{max} [c]	Power-losses per conductor, P_v	Max. operating current, I_{max} [d]	Power-losses per conductor, P_v
mm²	mΩ/m	A	W/m	A	W/m	A	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

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[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.

$$I_{max} = I_{30} \times k_1 \times k_2$$

$$P_v = I_{max}^2 \times R_{20} \times \left[1 + \alpha \times (T_c - 20\,°C)\right]$$

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.

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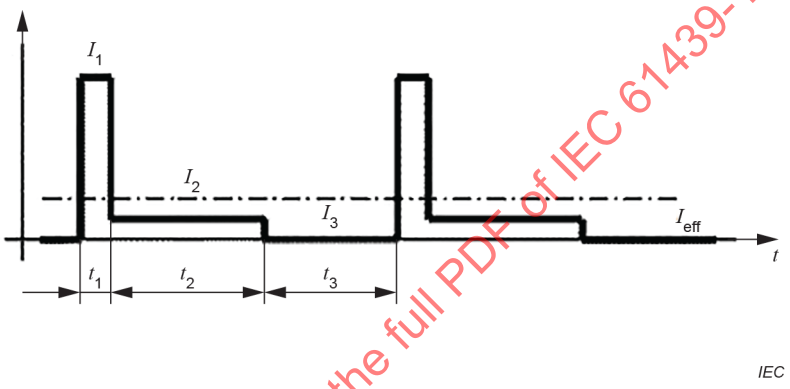
Annex I
(informative)

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

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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

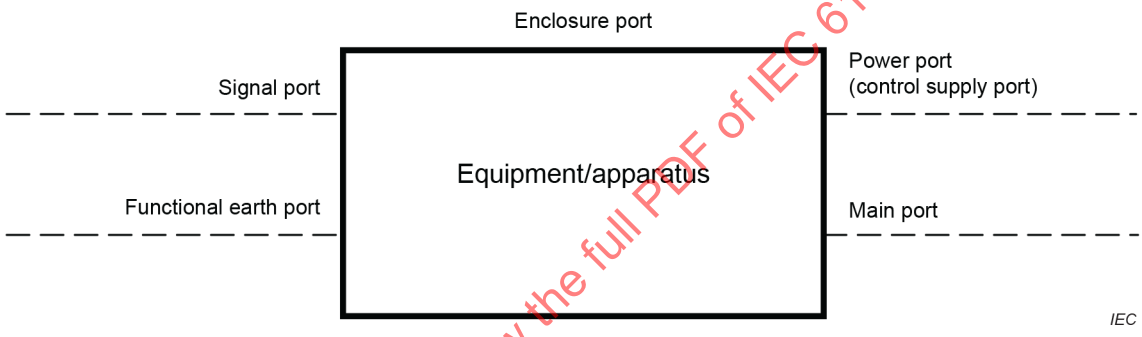

Figure J.1 – Examples of ports

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]

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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.

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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.

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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.

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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] 0 % during 0,5 cycle and 1 cycle 70 % during 25 / 30 cycles	Class 3 [c, d, e] 0 % during 0,5 cycle and 1 cycle 40 % during 10 / 12 cycles 70 % during 25 / 30 cycles 80 % during 250 / 300 cycles	C C B 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.

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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.

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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.

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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.

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NOTE 1 The operating current values given in Table K.1 only apply for the specific bar configurations given.

$$P_V = \frac{I^2 \times k_3}{\kappa \times A} \times \left[1 + \alpha \times (T_c - 20\,°C)\right]$$

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, $\kappa = 56 \dfrac{\text{m}}{\Omega \times \text{mm}^2}$;

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.

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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.

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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,

c) 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.

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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

It is the manufacturer's responsibility to select the appropriate method for temperature-rise verification.

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).

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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.

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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

L.4.1 General

Various methods of verifying temperature-rise performance by calculation are included within this document.

L.4.2 Single compartment assembly with a rated current (I_{nA}) not exceeding 630 A

This is a very simple method of temperature-rise verification that requires confirmation that the total power loss of the components and conductors within the assembly do not exceed the known power dissipation capability of the enclosure. The scope of this approach is very limited and in order that there are no difficulties with hot spots, all components should be de-rated to 80 % of their free air current rating or less.

L.4.3 Assembly with rated currents (I_{nA}) not exceeding 1 600 A

Temperature-rise verification is by calculation in accordance with IEC TR 60890:2014 with additional margins. The scope of this approach is limited to an assembly rating, I_{nA}, of 1 600 A, components are de-rated to 80 % of their free air rating or less, and any horizontal partitions should have, as a minimum, a 50 % open area.

L.5 Verification by comparison with a reference design

This document allows, in clearly defined circumstances, for the derivation of ratings from similar variants that have been verified by test. For example, if the current rating of a double lamination busbar has been established by test, it is acceptable to assign a rating equal to 50 % of the tested arrangement to a busbar comprising a single lamination with the same width and thickness as the tested laminations, when all other considerations are the same.

The rating of all circuits within a group of comparable functional units (all devices shall be of the same frame size and belong to the same series) can be derived from a single temperature-rise test on the critical variant within the group. An example of this may be to test a nominal 250 A outgoing circuit-breaker and establish a rating for it in the assembly. Then, assuming the same frame size breaker is being considered and other specified conditions are met, verify by calculation the rating of a nominal 160 A circuit-breaker within the same enclosure.

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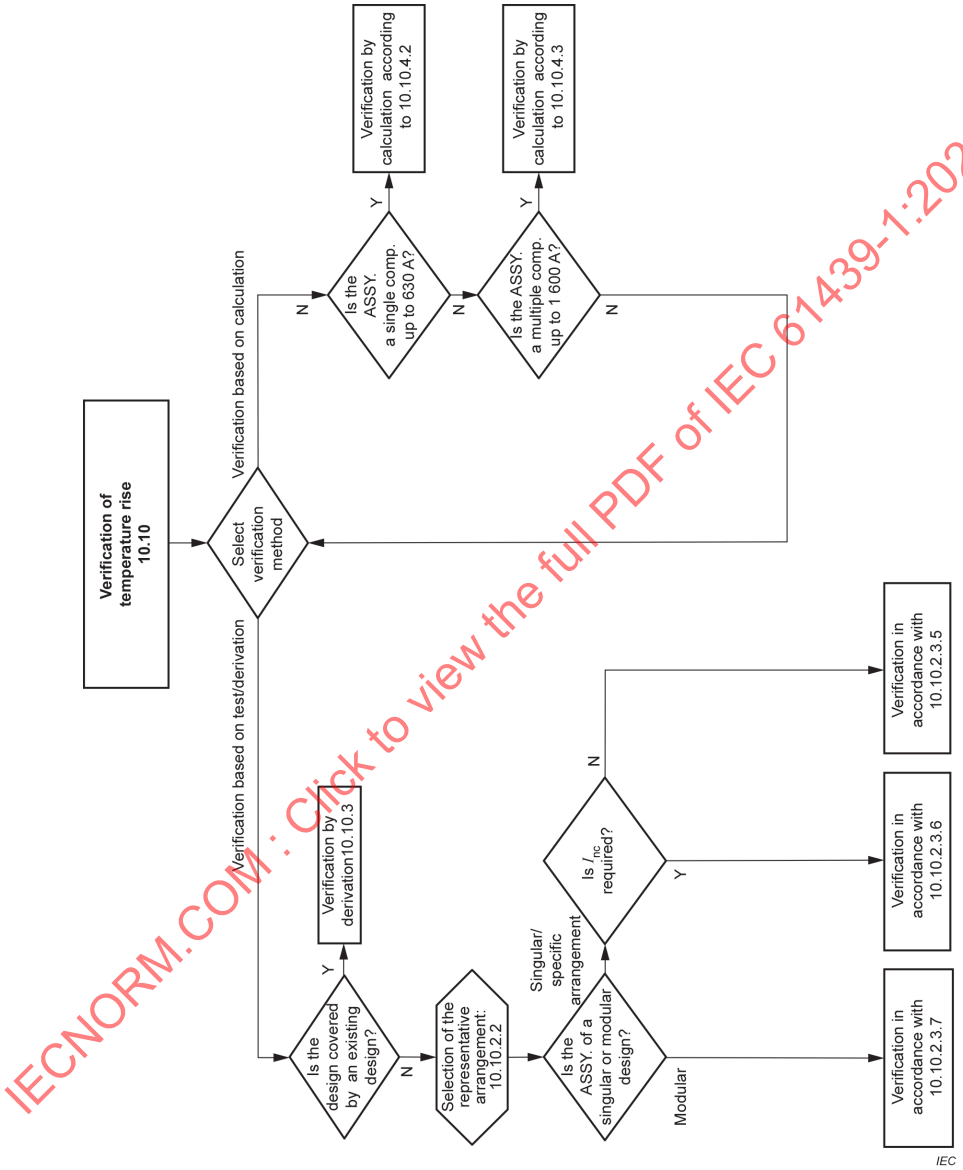
In respect of temperature-rise, there are very strict design rules that permit the substitution of a device with a similar device from another series or even another make, without retesting. In this case, in addition to the physical arrangement being essentially the same, the power loss and terminal temperature-rise of the substitute device, when it is tested in accordance with its own product standard, should not be higher than those of the original device.

When considering device substitution, all other performance criteria, in particular that dealing with short-circuit capability, should be considered and satisfied, in accordance with this document, before an assembly is deemed to be verified.



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Key

ASSY. = assembly

Comp. = compartment

Figure L.1 – Verification of temperature-rise

Annex M
(normative)

Verification of the short-circuit withstand strength of busbar structures by comparison with a reference design by calculation

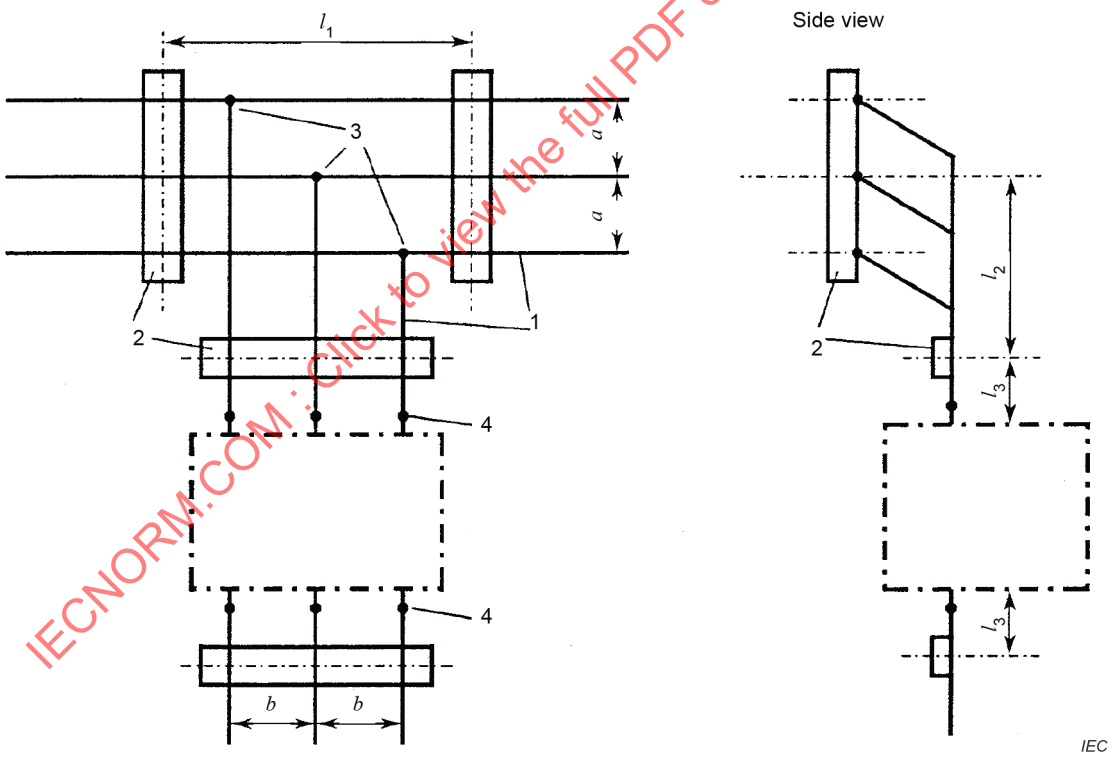
M.1 General

Annex M describes a method for assessing the short-circuit withstand strength of busbar structures of an assembly by a comparison of the assembly to be assessed with an assembly already verified by test (see 10.11.5).

M.2 Terms and definitions

For the purposes of Annex M, the following terms and definitions apply.

M.2.1
tested busbar structure
TS
structure whose arrangement and equipment are documented by drawings, parts lists and descriptions in the test certificate (Figure M.1)



Key

1	busbar
2	support
3	busbar connection
4	equipment connection
a, b, l	distances

Figure M.1 – Tested busbar structure (TS)

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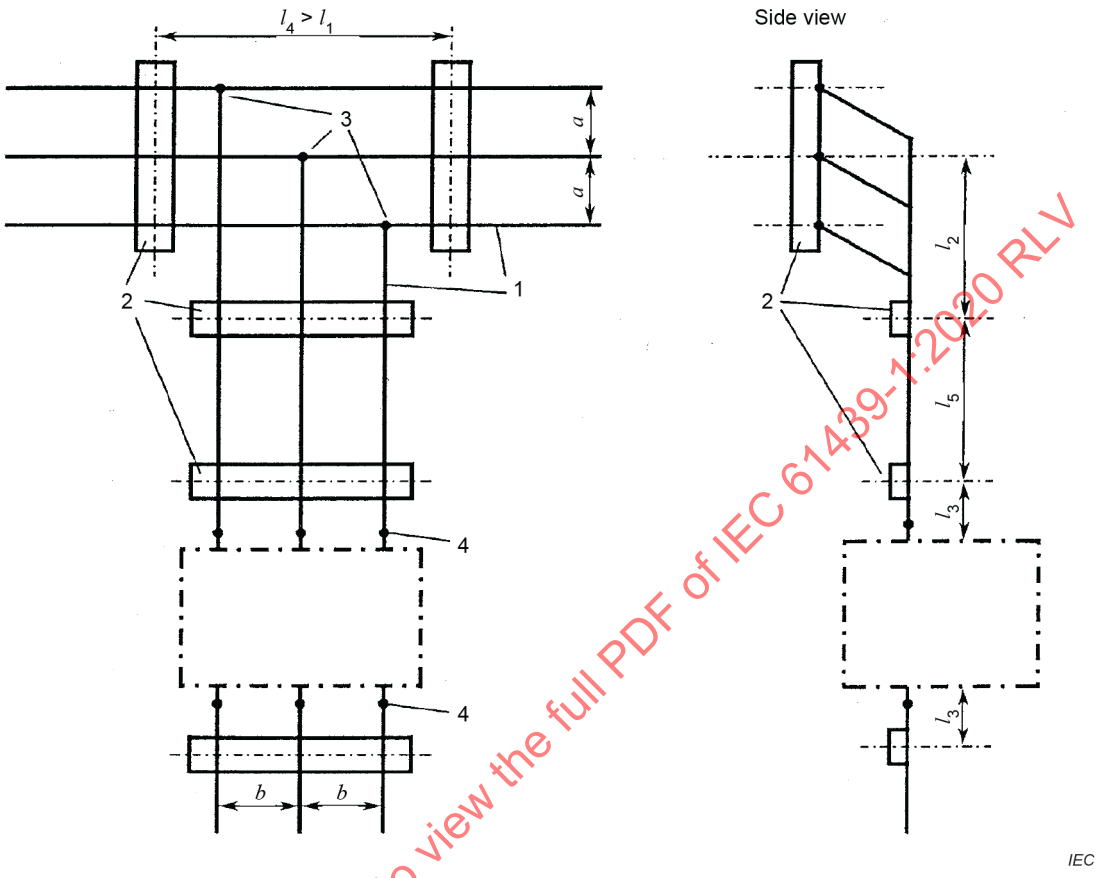
M.2.2
non tested busbar structure
NTS
structure which requires verification of short-circuit withstand strength (Figure M.2)



Key

1	busbar
2	support
3	busbar connection
4	equipment connection
a, *b*, *l*	distances

Figure M.2 – Non tested busbar structure (NTS)

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M.3 Method of verification

The short-circuit withstand strength of a derived busbar structure, i.e. an NTS, is verified from a tested busbar structure (TS) by applying calculations according to IEC 60865-1:2011 to both structures. The short-circuit withstand strength of the NTS is considered verified if the calculations show that the NTS does not have to withstand higher mechanical and thermal stresses than the tested structure.

M.4 Conditions for application

M.4.1 General

Changes of parameters, such as busbar clearances, busbar cross-section and busbar configuration are permissible only in so far as the following conditions in M.4.2 to M.4.7 are adhered to.

M.4.2 Peak short-circuit current

The short-circuit current may be changed only to lower values.

M.4.3 Thermal short-circuit strength

The thermal short-circuit strength of an NTS shall be verified by calculations according to IEC 60865-1:2011. The calculated temperature-rise of the NTS shall not be higher than that of the TS.

M.4.4 Busbar supports

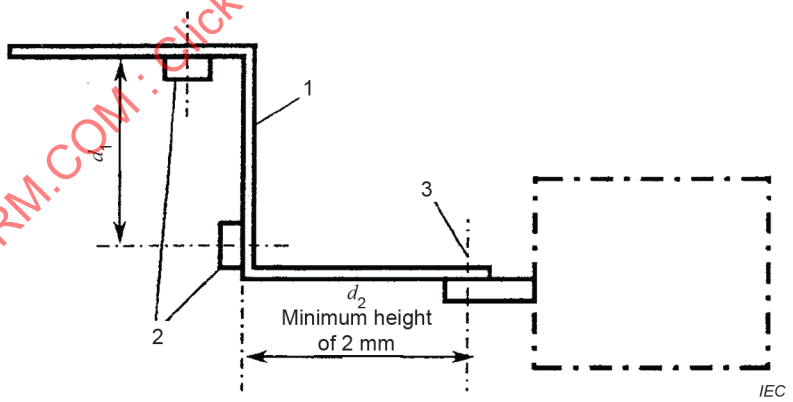
Changes of material or shape of supports taken from an assembly verified by test are not permitted. However, other supports may be used but they shall have been previously tested for the required mechanical strength with a short-circuit test in a representative arrangement.

M.4.5 Busbar connections, equipment connections

The type of busbar and equipment connections shall have been previously verified by test.

M.4.6 Angular busbar configurations

IEC 60865-1:2011 is applicable only to straight busbar configurations. Angular busbar configurations may be considered as a series of straight configurations when supports are provided at the corners (see Figure M.3).



Key

1 busbar

2 support

3 equipment connection

d support distance

Figure M.3 – Angular busbar configuration with supports at the corners

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M.4.7 Calculations with special regard to conductor oscillation

For calculations in conformity with IEC 60865-1:2011 on the tested structure (TS), the following values of the factors V_σ, $V_{\sigma s}$ and V_F shall be used:

$$V_\sigma = V_{\sigma s} = V_F = 1{,}0$$

where

V_σ is the ratio between dynamic and static main conductor stress;

$V_{\sigma s}$ is the ratio between dynamic and static sub-conductor stress;

V_F is the ratio between dynamic and static force on support.

For the NTS:

$V_\sigma = V_{\sigma s} = 1{,}0$ and

V_F is found from calculations in accordance with IEC 60865-1:2011, but $V_F < 1{,}0$ is to be replaced by $V_F = 1{,}0$.

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Annex N
(informative)

List of notes concerning certain countries

Subclause	Text
3.1.14	In the Russian Federation, the term "line conductor" is defined differently: **line conductor** (L) conductor which is energized under normal conditions and used for the transmission of electric energy but which is not a neutral or mid conductor
3.1.14	In the Russian Federation, the following definition applies: **earthed line conductor** (LE) line conductor which has an electrical connection with a local earth
3.1.14	In the Russian Federation, the following definition applies: **phase conductor** line conductor which is used in an AC electric circuit
3.1.14	In the Russian Federation, the following definition applies: **pole conductor** line conductor which is used in a DC electric circuit
3.4.11	In the Russian Federation, the term (electrically) protective barrier is defined differently: **(electrically) protective barrier** part providing protection against contact with hazardous-live-parts from any usual direction of access
3.4.12	In the Russian Federation, the term (electrically) protective obstacle is defined differently: (electrically) **protective obstacle** part preventing unintentional contact with hazardous-live-parts, but not preventing such contact by deliberate action
3.7	In the Russian Federation, the term current-carrying part is defined: **earth fault** occurrence of an accidental conductive path between a live part and the Earth or exposed-conductive-part, or extraneous-conductive-part, or protective conductor
3.7.1	Add the following after Note 1 to entry: Note 2 to entry: In Norway, the neutral is required to be switched for isolation, and disconnection of the neutral may also be necessary for protection against overcurrents.
3.7.3	In the Russian Federation, the term "exposed-conductive-part" is defined differently: **exposed-conductive-part** conductive part of equipment, which can be touched and which is not live under normal conditions, but which can become live when basic insulation fails
3.7.4	In the Russian Federation, the term "protective conductor" is defined differently: **protective conductor** (PE) conductor provided for purposes of electrical safety, for example protection against electric shock
3.7.5	In the Russian Federation, the term "neutral conductor" is defined differently: **neutral conductor** (N) conductor electrically connected to the neutral and used for the transmission of electric energy

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Subclause	Text
3.7.7	In the Russian Federation, the following definition applies: **earth-fault current** current flowing to the earth, exposed-conductive-part, extraneous-conductive-part or protective conductor due to an insulation fault of a live part
3.7.8	In the Russian Federation, the term "basic protection" is defined differently: **basic protection** protection against electric shock under normal conditions
3.7.9	In the Russian Federation, the term "basic insulation" is defined differently: **basic insulation** insulation of live-parts which provides basic protection
3.7.11	In the Russian Federation, the term "protective extra low-voltage system" is defined differently: **protective extra low-voltage system** (PELV system) electric system in which the voltage cannot exceed the value of extra-low-voltage: – under normal conditions and – under single fault conditions, except earth faults in other electric circuits
3.7.12	In the Russian Federation, the term "safety extra low-voltage system" is defined differently: **safety extra low-voltage system** (SELV system) electric system in which the voltage cannot exceed the value of extra-low-voltage: – under normal conditions and – under single fault conditions, including earth faults in other electric circuits
3.7.18	In the Russian Federation, the term "mid conductor" is defined differently: **mid conductor** (M) conductor electrically connected to the mid live part of the DC electrical system and used for the transmission of electric energy
3.7.24	In the Russian Federation, the term "class I equipment" is defined differently: **class I equipment** electrical equipment in which a basic insulation is used as a protective provision for a basic protection, and a protective bonding is used as a protective provision for a fault protection Note to entry: The protective bonding is electrical connection of an exposed-conductive-part of the class I electrical equipment to a protective conductor.
3.7.25	In the Russian Federation, the term "class II equipment" is defined differently: **class II equipment** electrical equipment in which a basic insulation is used as a protective provision for a basic protection, and a supplementary insulation is used as a protective provision for a fault protection, or in which the basic protection and the fault protection are provided by a reinforced insulation.
3.8.6	In the Russian Federation, the term short-circuit current is defined differently: **short-circuit current** overcurrent in an electric circuit under short-circuit
3.10.2	Add the following note to entry. Note 2 to entry: In the UK, when the party installing the assembly completes the final assembly on site by the installation of equipment strictly in accordance with the assembly manufacturer's instructions, they are not necessarily considered to be the assembly manufacturer.

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<table>
<tr><th>Subclause</th><th>Text</th></tr>
<tr><td>3.10.2</td><td>Add a note,

Note 3 to entry: Within the European Union the assembly manufacturer is defined as the manufacturer in respect of relevant Directive, e.g. Low-voltage Directive, EMC Directive.</td></tr>
<tr><td>5.4</td><td>Add the following note after the last paragraph:

NOTE 3 In Norway, the overload protection of conductors shall not solely be based on the use of diversity factors of the downstream circuits.</td></tr>
<tr><td>6.1</td><td>Add the following NOTE 2 after the note:

NOTE 2 In Norway climate conditions deviate from those specified in this document (see 7.1.1) and the assembly is not intended for a fixed location.</td></tr>
<tr><td>7.1.1</td><td>Add the following note:

NOTE In Norway, assemblies suitable for normal operation at a lower ambient air temperature than −25 °C shall also comply with the requirements of this document.</td></tr>
<tr><td>8.2.2</td><td>Add the following after the first paragraph:

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 assembly. 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</td></tr>
<tr><td>8.3.1</td><td>Add the following:

In the United States of America (USA) and Mexico National Electrical Codes are used to specify minimum creepage distances. In the USA, National Electric Code NFPA 70, Article 408.56 is applicable. In Mexico NOM-001-SEDE is applicable. For applications in Canada minimum creepage distances are specified in the Canadian Electrical Code, Part 2 Product Safety Standards.

Minimum clearance and creepage distances for North American region are given in Table 1 and Table 2, respectively.

Table 1 – Minimum clearances in air
<table>
<tr><th rowspan="2">Rated operational voltage
V</th><th colspan="2">Minimum clearances
mm</th></tr>
<tr><th>Phase to phase</th><th>Phase to earth</th></tr>
<tr><td>(150)[a] 125 or less</td><td>12,7</td><td>12,7</td></tr>
<tr><td>(151)[a] 126 to 250</td><td>19,1</td><td>12,7</td></tr>
<tr><td>251 to 600</td><td>25,4</td><td>25,4</td></tr>
<tr><td colspan="3">[a] Values in brackets are applicable in Mexico.</td></tr>
</table>
Table 2 – Minimum creepage distances
<table>
<tr><th rowspan="2">Rated operational voltage
V</th><th colspan="2">Minimum creepage distances
mm</th></tr>
<tr><th>Phase to phase</th><th>Phase to earth</th></tr>
<tr><td>(150)[a] 125 or less</td><td>19,1</td><td>12,7</td></tr>
<tr><td>(151)[a] 126 to 250</td><td>31,8</td><td>12,7</td></tr>
<tr><td>251 to 600</td><td>50,8</td><td>25,4</td></tr>
<tr><td colspan="3">[a] Values in brackets are applicable in Mexico.</td></tr>
</table>
This is not a complete and exhaustive listing of all regulations that are specific to the North American marketplace.</td></tr>
<tr><td>8.4.2.3</td><td>Add the following note after the end of item b):

NOTE In Norway, the neutral conductor shall be isolated or switched.</td></tr>
</table>

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<table>
<tr><th>Subclause</th><th>Text</th></tr>
<tr><td>8.4.3.1</td><td>Add the following note after the end of item b):

NOTE In the Netherlands, it is permitted to use overcurrent protective device for a TT system.</td></tr>
<tr><td>8.6.6</td><td>Add the following note after the last paragraph:

NOTE In the USA, Australia, South Africa, Korea, other colours for the neutral conductor are required.</td></tr>
<tr><td>8.8</td><td>Add the following note after the fifth paragraph:

NOTE 1 In the United States of America (USA) and Mexico, National Electrical Codes should be used for determining the minimum wire bending space requirements. In the USA NFPA 70, Article 312 is applicable. In Mexico, NOM-001-SEDE is applicable. In Canada, wire space and wire bending space is required in the Canadian Electrical Code, Part 2 Standard, C22.2 No. 0.12, Wire Space and Wire Bending Space in Enclosures for Equipment Rated 750 V or Less.</td></tr>
<tr><td>9.2</td><td>Add the following:

In the United States of America (USA) and Mexico, National Electrical Codes, are used to specify maximum temperature-rises. In the USA, NFPA 70, Article 110.14C is applicable. In Mexico, NOM-001-SEDE is applicable. For these applications, temperature-rises shall be selected using the values given below. In Canada, maximum temperature-rise is prescribed in the Canadian Electrical Code, Part 2, Product Safety Standards.

These values are based upon the allowable rises permitted for the devices connected (wire connectors, cables, circuit-breakers, etc). In order to maintain the proper and safe performance of the entire electrical system, these shall be taken into account.

Table 3 – North American temperature-rise limits
<table>
<tr><th>Parts of assemblies</th><th>Temperature-rise
K</th></tr>
<tr><td>Unplated busbars</td><td>50</td></tr>
<tr><td>Plated busbars</td><td>65</td></tr>
<tr><td>Terminals except as covered below</td><td>50</td></tr>
<tr><td>Terminals for devices marked for use with 90 °C conductors, based upon 75 °C ampacity (current-carrying capacity)</td><td>60</td></tr>
<tr><td>Terminals for devices rated 110 A and less, if marked for use with 75 °C conductors</td><td>65</td></tr>
</table></td></tr>
</table>

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Subclause	Text
10.10.3.5	Add the following note after the last paragraph: NOTE In CO, AU and NZ, a similar device from another manufacturer can be substituted if the conditions of this clause are satisfied and the device rating does not exceed 3 150 A.
10.10.3.5	Add the following note after the last paragraph: NOTE In the US, a device within a circuit with a rated current I_{nc} not exceeding 1 200 A can be considered for substitution.
10.10.3.5	Add the following note after the last paragraph: NOTE In the US, no individual dimension and the overall dimension of the substitute device, height × width × depth, shall not exceed 110 % of the original device. In addition, when the substitution device is installed as intended in the assembly, the distance to adjacent devices shall not be less than 90 % of the distance for the original device.
10.10.3.5	Add the following note after the last paragraph: NOTE In Italy, the value of the devices terminals temperature-rise (when tested in accordance with the relevant product standard) is not significant to define if the substitution is possible, providing that both devices are totally fulfilling the product standards requirements.
10.11.5.4	Add the following note at the end of item b): NOTE In South Africa (ZA) the National Standard SANS 10142-1 for the *Wiring of Premises Part 1: Low-voltage installations*, requires that the supply voltage could be equal to 1,1 times the nominal voltage where the operational voltages are up to and including 525 V.
10.11.5.6.1	Add the following note at the end of the subclause: NOTE In South Africa (ZA), the allowable voltage variations require that the test voltage be equal to 1,1 times the nominal voltage.
Table 6	Add the following note to footnote b: NOTE In the United Kingdom (UK), where an installation conductor operates at a temperature exceeding 70 °C, it shall be ascertained that the equipment connected to the conductor is suitable for the resulting temperature at the connection. See IEC 60364-5-52:2009, Table 52.1. Installation circuit conductors having an in service operating temperature exceeding 70 °C shall not be connected to assemblies manufactured to a standard in this series unless; the circuit(s) in question is/are specifically agreed and recorded by the manufacture in the assembly documentation that, the above requirement has been verified by test.
Table 13	Replace the text of item 6 after the first paragraph with the following note: NOTE In Norway, if the short-circuit protective devices are not equivalent, they shall: • have a breaking capacity not less than the short-circuit rating of the assembly at the rated operational voltage of the assembly, and • 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, and • 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, and • have a heat dissipation less or equal to that of the reference design when applied for a current corresponding to the rated breaking capacity of the device, and • fulfil the requirements of coordination with upstream and downstream devices (see 9.3.4), if required, and • have the same arrangement as in the reference design.

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Subclause	Text
Table 13	Add in item 6 the following note: NOTE In Colombia (CO), South Africa (ZA), Singapore (SG), Australia (AU) and New Zealand (NZ) short-circuit protective devices from another manufacturer may be substituted if the conditions of Table 13 footnote a are satisfied and the substituting device has limitation characteristics (I^2t, I_{pk}) equal to or better than the verified substituted device.

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COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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ENSEMBLES D'APPAREILLAGE À BASSE TENSION –

Partie 1: Règles générales

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8) L'attention est attirée sur les références normatives citées dans cette publication. L'utilisation de publications référencées est obligatoire pour une application correcte de la présente publication.
9) L'attention est attirée sur le fait que certains des éléments de la présente Publication de l'IEC peuvent faire l'objet de droits de brevet. L'IEC ne saurait être tenue pour responsable de ne pas avoir identifié de tels droits de brevets et de ne pas avoir signalé leur existence.

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La Norme internationale IEC 61439-1 a été établie par le sous-comité 121B: Ensembles d'appareillages à basse tension, du comité d'études 121 de l'IEC: Appareillages et ensembles d'appareillages basse tension.

Cette troisième édition annule et remplace la deuxième édition parue en 2011. Elle constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

a) clarification du fait que les systèmes et matériels électroniques de conversion de puissance, les alimentations à découpage, les alimentations sans interruption et les systèmes d'entraînements électriques de puissance à vitesse variable sont soumis à essai

conformément à leur propre norme de produit, mais que lorsqu'ils sont incorporés dans des ensembles, l'incorporation est conforme à la série de normes IEC 61439;

b) introduction d'un courant assigné de groupe pour les circuits au sein d'un ensemble chargé et recentrage de la vérification de l'échauffement sur cette nouvelle caractéristique;

c) ajout d'exigences relatives au courant continu;

d) introduction du concept d'ensembles de classe I et de classe II en matière de protection contre les chocs électriques.

Le texte de cette Norme internationale est issu des documents suivants:

FDIS	Rapport de vote
121B/99/FDIS	121B/103/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette Norme internationale.

L'attention du lecteur est attirée sur le fait que l'Annexe N énumère tous les articles traitant des différences à caractère moins permanent inhérentes à certains pays, relatifs au présent document.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 61439, publiées sous le titre général *Ensembles d'appareillage à basse tension*, peut être consultée sur le site web de l'IEC.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "http://webstore.iec.ch" dans les données relatives au document recherché. A cette date, le document sera

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INTRODUCTION

Le but du présent document est d'harmoniser, autant que possible, l'ensemble des règles et des exigences de nature générale qui sont applicables aux ensembles d'appareillage à basse tension afin d'obtenir l'uniformité des exigences et de la vérification pour les ensembles et pour éviter toute vérification nécessaire selon d'autres normes. Toutes ces exigences relatives aux différentes normes applicables aux ensembles qui peuvent être considérées comme d'ordre général ont ainsi été rassemblées dans le présent document avec des aspects spécifiques présentant une portée et une application étendues, par exemple l'échauffement, les propriétés diélectriques, etc.

Pour chaque type d'ensemble d'appareillage à basse tension, seules deux normes principales sont nécessaires pour déterminer toutes les exigences et toutes les méthodes correspondantes de vérification:

– la norme de base (le présent document) désignée sous l'appellation "IEC 61439-1" dans les normes particulières couvrant les différents types d'ensembles d'appareillage à basse tension;

– la norme particulière applicable à un ensemble désignée ci-après également sous l'appellation norme d'ensemble applicable.

Pour qu'une règle générale s'applique à une norme d'ensemble, il convient de citer celle-ci explicitement en indiquant le présent document suivi du numéro de l'article ou du paragraphe correspondant, par exemple "IEC 61439-1:2020, 9.1.3".

Une norme d'ensemble particulière peut ne pas exiger et donc ne pas renvoyer à une règle générale lorsque cette règle n'est pas applicable, ou elle peut ajouter des exigences si la règle générale est considérée comme inappropriée dans le cas particulier traité, mais elle ne peut pas introduire de divergences sauf si une justification technique importante est donnée dans la norme d'ensemble particulière.

Lorsque, dans le présent document, des références de mise en correspondance sont faites à un autre article, la référence doit s'appliquer à l'article considéré tel que modifié par la norme d'ensemble particulière, le cas échéant.

Les exigences du présent document qui sont sujettes à un accord entre le constructeur d'ensembles et l'utilisateur sont rassemblées à l'Annexe C (informative). Cette liste facilite également la fourniture des informations sur les conditions de base et les spécifications supplémentaires de l'utilisateur afin de permettre la conception, la mise en œuvre et l'utilisation correctes de l'ensemble.

Pour la série IEC 61439, les parties suivantes sont publiées:

a) IEC 61439-1: Règles générales;

b) IEC 61439-2: Ensembles d'appareillage de puissance (ensembles EAP) [1];

c) IEC 61439-3: Tableaux de répartition destinés à être utilisés par des personnes ordinaires (DBO);

d) IEC 61439-4: Exigences particulières pour ensembles de chantiers (EC);

e) IEC 61439-5: Ensembles pour réseaux de distribution publique;

f) IEC 61439-6: Systèmes de canalisation préfabriquée;

g) IEC 61439-7: Ensembles pour installations publiques particulières telles que les marinas, les terrains de camping, les marchés et les emplacements analogues, et pour les bornes de charge de véhicules électriques;

[1] L'IEC 61439-2 comprend les exigences pour les ensembles destinés aux installations photovoltaïques.

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h) IEC TR 61439-0: Guidance to specifying assemblies (disponible en anglais seulement).

Cette liste n'est pas exhaustive; des parties supplémentaires peuvent être élaborées en fonction des besoins.

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ENSEMBLES D'APPAREILLAGE À BASSE TENSION –

Partie 1: Règles générales

1 Domaine d'application

La présente partie de l'IEC 61439 formule les définitions générales et les conditions d'emploi, les exigences de construction, les caractéristiques techniques et les exigences de vérification pour les ensembles d'appareillage à basse tension.

NOTE Dans le présent document, le terme ensemble(s) (voir 3.1.1) est utilisé pour désigner un ou des ensembles d'appareillage à basse tension.

Dans le but de déterminer la conformité de l'ensemble, les exigences de la partie applicable de la série IEC 61439 (à partir de la Partie 2), s'appliquent, de même que les exigences citées dans le présent document. Pour les ensembles non couverts par les parties à partir de la Partie 3, la Partie 2 s'applique.

Le présent document s'applique, uniquement lorsque la norme d'ensemble applicable l'exige, aux ensembles tels que décrits ci-après:

– les ensembles dont la tension assignée ne dépasse pas 1 000 V en courant alternatif ou 1 500 V en courant continu;
– les ensembles conçus pour une fréquence nominale de l'alimentation ou des alimentations d'entrée ne dépassant pas 1 000 Hz;
– les ensembles conçus pour des applications d'intérieur ou d'extérieur;
– les ensembles fixes ou mobiles, avec ou sans enveloppe;
– les ensembles destinés à être utilisés avec des équipements conçus pour la production, le transport, la distribution et la conversion de l'énergie électrique et la commande des matériels consommant de l'énergie électrique.

Le présent document ne s'applique pas aux appareils considérés individuellement et aux composants indépendants, tels que démarreurs de moteur, fusibles-interrupteurs, systèmes et appareils électroniques de conversion de puissance (SECP), alimentations à découpage (SMPS, *Switch Mode Power Supplies*), alimentations sans interruption (ASI), modules d'entraînement principaux (MEP), modules d'entraînement complets (MEC), entraînements électriques de puissance (PDS, *Power Drive System*) à vitesse variable et autres matériels électroniques qui sont conformes aux normes de produit les concernant. Le présent document décrit l'intégration d'appareils et de constituants indépendants dans un ensemble ou dans une enveloppe vide formant un ensemble.

Pour certaines applications impliquant, par exemple, des atmosphères explosives ou la sécurité fonctionnelle, il peut être nécessaire de satisfaire aux exigences d'autres normes ou d'une autre législation, en plus de celles spécifiées dans la série IEC 61439.

2 Références normatives

Les documents suivants sont cités dans le texte de sorte qu'ils constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60068-2-2:2007, *Essais d'environnement – Partie 2-2: Essais – Essai B: Chaleur sèche*

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IEC 60068-2-11:1981, *Essais fondamentaux climatiques et de robustesse mécanique – Partie 2-11: Essais – Essai Ka: Brouillard salin*

IEC 60068-2-30:2005, *Essais d'environnement – Partie 2-30: Essais – Essai Db: Essai cyclique de chaleur humide (cycle de 12 h + 12 h)*

IEC 60073:2002, *Principes fondamentaux et de sécurité pour l'interface homme-machine, le marquage et l'identification – Principes de codage pour les indicateurs et les organes de commande*

IEC 60085:2007, *Isolation électrique – Evaluation et désignation thermiques*

IEC 60364 (toutes les parties), *Installations électriques à basse tension*

IEC 60364-4-41:2005, *Installations électriques à basse tension – Partie 4-41: Protection pour assurer la sécurité – Protection contre les chocs électriques*
IEC 60364-4-41:2005/AMD1:2017

IEC 60364-5-51:2005, *Installations électriques des bâtiments – Partie 5-51: Choix et mise en œuvre des matériels électriques – Règles communes*

IEC 60364-5-52:2009, *Installations électriques à basse tension – Partie 5-52: Choix et mise en œuvre des matériels électriques – Canalisations*

IEC 60439 (toutes les parties), *Ensembles d'appareillage à basse tension* [2]

IEC 60445:2017, *Principes fondamentaux et de sécurité pour les interfaces homme-machines, le marquage et l'identification – Identification des bornes de matériels, des extrémités de conducteurs et des conducteurs*

IEC 60447:2004, *Principes fondamentaux et de sécurité pour l'interface homme-machine, le marquage et l'identification – Principes de manœuvre*

IEC 60529:1989, *Degrés de protection procurés par les enveloppes (Code IP)* [3]
IEC 60529:1989/AMD1:1999
IEC 60529:1989/AMD2:2013

IEC 60695-2-10:2013, *Essais relatifs aux risques du feu – Partie 2-10: Essais au fil incandescent/chauffant – Appareillage et méthode commune d'essai*

IEC 60695-2-11:2014, *Essais relatifs aux risques du feu – Partie 2-11: Essais au fil incandescent/chauffant – Méthode d'essai d'inflammabilité pour produits finis (GWEPT)*

IEC 60695-2-12, *Essais relatifs aux risques du feu – Partie 2-12: Essais au fil incandescent/chauffant – Méthode d'essai d'indice d'inflammabilité au fil incandescent (GWFI) pour matériaux*

IEC 60865-1:2011, *Courants de court-circuit – Calcul des effets – Partie 1: Définitions et méthodes de calcul*

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2 Supprimée. La série IEC 60439 a été annulée et remplacée par la série IEC 61439.

3 Il existe une édition 2.2 consolidée (2013) de ce document, qui comprend l'IEC 60529 (1989), son Amendement 1 (1999) et son Amendement 2 (2013).

IEC TR 60890:2014, *Méthode de vérification par calcul des échauffements pour les ensembles d'appareillage à basse tension*

IEC 60947-4:1:2018, *Appareillage à basse tension – Partie 4-1: Contacteurs et démarreurs de moteurs – Contacteurs et démarreurs électromécaniques*

IEC 61000-4-2:2008*, Compatibilité électromagnétique (CEM) – Partie 4-2: Techniques d'essai et de mesure – Essai d'immunité aux décharges électrostatiques*

IEC 61000-4-3:2006, *Compatibilité électromagnétique (CEM) – Partie 4-3: Techniques d'essai et de mesure – Essai d'immunité aux champs électromagnétiques rayonnés aux fréquences radioélectriques* [4]
IEC 61000-4-3:2006/AMD1:2007
IEC 61000-4-3:2006/AMD2:2010

IEC 61000-4-4:2012, *Compatibilité électromagnétique (CEM) – Partie 4-4: Techniques d'essai et de mesure – Essais d'immunité aux transitoires électriques rapides en salves*

IEC 61000-4-5:2014, *Compatibilité électromagnétique (CEM) – Partie 4-5: Techniques d'essai et de mesure – Essai d'immunité aux ondes de choc* [5]
IEC 61000-4-5:2014/AMD1:2017

IEC 61000-4-6:2013, *Compatibilité électromagnétique (CEM) – Partie 4-6: Techniques d'essai et de mesure – Immunité aux perturbations conduites, induites par les champs radioélectrique*s

IEC 61000-4-8:2009, *Compatibilité électromagnétique (CEM) – Partie 4-8: Techniques d'essai et de mesure – Essai d'immunité au champ magnétique à la fréquence du réseau*

IEC 61000-4-11:2004, *Compatibilité électromagnétique (CEM) – Partie 4-11: Techniques d'essai et de mesure – Essais d'immunité aux creux de tension, coupures brèves et variations de tension*
IEC 61000-4-11:2004/AMD1:2017

IEC 61000-6-3:2006, *Compatibilité électromagnétique (CEM) – Partie 6-3: Normes génériques – Norme sur l'émission pour les environnements résidentiels, commerciaux et de l'industrie légère*
IEC 61000-6-3:2006/AMD1:2010

IEC 61000-6-4:2018, *Compatibilité électromagnétique (CEM) – Partie 6-4: Normes génériques – Norme sur l'émission pour les environnements industriels*

IEC 61082-1:2014, *Etablissement des documents utilisés en électrotechnique – Partie 1: Règles*

IEC 61180:2016, *Techniques des essais à haute tension pour matériel à basse tension – Définitions, exigences relatives aux essais, matériel d'essai*

IEC 61439 (toutes les parties*), Ensembles d'appareillage à basse tension*

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4 Il existe une édition 3.2 consolidée (2010) qui comprend l'IEC 61000-4-3 (2006), l'Amendement 1 (2007) et l'Amendement 2 (2010).

5 Il existe une édition 3.1 consolidée (2017) qui comprend l'IEC 61000-4-5 (2014) et son Amendement 1 (2017).

IEC 61921:2017, *Condensateurs de puissance – Batteries de compensation du facteur de puissance basse tension*

IEC 62208:2011, *Enveloppes vides destinées aux ensembles d'appareillage à basse tension – Règles générales*

IEC 81346-1:2009, *Systèmes industriels, installations et appareils, et produits industriels – Principes de structuration et désignations de référence – Partie 1: Règles de base*

IEC 81346-2:2019, *Systèmes industriels, installations et appareils, et produits industriels – Principes de structuration et désignations de référence – Partie 2: Classification des objets et codes pour les classes*

CISPR 11:2015, *Appareils industriels, scientifiques et médicaux – Caractéristiques de perturbations radioélectriques – Limites et méthodes de mesure*
CISPR 11:2015/AMD1:2016
CISPR 11:2015/AMD2:2019

CISPR 32:2015, *Compatibilité électromagnétique des équipements multimédia – Exigences d'émission*
CISPR 32:2015/AMD1:2019

ISO 178:2010, *Plastiques – Détermination des propriétés en flexion*
ISO 178:2010/AMD1:2013

ISO 179-1:2010, *Plastiques – Détermination des caractéristiques au choc Charpy – Partie 1: Essai de choc non instrumenté*

ISO 179-2:1997, *Plastiques – Détermination des caractéristiques au choc Charpy – Partie 2: Essai de choc instrumenté*
ISO 179-2:1997/AMD1:2011

ISO 2409:2013, *Peintures et vernis – Essai de quadrillage*

ISO 4628-3:2016, *Peintures et vernis – Evaluation de la dégradation des revêtements – Désignation de la quantité et de la dimension des défauts, et de l'intensité des changements uniformes d'aspect – Partie 3: Evaluation du degré d'enrouillement*

ISO 4892-2:2013, *Plastiques – Méthodes d'exposition à des sources lumineuses de laboratoire – Partie 2: Lampes à arc au xénon*

ISO 7010, *Symboles graphiques – Couleurs de sécurité et signaux de sécurité – Signaux de sécurité enregistrés*

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3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obp

3.1 Termes généraux

3.1.1
ensemble d'appareillage à basse tension
ensemble
combinaison d'un ou de plusieurs appareils de connexion à basse tension avec les matériels associés de commande, de mesure, de signalisation, de protection, de régulation, avec toutes leurs liaisons internes mécaniques et électriques et tous leurs éléments de structures, tels que définis par le constructeur d'origine et pouvant être assemblés conformément aux instructions du constructeur d'origine

Note 1 à l'article: Dans le présent document, le terme ensemble(s) est utilisé pour désigner un ou des ensembles d'appareillage à basse tension.

Note 2 à l'article: Le terme "appareil de connexion" comprend les appareils de connexion mécaniques et les appareils de connexion à semiconducteurs, par exemple les dispositifs de démarrage progressif, les relais à semiconducteurs, les convertisseurs de fréquence. Les circuits auxiliaires peuvent également comprendre des appareils électromécaniques, par exemple des relais de commande, des blocs de jonction, et des appareils électroniques, par exemple des appareils de commande de moteur électroniques, des appareils de mesure et de protection électroniques, un bus de communication, des systèmes d'automates programmables.

3.1.2
système d'ensemble
gamme complète de composants électriques et mécaniques (enveloppes, jeux de barres, unités fonctionnelles, circuits auxiliaires et commandes associées, etc.), tels que définis par le constructeur d'origine et pouvant être assemblés conformément aux instructions du constructeur d'origine en vue de la fabrication de différents ensembles

3.1.3
circuit principal
toutes les pièces conductrices d'un ensemble qui font partie d'un circuit destiné à transporter l'énergie électrique

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

3.1.4
circuit auxiliaire
toutes les pièces conductrices d'un ensemble insérées dans un circuit, autre que le circuit principal, destinées à la commande, la mesure, la signalisation, la régulation et au traitement de données, etc.

Note 1 à l'article: Les circuits auxiliaires d'un ensemble comprennent les circuits de commande et les circuits auxiliaires des appareils de connexion.

[SOURCE: IEC 60050-441:2000, 441-13-03, modifié – À la fin de la définition, l'expression "et au traitement de données, etc." a été ajoutée.]

3.1.5
jeu de barres
conducteur de faible impédance auquel peuvent être reliés plusieurs circuits électriques en des points séparés

Note 1 à l'article: Le terme "jeu de barres" est générique et ne préjuge pas du matériau, de la forme géométrique, de la taille ou des dimensions du ou des conducteurs.

[SOURCE: IEC 60050-151:2001, 151-12-30, modifié – Le terme "barre omnibus" a été remplacé par "jeu de barres" et le texte de la note a été remplacé.]

3.1.6
jeu de barres principal
jeu de barres auquel un ou plusieurs jeux de barres de distribution et/ou des unités d'arrivée et de départ sont raccordés

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Note 1 à l'article: Des conducteurs reliant une unité fonctionnelle et un jeu de barres principal ne sont pas considérés comme partie intégrante du jeu de barres principal.

3.1.7
jeu de barres de distribution
jeu de barres à l'intérieur d'une colonne qui est raccordé à un jeu de barres principal et à partir duquel des unités de départ sont alimentées

Note 1 à l'article: Des conducteurs reliant une unité fonctionnelle et un jeu de barres de distribution ne sont pas considérés comme partie intégrante des jeux de barres de distribution.

3.1.8
unité fonctionnelle
partie d'un ensemble comprenant tous les éléments mécaniques et électriques, y compris les appareils de connexion, qui contribuent à l'exécution d'une seule fonction

Note 1 à l'article: Les conducteurs reliant une unité fonctionnelle aux jeux de barres principaux ou de distribution et aux bornes pour conducteurs externes font partie de l'unité fonctionnelle. D'autres conducteurs reliés à une unité fonctionnelle, mais extérieurs à son compartiment ou espace protégé clos (par exemple câbles auxiliaires reliés dans un compartiment commun) ne sont pas considérés comme faisant partie de l'unité fonctionnelle.

3.1.9
unité d'arrivée
unité fonctionnelle à travers laquelle l'énergie électrique est normalement fournie à l'ensemble

3.1.10
unité de départ
unité fonctionnelle à travers laquelle l'énergie électrique est normalement fournie à un ou plusieurs circuits externes

3.1.11
dispositif de protection contre les courts-circuits
DPCC
dispositif destiné à protéger un circuit ou des parties d'un circuit contre les courants de court-circuit par l'interruption de ceux-ci

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

3.1.12
dispositif limiteur de courant
DPCC qui, à l'intérieur d'une plage de courant spécifiée, empêche le courant coupé limité d'atteindre la valeur de crête présumée et qui limite l'énergie coupée limitée (I^2t)

Note 1 à l'article: Le courant coupé limité est également appelé le courant de coupure (voir IEC 60050-441:2000, 441-17-12).

Note 2 à l'article: Des exemples de dispositifs limiteurs de courant sont les disjoncteurs limiteurs de courant conformément à l'IEC 60947-2 et les fusibles conformément à l'IEC 60269-2.

3.1.13
dispositif non limiteur de courant
DPCC qui, à l'intérieur d'une plage de courant spécifiée, autorise le courant coupé limité à atteindre la valeur de crête présumée et qui peut avoir un courant assigné de courte durée admissible (I_{cw}) lui permettant de supporter l'énergie coupée limitée pendant la durée du courant de courte durée

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3.1.14
conducteur de ligne
L
DECONSEILLE: conducteur de phase (dans les systèmes à courant alternatif)
DECONSEILLE: conducteur de pôle (dans les systèmes à courant continu)
conducteur sous tension en service normal et capable de participer au transport ou à la distribution de l'énergie électrique, mais qui n'est ni un conducteur neutre ni un conducteur de point milieu

[SOURCE: IEC 60050-195:1998, 195-02-08, modifié – Dans la définition, "conducteur de neutre" a été remplacé par "conducteur neutre".]

3.1.15
norme d'ensemble applicable
norme de la série IEC 61439, à partir de la Partie 2, couvrant un type générique d'ensemble

EXEMPLE Ensembles d'appareillage de puissance.

3.2 Unités de construction des ensembles

3.2.1
partie fixe
partie constituée d'éléments assemblés et câblés entre eux sur un support commun et qui est conçue pour rester fixe

3.2.2
partie amovible
partie constituée d'éléments assemblés et câblés entre eux sur un support commun et qui est conçue pour être entièrement retirée de l'ensemble et remise en place, même lorsque le circuit principal auquel elle est raccordée est sous tension

3.2.3
position raccordée
position d'une partie amovible lorsque celle-ci est entièrement raccordée pour la fonction à laquelle elle est destinée

3.2.4
position retirée
position d'une partie amovible lorsque celle-ci se trouve à l'extérieur de l'ensemble et en est séparée mécaniquement et électriquement

3.2.5
verrouillage d'insertion
dispositif empêchant l'introduction d'une partie amovible dans un emplacement pour lequel elle n'est pas conçue

3.2.6
connexion fixe
connexion qui peut être connectée au moyen d'un outil ou sans outil et déconnectée uniquement au moyen d'un outil

3.2.7
colonne
unité de construction d'un ensemble entre deux séparations verticales successives

3.2.8
élément de colonne
unité de construction d'un ensemble entre deux séparations horizontales ou verticales successives à l'intérieur d'une colonne

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3.2.9
compartiment
colonne ou élément de colonne sous enveloppe à l'exception des ouvertures nécessaires aux raccordements, à la commande ou à la ventilation

3.2.10
unité de transport
partie d'un ensemble ou ensemble complet pouvant être transporté sans être démonté

3.2.11
volet
partie d'un ensemble qui peut être déplacée entre:

– une position dans laquelle elle permet l'embrochage des contacts d'une partie amovible sur des contacts fixes, et
– une position dans laquelle elle constitue une partie d'un panneau ou d'une cloison protégeant les contacts fixes

[SOURCE: IEC 60050-441:2000, 441-13-07, modifié – La présentation du texte a été transformée en une liste à puces à deux points.]

3.3 Présentation extérieure des ensembles

3.3.1
ensemble ouvert
ensemble constitué d'un châssis qui supporte le matériel électrique, les parties actives du matériel électrique étant accessibles

3.3.2
ensemble ouvert à protection frontale
ensemble ouvert avec un panneau avant, les parties actives étant potentiellement accessibles à partir des faces autres que la face avant

3.3.3
ensemble sous enveloppe
ensemble comportant une paroi sur toutes les faces, sauf éventuellement sur la surface de montage, de façon à assurer un degré de protection défini

3.3.4
ensemble en armoire
ensemble sous enveloppe reposant sur le sol, pouvant comprendre plusieurs colonnes, éléments de colonnes ou compartiments

3.3.5
ensemble en armoires multiples
combinaison d'ensembles en armoire joints mécaniquement

3.3.6
ensemble en pupitre
ensemble sous enveloppe présentant un pupitre de commande horizontal ou incliné, ou une combinaison des deux, et équipé d'appareillage de commande, de mesure, de signalisation, etc.

3.3.7
ensemble en coffret
ensemble sous enveloppe prévu pour être monté sur un plan vertical

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3.3.8
ensemble en coffrets multiples
combinaison d'ensembles en coffrets reliés mécaniquement entre eux, avec ou sans charpente commune, les liaisons électriques entre deux coffrets voisins passant par des ouvertures aménagées sur les faces qui leur sont communes

3.3.9
ensemble pour fixation en saillie sur mur
ensemble destiné à être fixé sur la surface d'un mur

3.3.10
ensemble à encastrer dans un mur
ensemble destiné à être installé dans un renfoncement de mur, l'enveloppe ne supportant pas la partie de mur située au-dessus

3.3.11
ensemble reposant sur le sol
ensemble destiné à être installé sur le sol

3.4 Eléments de structure des ensembles

3.4.1
châssis
structure faisant partie d'un ensemble et conçue pour supporter divers constituants de l'ensemble et, le cas échéant, une enveloppe

3.4.2
charpente
structure ne faisant pas partie d'un ensemble, conçue pour supporter un ensemble

3.4.3
plaque de montage
support plan conçu pour supporter divers constituants et pouvant être installé dans un ensemble

3.4.4
cadre
structure conçue pour supporter divers constituants et pouvant être installée dans un ensemble

3.4.5
enveloppe
enceinte assurant le type et le degré de protection approprié pour l'application prévue

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

3.4.6
panneau
partie extérieure de l'enveloppe d'un ensemble

3.4.7
porte
panneau pivotant ou glissant

3.4.8
panneau amovible
panneau destiné à fermer une ouverture dans l'enveloppe extérieure et qui peut être enlevé pour effectuer certaines opérations d'exploitation et de maintenance

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3.4.9
plaque de fermeture
partie d'un ensemble utilisée pour fermer une ouverture dans l'enveloppe extérieure et conçue pour être fixée par vis ou moyens semblables

Note 1 à l'article: Elle n'est pas normalement enlevée après la mise en service de l'équipement.

Note 2 à l'article: La plaque de fermeture peut être dotée d'entrées de câble.

3.4.10
cloison
partie d'un ensemble séparant un compartiment des autres compartiments

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

3.4.11
barrière
partie assurant la protection contre les contacts directs dans toute direction habituelle d'accès

[SOURCE: IEC 60050-195:1998, 195-06-15, modifié – L'expression "de protection (électrique)" a été supprimée du terme.]

3.4.12
obstacle
élément empêchant un contact direct fortuit, mais ne s'opposant pas à un contact direct par une action délibérée

Note 1 à l'article: Les obstacles sont destinés à empêcher tout contact fortuit avec les parties actives, mais pas un contact fortuit par contournement délibéré de l'obstacle. Ils sont destinés à protéger les personnes qualifiées, compétentes, autorisées ou averties, mais ne sont pas prévus pour protéger les personnes ordinaires.

[SOURCE: IEC 60050-195:1998, 195-06-16, modifié – L'expression "de protection (électrique)" a été supprimée du terme; la Note 1 à l'article a été ajoutée.]

3.4.13
cache-bornes
partie renfermant des bornes et procurant un degré de protection défini contre l'accès aux parties actives par des personnes ou des objets

3.4.14
entrée de câbles
partie comportant des ouvertures permettant le passage de câbles à l'intérieur de l'ensemble

3.4.15
espace protégé
partie d'un ensemble destinée à renfermer des composants électriques et procurant une protection définie contre les influences externes et les contacts avec les parties actives

3.5 Conditions d'installation des ensembles

3.5.1
ensemble pour installation à l'intérieur
ensemble conçu pour être utilisé dans des locaux où les conditions normales d'emploi pour l'intérieur, spécifiées en 7.1, s'appliquent

3.5.2
ensemble pour installation à l'extérieur
ensemble conçu pour être utilisé dans des locaux où les conditions normales d'emploi pour l'extérieur, spécifiées en 7.1, s'appliquent

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3.5.3
ensemble fixe
ensemble conçu pour être fixé à son emplacement d'installation, par exemple au sol ou sur un mur, et être utilisé à cet emplacement

3.5.4
ensemble mobile
ensemble prévu pour pouvoir être facilement déplacé d'un emplacement d'utilisation à un autre

3.6 Caractéristiques d'isolement

3.6.1
distance d'isolement
plus petite distance dans l'air entre deux parties conductrices

Note 1 à l'article: La distance peut être mesurée le long d'un fil tendu suivant le plus court trajet possible entre ces deux parties conductrices.

[SOURCE: IEC 60050-581:2008, 581-27-76, modifié – La Note 1 à l'article a été ajoutée.]

3.6.2
ligne de fuite
distance la plus courte, le long de la surface d'un isolant solide, entre deux parties conductrices

Note 1 à l'article: Un joint entre deux portions d'isolant solide est considéré comme faisant partie de la surface.

[SOURCE: IEC 60050-151:2001, 151-15-50, modifié – La Note 1 à l'article a été ajoutée.]

3.6.3
surtension
tension ayant une valeur de crête dépassant la valeur de crête correspondante de la tension maximale en régime permanent dans les conditions normales de fonctionnement

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

3.6.4
surtension temporaire
surtension à fréquence industrielle d'une durée de plusieurs secondes

3.6.5
surtension transitoire
surtension de courte durée, ne dépassant pas quelques millisecondes, oscillatoire ou non, généralement fortement amortie

[SOURCE: IEC 60050-614:2016, 614-03-14, modifié – Dans la définition, l'expression "surtension d'une durée" a été remplacée par "surtension de courte durée"; la Note 1 à l'article et la Note 2 à l'article ont été supprimées.]

3.6.6
tension de tenue à fréquence industrielle
valeur efficace d'une tension sinusoïdale à fréquence industrielle qui ne provoque pas de claquage dans des conditions d'essai spécifiées

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

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3.6.7
tension de tenue aux chocs
valeur de crête la plus élevée d'une tension de choc, de forme et de polarité prescrites, qui ne provoque pas de claquage dans des conditions d'essai spécifiées

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

3.6.8
pollution
apport de matériau étranger solide, liquide ou gazeux, qui peut entraîner une réduction de la rigidité diélectrique ou de la résistivité superficielle de l'isolation

[SOURCE: IEC 60050-442:1998, 442-01-28, modifié – Dans la définition, l'expression "qui peut entraîner une réduction permanente de la rigidité diélectrique" a été remplacée par "qui peut entraîner une réduction de la rigidité diélectrique" et la Note 1 à l'article a été supprimée.]

3.6.9
degré de pollution
<des conditions d'environnement> nombre conventionnel, basé sur la quantité de poussières conductrices ou hygroscopiques, de gaz ionisés ou de sels, et sur l'humidité relative et sa fréquence d'apparition se traduisant par l'absorption ou la condensation d'humidité, ayant pour effet de diminuer la rigidité diélectrique et/ou la résistivité superficielle

Note 1 à l'article: Le degré de pollution auquel les matériaux isolants des appareils et des composants sont exposés peut être différent de celui du macroenvironnement dans lequel sont situés les ensembles, en raison de la protection assurée par des moyens tels qu'une enveloppe ou un chauffage interne empêchant l'absorption ou la condensation d'humidité.

Note 2 à l'article: Dans le cadre du présent document, le degré de pollution est celui du microenvironnement à l'intérieur de l'ensemble, sauf indication contraire dans l'article applicable.

[SOURCE: IEC 60947-1:2020, 3.7.57, modifié – Les Notes à l'article ont été adaptées aux conditions associées aux ensembles.]

3.6.10
environnement

3.6.10.1
microenvironnement
environnement immédiat de l'isolation qui influence en particulier le dimensionnement des lignes de fuite

Note 1 à l'article: C'est l'effet du microenvironnement sur les lignes de fuite ou des distances d'isolement qui détermine le choix de l'isolation à l'intérieur de l'ensemble. Le microenvironnement peut être meilleur ou pire que le macroenvironnement.

[SOURCE: IEC 60050-851:2008, 851-15-16, modifié – La Note 1 à l'article a été ajoutée.]

3.6.10.2
macroenvironnement
environnement de la pièce ou de tout autre endroit dans lequel l'ensemble est installé ou utilisé

[SOURCE: IEC 60050-442:2014, modifié – Dans la définition, l'expression "le matériel" a été remplacée par "l'ensemble".]

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3.6.11
catégorie de surtension
<d'un circuit ou dans un réseau> nombre conventionnel, basé sur la limitation (ou la commande) des valeurs de surtensions transitoires présumées apparaissant dans un circuit (ou dans un réseau où existent des sections de tensions nominales différentes) et dépendant des moyens employés pour agir sur ces surtensions

Note 1 à l'article: Dans un réseau, le passage d'une catégorie de surtension à une autre catégorie inférieure est réalisé à l'aide de moyens appropriés répondant aux exigences d'interface, tels qu'un dispositif de protection contre les surtensions ou des impédances de shunt disposées en série capables de dissiper, d'absorber ou de détourner l'énergie du courant de surcharge correspondant, afin d'abaisser la valeur des surtensions transitoires à celle qui correspond à la catégorie de surtension inférieure recherchée.

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

3.6.12
parafoudre
SPD
dispositif destiné à protéger le matériel électrique contre les surtensions transitoires élevées et à limiter la durée et souvent l'amplitude du courant résiduel

Note 1 à l'article: L'abréviation "SPD" est dérivée du terme anglais développé correspondant "surge protective device".

[SOURCE: IEC 60947-1:2020, 3.4.22, modifié – Ajout du terme "SPD", remplacement de "l'appareillage électrique" par " le matériel électrique" et remplacement de "courant de suite" par "courant résiduel". Nouvelle Note 1 à l'article.]

3.6.13
coordination de l'isolement
correspondance mutuelle des caractéristiques d'isolement du matériel électrique en tenant compte du micro-environnement prévu et des autres contraintes ayant une influence

[SOURCE: IEC 60050-442:2014, 442-09-01]

3.6.14
champ non homogène
champ électrique dont le gradient de tension entre électrodes n'est pas essentiellement constant

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

3.6.15
cheminement
formation progressive de trajets conducteurs produits à la surface d'un isolant solide sous l'effet combiné des contraintes électriques et de la contamination électrolytique de cette surface

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

3.6.16
indice de résistance au cheminement
IRC
valeur numérique de la tension maximale, exprimée en volts, qu'un matériau peut supporter sans cheminement et sans apparition de flammes persistantes dans des conditions d'essai spécifiées

Note 1 à l'article: Il convient que la valeur de chaque tension d'essai et de l'indice de résistance au cheminement soit divisible par 25.

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[SOURCE: IEC 60947-1:2020, 3.7.64, modifié – La Note 1 à l'article a été ajoutée.]

3.6.17
décharge disruptive
phénomène associé à la défaillance de l'isolation sous l'action d'une contrainte électrique et dans lesquels la décharge court-circuite complètement l'isolation en essai, réduisant la tension entre électrodes à une valeur nulle ou presque nulle

Note 1 à l'article: Une décharge disruptive dans un diélectrique solide produit une perte permanente de rigidité diélectrique; dans un diélectrique liquide ou gazeux, cette perte peut n'être que momentanée.

Note 2 à l'article: Le terme "décharge" est utilisé lorsqu'une décharge disruptive se produit dans un diélectrique liquide ou gazeux.

Note 3 à l'article: Le terme "amorçage" est utilisé lorsqu'une décharge disruptive se produit à la surface d'un diélectrique dans un milieu gazeux ou liquide.

Note 4 à l'article: Le terme "perforation" est utilisé lorsqu'une décharge disruptive se produit à travers un diélectrique solide.

3.7 Protection contre les chocs électriques

3.7.1
partie active
partie conductrice destinée à être sous tension dans les conditions normales, y compris le conducteur neutre ou un conducteur de point milieu, mais par convention, excepté le conducteur PEN, le conducteur PEM ou le conducteur PEL

Note 1 à l'article: Ce terme n'implique pas nécessairement un risque de choc électrique. Lorsque le conducteur neutre est mis à la terre de manière efficace, il ne représente pas une partie active dangereuse et n'est par conséquent pas coupé dans les schémas TN-S ou TN-C-S, sauf exigence spécifique dans d'autres normes.

[SOURCE: IEC 61140:2016, 3.4, modifié – La Note 1 à l'article a été modifiée.]

3.7.2
partie active dangereuse
partie active qui peut provoquer, dans certaines conditions, un choc électrique nuisible

[SOURCE: IEC 61140:2016, 3.5, modifié – La Note 1 à l'article a été supprimée.]

3.7.3
partie conductrice accessible
masse (dans une installation)
partie conductrice d'un ensemble, susceptible d'être touchée et qui n'est pas normalement sous tension, mais qui peut le devenir lorsque l'isolation principale est défaillante

Note 1 à l'article: Une partie conductrice d'un ensemble qui ne peut être mise sous tension que par l'intermédiaire d'une masse qui est devenue sous tension n'est pas considérée comme une masse à proprement parler.

[SOURCE: IEC 60050-195:1998, 195-06-10, modifié – Dans la définition, l'expression "d'un matériel" a été remplacée par "d'un ensemble"; la Note 1 à l'article a été ajoutée.]

3.7.4
conducteur de protection
PE
conducteur prévu à des fins de sécurité, par exemple protection contre les chocs électriques

Note 1 à l'article: Par exemple, un conducteur de protection peut raccorder électriquement les parties suivantes:

– parties conductrices accessibles ou masses (dans une installation électrique);
– éléments conducteurs étrangers à l'installation;
– borne principale de terre;

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– prise de terre;

– point de l'alimentation relié à la terre ou point neutre artificiel.

Note 2 à l'article: Un conducteur de protection est parfois désigné par l'expression "conducteur de mise à la terre de protection".

[SOURCE: IEC 60050-826:2004, 826-13-22, modifié – La Note 1 à l'article a été modifiée et la Note 2 à l'article a été ajoutée.]

3.7.5
conducteur neutre
N
conducteur relié électriquement au point neutre et pouvant contribuer à la distribution de l'énergie électrique

[SOURCE: IEC 60050-195:1998, 195-02-06, modifié – L'abréviation "N" a été ajoutée.]

3.7.6
conducteur PEN
conducteur assurant à la fois les fonctions de conducteur de mise à la terre de protection et de conducteur neutre

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

3.7.7
courant de défaut
courant résultant d'un défaut de l'isolation, du contournement de l'isolation ou d'un raccordement incorrect dans un circuit électrique

3.7.8
protection principale
protection contre les chocs électriques en l'absence de défaut

Note 1 à l'article: La protection principale est destinée à empêcher tout contact avec les parties actives et elle correspond généralement à la protection contre les contacts directs.

[SOURCE: IEC 60050-195:1998, 195-06-01, modifié – La Note 1 à l'article a été ajoutée.]

3.7.9
isolation principale
isolation des parties actives dangereuses qui assure la protection principale

Note 1 à l'article: Cette notion n'est pas applicable à l'isolation exclusivement utilisée à des fins fonctionnelles.

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

3.7.10
protection en cas de défaut
protection contre les chocs électriques en condition de premier défaut

Note 1 à l'article: La défaillance de l'isolation principale (3.7.9) est un exemple d'une condition de premier défaut.

Note 2 à l'article: La protection en cas de défaut correspond généralement à la protection contre les contacts indirects, essentiellement en cas de défaillance de l'isolation principale.

[SOURCE: IEC 60050-195:1998, 195-06-02, modifié – Les Notes à l'article ont été ajoutées.]

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3.7.11
schéma TBTP
schéma électrique dont la tension ne peut pas dépasser les valeurs données dans l'IEC 60364-4-41:2005, Article 414:

– dans des conditions normales, et
– dans des conditions de premier défaut, à l'exception des défauts à la terre apparaissant dans les autres circuits électriques

Note 1 à l'article: TBTP est l'abréviation de très basse tension de protection.

Note 2 à l'article: Les circuits TBTP et/ou les parties conductrices exposées de l'équipement alimentées par les circuits TBTP peuvent être mis à la terre.

[SOURCE: IEC 60050-826:2004, 826-12-32, modifié – La référence à l'IEC 60364-4-41:2005 a été ajoutée à la définition, et la Note 2 à l'article a été ajoutée.]

3.7.12
schéma TBTS
schéma électrique dont la tension ne peut pas dépasser les valeurs données dans l'IEC 60364-4-41:2005, Article 414:

– dans des conditions normales, et
– dans des conditions de premier défaut, y compris les défauts à la terre dans les autres circuits électriques

Note 1 à l'article: TBTS est l'abréviation de très basse tension de sécurité.

Note 2 à l'article: Les circuits TBTS ont une isolation principale entre les parties actives et la terre.

[SOURCE: IEC 60050-826:2004, 826-12-31, modifié – La référence à l'IEC 60364-4-41:2005 a été ajoutée à la définition, la deuxième entrée de la liste à puce a été modifiée et la Note 2 à l'article a été ajoutée.]

3.7.13
personne qualifiée (en électricité)
personne ayant la formation et l'expérience appropriées pour lui permettre de percevoir les risques et d'éviter les dangers que peut présenter l'électricité

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

3.7.14
personne compétente
personne qui peut juger le travail assigné et reconnaître les dangers possibles sur la base de sa formation, son expérience et sa connaissance du matériel concerné

Note 1 à l'article: Plusieurs années de pratique dans le domaine technique concerné peuvent être prises en considération pour l'estimation de la formation professionnelle.

[SOURCE: IEC 60050-851:2008, 851-11-10, modifié – Le qualificatif "ses connaissances" a été supprimé.]

3.7.15
personne avertie
personne suffisamment informée ou surveillée par des personnes qualifiées en électricité pour lui permettre de percevoir les risques et d'éviter les dangers que peut présenter l'électricité

[SOURCE: IEC 60050-826:2004, 826-18-02, modifié – "en électricité" a été supprimé du terme.]

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3.7.16
personne ordinaire
personne qui n'est ni une personne qualifiée ni une personne avertie

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

3.7.17
personne autorisée
personne qualifiée ou avertie qui a reçu l'autorisation de réaliser des travaux définis

3.7.18
conducteur de point milieu
M
conducteur relié électriquement au point milieu et pouvant transporter l'énergie électrique

Note 1 à l'article: Le terme conducteur de point milieu est le plus fréquemment associé à des applications en courant continu.

[SOURCE: IEC 60050-195:1998, 195-02-07, modifié – Dans la définition, l'expression "capable de participer à la distribution de" a été remplacée par "pouvant transporter"; la Note 1 à l'article a été ajoutée.]

3.7.19
conducteur PEM
conducteur assurant les fonctions de conducteur de mise à la terre de protection et de conducteur de point milieu

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

3.7.20
conducteur PEL
conducteur assurant à la fois les fonctions de conducteur de mise à la terre de protection et de conducteur de ligne

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

3.7.21
isolation supplémentaire
isolation indépendante prévue, en plus de l'isolation principale, en tant que protection en cas de défaut

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

3.7.22
double isolation
isolation comprenant à la fois une isolation principale et une isolation supplémentaire

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

3.7.23
isolation renforcée
isolation des parties actives dangereuses assurant un degré de protection contre les chocs électriques équivalant à celui d'une double isolation

Note 1 à l'article: L'isolation renforcée peut comporter plusieurs couches qui ne peuvent pas être soumises à essai séparément en tant qu'isolation principale ou isolation supplémentaire.

Note 2 à l'article: L'isolation renforcée est conforme à l'IEC 60664-1:2007.

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[SOURCE: IEC 60050-826:2004, 826-12-17, modifié – Nouvelle Note 2 à l'article.]

3.7.24
ensemble de classe I
ensemble ayant au moins une disposition de protection principale et une connexion à un conducteur de protection comme disposition de protection en cas de défaut

Note 1 à l'article: Pour plus de détails, voir l'IEC 61140:2016, 7.3.

Note 2 à l'article: Un ensemble de classe I peut être équipé d'une enveloppe isolée pour la protection principale et d'un conducteur de protection assurant la protection en cas de défaut de circuits externes alimentés par l'ensemble de classe I.

3.7.25
ensemble de classe II
ensemble comprenant les éléments suivants:

– une isolation principale comme protection principale; et
– une isolation supplémentaire comme protection en cas de défaut;

ou dans lequel:

– la protection principale et la protection en cas de défaut sont assurées par une isolation renforcée

Note 1 à l'article: Voir l'IEC 61140:2016, 7.4.

3.8 Caractéristiques

3.8.1
valeur nominale
valeur d'une grandeur, utilisée pour dénommer et identifier un composant, un appareil, un matériel ou un système

Note 1 à l'article: La valeur nominale est généralement une valeur arrondie.

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

3.8.2
valeur limite
dans une spécification d'un composant, appareil, matériel ou système, la plus grande ou la plus petite valeur admissible d'une grandeur

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

3.8.3
valeur assignée
valeur d'une grandeur, utilisée à des fins de spécification, correspondant à un ensemble spécifié de conditions de fonctionnement d'un composant, appareil, matériel ou système

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

3.8.4
caractéristiques assignées
ensemble des valeurs assignées et des conditions d'exploitation

[SOURCE: IEC 60050-151:2001, 151-16-11, modifié – "conditions de fonctionnement" a été remplacé par "conditons d'exploitation".]

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3.8.5
tension nominale
valeur arrondie de la tension utilisée pour dénommer ou identifier un réseau électrique

[SOURCE: IEC 60050-601:1985, 601-01-21, modifié – Suppression de "(d'un réseau)" dans le terme et ajout de "électrique" dans la définition.]

3.8.6
courant de court-circuit
I_c
surintensité résultant d'un court-circuit dû à un défaut ou à un branchement incorrect dans un circuit électrique

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

3.8.7
courant de court-circuit présumé
I_{cp}
courant qui circule lorsque les conducteurs d'alimentation du circuit sont court-circuités par un conducteur d'impédance négligeable placé aussi près que la pratique le permet des bornes d'alimentation de l'ensemble

Note 1 à l'article: Pour les applications en courant alternatif et les applications en courant continu, le courant correspond respectivement à la valeur efficace et à la valeur moyenne dans un régime établi.

3.8.8
courant de coupure
courant coupé limité
I_{lt}
valeur instantanée maximale du courant atteinte au cours de la coupure effectuée par un appareil de connexion ou un fusible

Note 1 à l'article: Cette notion est d'une importance particulière si l'appareil de connexion ou le fusible fonctionne de telle manière que la valeur de crête du courant présumé du circuit n'est pas atteinte.

[SOURCE: IEC 60050-441:2000, 441-17-12, modifié – Nouveau terme "courant de coupure".]

3.8.9
caractéristiques assignées de tension

3.8.9.1
tension assignée
U_n
tension nominale la plus élevée du réseau électrique, déclarée par le constructeur d'ensembles, à laquelle le ou les circuits principaux de l'ensemble sont prévus d'être raccordés

Note 1 à l'article: Pour les circuits polyphasés, il s'agit de la tension entre lignes.

Note 2 à l'article: Les transitoires sont ignorées.

Note 3 à l'article: La valeur de la tension d'alimentation peut dépasser la tension assignée dans les limites des tolérances admissibles du réseau.

Note 4 à l'article: Pour les applications en courant alternatif et les applications en courant continu, la tension correspond respectivement à la valeur efficace et à la valeur moyenne.

3.8.9.2
tension assignée d'emploi
U_e
valeur de tension en courant alternatif (valeur efficace) ou en courant continu (valeur moyenne), déclarée par le constructeur d'ensembles pour l'ensemble ou le circuit d'un ensemble, qui, combinée au courant assigné, détermine son utilisation

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Note 1 à l'article: Pour les circuits polyphasés, il s'agit de la tension entre lignes.

3.8.9.3
tension assignée d'isolement
U_i
valeur efficace de tension de tenue fixée par le constructeur d'ensembles (3.10.2) à l'ensemble ou à un circuit d'un ensemble, caractérisant la capacité de tenue spécifiée (à long terme) de son isolation

Note 1 à l'article: Pour les circuits polyphasés, il s'agit de la tension entre lignes.

Note 2 à l'article: La tension assignée d'isolement n'est pas nécessairement égale à la tension assignée d'emploi des matériels, qui est principalement liée aux caractéristiques fonctionnelles.

[SOURCE: IEC 60664-1:2007, 3.9.1, modifié – Le symbole U_i a été ajouté; dans la définition, l'expression "fabricant" a été remplacée par "constructeur d'ensembles (3.10.2)", l'expression "aux matériels ou à une partie d'entre eux" a été remplacée par "à l'ensemble ou à un circuit d'un ensemble"; la Note 1 à l'article a été ajoutée.]

3.8.9.4
tension assignée de tenue aux chocs
U_{imp}
valeur de tension de tenue aux chocs fixée par le constructeur d'ensembles à l'ensemble ou à un circuit d'un ensemble, caractérisant la capacité de tenue spécifiée de l'isolation contre des surtensions transitoires

[SOURCE: IEC 60664-1:2007, 3.9.2, modifié – Le symbole U_{imp} a été ajouté; dans la définition, l'expression "aux matériels ou à une partie d'entre eux" a été remplacée par "à l'ensemble ou à un circuit d'un ensemble".]

3.8.10
caractéristiques assignées de courant

3.8.10.1
courant assigné
valeur du courant permanent, déclarée par le constructeur d'ensembles, qu'un circuit peut conduire sans que l'échauffement des différentes parties de l'ensemble ne dépasse les limites spécifiées dans des conditions données

Note 1 à l'article: Pour le courant assigné de l'ensemble (I_{nA}), voir 3.8.10.7 et 5.3.1, pour le courant assigné d'un circuit principal (I_{nc}), voir 3.8.10.5 et 5.3.2, et pour le courant assigné de groupe d'un circuit principal (I_{ng}), voir 3.8.10.6 et 5.3.3.

Note 2 à l'article: En principe, il n'est pas nécessaire de prendre en compte les courants d'appel pour les moteurs, les transformateurs, etc., lors de la détermination du courant assigné d'un circuit.

3.8.10.2
valeur de crête du courant assigné admissible
I_{pk}
valeur de crête du courant de court-circuit déclarée par le constructeur d'ensembles, à laquelle le circuit peut résister dans des conditions spécifiées

3.8.10.3
courant assigné de courte durée admissible
I_{cw}
valeur efficace du courant alternatif ou valeur moyenne du courant continu du courant de courte durée, déclarée par le constructeur d'ensembles, à laquelle le circuit peut résister dans des conditions spécifiées, définies en ce qui concerne le courant et la durée

Note 1 à l'article: Le courant assigné de courte durée admissible est différent à la valeur assignée de défaut d'arc interne donnée dans l'IEC TR 61641.

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3.8.10.4
courant conditionnel de court-circuit assigné
I_{cc}
valeur du courant de court-circuit présumé, déclarée par le constructeur d'ensembles à laquelle un circuit protégé par un DPCC peut résister pendant la durée totale de fonctionnement (temps de coupure) de ce dispositif dans des conditions spécifiées

3.8.10.5
courant assigné d'un circuit principal
I_{nc}
courant assigné qu'un circuit principal peut conduire lorsqu'il est le seul circuit principal à l'intérieur d'une colonne de l'ensemble qui transporte du courant

Note 1 à l'article: Le courant assigné d'un circuit principal peut être inférieur aux courants assignés des dispositifs installés dans le circuit principal, conformément aux normes d'appareil applicables.

Note 2 à l'article: Etant donné la complexité des facteurs qui déterminent les courants assignés, aucune valeur normalisée ne peut être donnée.

Note 3 à l'article: Un ensemble peut comprendre seulement une colonne unique.

3.8.10.6
courant assigné de groupe d'un circuit principal
I_{ng}
courant assigné qu'un circuit principal peut conduire en tenant compte des influences thermiques mutuelles des autres circuits qui sont chargés simultanément dans la même colonne de l'ensemble

Note 1 à l'article: I_{ng} peut être égal à I_{nc} dans certaines conceptions d'ensembles.

Note 2 à l'article: Un ensemble peut comprendre seulement une colonne unique.

3.8.10.7
courant assigné d'un ensemble
I_{nA}
courant assigné qui peut être distribué par un ensemble sans que l'échauffement de l'une quelconque des parties dépasse les limites spécifiées

Note 1 à l'article: L'ajout ultérieur d'autres circuits n'est pas une opération susceptible d'entraîner un dépassement du courant assigné d'un ensemble.

3.8.10.8
courant d'emploi (d'un circuit électrique)
I_B
courant électrique destiné à être transporté dans un circuit électrique en fonctionnement normal

Note 1 à l'article: I_B est normalement fourni par l'utilisateur.

[SOURCE: IEC 60050-826:2004, 826-11-10, modifié – La Note 1 à l'article a été ajoutée.]

3.8.11
facteur de diversité assigné
RDF
valeur, calculée en divisant le courant assigné de groupe d'un circuit principal de départ, I_{ng}, par le courant assigné, I_{nc}, du même circuit principal de départ, où I_{ng} et I_{nc} sont déterminés par essai

Note 1 à l'article: RDF représente par conséquent la proportion de la valeur de I_{nc} à laquelle deux circuits de départ ou plus dans la même colonne d'un ensemble peuvent être chargés de manière continue et simultanée, en tenant compte des influences thermiques mutuelles.

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Note 2 à l'article: Pour un groupe de circuits qui sont chargés de manière continue et simultanée, le courant assigné d'un circuit (I_{nc}) multiplié par le facteur de diversité assigné (RDF) n'est normalement pas inférieur au courant d'emploi (I_B) du circuit normalement fourni par l'utilisateur, c'est-à-dire $I_{nc} \times RDF \geq I_B$.

3.8.12
fréquence assignée
f_n
valeur de fréquence déclarée par le constructeur d'ensembles, pour laquelle un circuit est conçu et à laquelle se réfèrent les conditions d'emploi

Note 1 à l'article: Il est permis d'attribuer à un circuit un certain nombre de fréquences assignées ou une plage de telles fréquences, ou les spécifier à la fois en courant alternatif et en courant continu.

3.8.13
compatibilité électromagnétique
CEM
aptitude d'un équipement ou d'un système à fonctionner dans son environnement électromagnétique de façon satisfaisante et sans produire lui-même des perturbations électromagnétiques intolérables pour tout ce qui se trouve dans cet environnement

Note 1 à l'article: Pour les termes et définitions liés à la CEM, voir Annexe J.

[SOURCE: IEC 60050-161:2018, 161-01-07, modifié – La Note 1 à l'article a été ajoutée.]

3.9 Vérification

3.9.1
vérification de la conception
vérification réalisée sur un échantillon d'un ensemble ou sur des parties d'ensembles pour montrer que la conception satisfait aux exigences de la norme d'ensemble applicable

Note 1 à l'article: La vérification de la conception peut comprendre une ou plusieurs méthodes équivalentes. Voir 3.9.1.1, 3.9.1.2 et 3.9.1.3.

3.9.1.1
essai de vérification
essai réalisé sur un échantillon d'un ensemble ou sur des parties d'ensembles pour vérifier que la conception satisfait aux exigences de la norme d'ensemble applicable

Note 1 à l'article: Les essais de vérification sont équivalents aux essais de type, comme dans la série de normes IEC 60439.

3.9.1.2
comparaison de vérification
comparaison structurée d'une proposition de conception d'un ensemble, ou de parties d'un ensemble, avec une ou plusieurs conceptions de référence vérifiées par essai

3.9.1.3
évaluation de vérification
vérification de conception employant des règles de conception strictes et/ou des calculs stricts appliqués à un ensemble ou à des parties d'ensembles pour montrer que la conception satisfait aux exigences de la norme d'ensemble applicable

3.9.1.4
conception de référence
conception d'un ensemble ou de parties d'un ensemble, qui a été vérifiée par essai

3.9.2
vérification individuelle de série
vérification de chaque ensemble, réalisée au cours et/ou à l'issue de la fabrication pour s'assurer de sa conformité aux exigences de la norme d'ensemble applicable

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3.9.3
examen
action comprenant un examen minutieux, y compris un examen visuel lorsque les conditions sont évidentes, d'un élément, effectué sans démontage ou avec l'ajout d'un démontage partiel, si cela est exigé, complété par des moyens tels que le mesurage, afin d'arriver à une conclusion fiable sur l'état d'un élément

[SOURCE: IEC 60050-426:2008, 426-14-02, modifié – La définition a été modifiée.]

3.10 Constructeur

3.10.1
constructeur d'origine
organisme qui a réalisé la conception d'origine et la vérification associée d'un ensemble, conformément à la norme d'ensemble applicable

3.10.2
constructeur d'ensembles
organisme prenant la responsabilité de l'ensemble fini

Note 1 à l'article: Le constructeur d'ensembles peut être le même organisme que le constructeur d'origine ou un organisme différent.

3.11
utilisateur
partie qui spécifie, achète, utilise et/ou exploite l'ensemble, ou toute personne agissant en son nom

4 Symboles et abréviations

Liste alphabétique des termes avec leurs symboles et abréviations accompagnés de la référence du paragraphe où ils sont utilisés la première fois:

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Symbole/Abréviation	Terme	Paragraphe donnant la définition du terme
IRC	indice de résistance au cheminement	3.6.16
CEM	compatibilité électromagnétique	3.8.13
f_n	fréquence assignée	3.8.12
I_c	courant de court-circuit	3.8.6
I_{cc}	courant conditionnel de court-circuit assigné d'un ensemble ou d'un circuit d'un ensemble	3.8.10.4
I_{lt}	courant de coupure, courant coupé limité	3.8.8
I_{cp}	courant de court-circuit présumé	3.8.7
I_{cw}	courant assigné de courte durée admissible	3.8.10.3
I_B	courant d'emploi (d'un circuit électrique)	3.8.10.8
I_{nA}	courant assigné d'un ensemble	3.8.10.7
I_{nc}	courant assigné d'un circuit principal	3.8.10.5
I_{ng}	courant assigné de groupe d'un circuit principal	3.8.10.6
I_{pk}	valeur de crête du courant assigné admissible	3.8.10.2
L	conducteur de ligne	3.1.14
M	conducteur de point milieu	3.7.18
N	conducteur neutre	3.7.5
PE	conducteur de protection	3.7.4
PEL	conducteur PEL	3.7.20
PEM	conducteur PEM	3.7.19
TBTP	très basse tension de protection	3.7.11
PEN	conducteur PEN	3.7.6
RDF	facteur de diversité assigné	3.8.11
DPCC	dispositif de protection contre les courts-circuits	3.1.11
TBTS	très basse tension de sécurité	3.7.12
SPD	parafoudre	3.6.12
U_e	tension assignée d'emploi	3.8.9.2
U_i	tension assignée d'isolement	3.8.9.3
U_{imp}	tension assignée de tenue aux chocs	3.8.9.4
U_n	tension assignée	3.8.9.1

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5 Caractéristiques d'interface

5.1 Généralités

Les caractéristiques de l'ensemble doivent assurer la compatibilité avec les caractéristiques assignées des circuits auxquels il est raccordé, ainsi qu'avec les conditions d'installation, et elles doivent être spécifiées par le constructeur d'ensembles à l'aide des critères identifiés de 5.2 à 5.6.

5.2 Caractéristiques assignées de tension

5.2.1 Tension assignée (U_n) (de l'ensemble)

La tension assignée doit être au moins égale à la tension nominale du réseau électrique.

NOTE Pour plus d'informations sur la tension nominale du réseau, voir l'IEC 60038.

5.2.2 Tension assignée d'emploi (U_e) (d'un circuit d'un ensemble)

La tension assignée d'emploi de tout circuit ne doit pas être inférieure à la tension nominale du réseau électrique auquel il est prévu pour être raccordé. Si la tension nominale est donnée pour un système triphasé, la tension assignée d'emploi de circuits monophasés ne doit pas être inférieure à la tension nominale divisée par $\sqrt{3}$.

Si elle est différente de la tension assignée de l'ensemble, la tension assignée d'emploi appropriée du circuit doit être spécifiée.

5.2.3 Tension assignée d'isolement (U_i) (d'un circuit d'un ensemble)

La tension assignée d'isolement d'un circuit d'un ensemble est la valeur de tension à laquelle les tensions d'essais diélectriques et les lignes de fuite se réfèrent.

La tension assignée d'isolement d'un circuit doit être supérieure ou égale aux valeurs spécifiées pour U_n et pour U_e pour le même circuit.

Pour les circuits monophasés provenant des réseaux IT (voir l'IEC 60364-5-52:2009), la tension assignée d'isolement doit être au moins égale à la tension entre les conducteurs de ligne de l'alimentation.

5.2.4 Tension assignée de tenue aux chocs (U_{imp}) (de l'ensemble)

La tension assignée de tenue aux chocs d'un ensemble est la valeur à laquelle les distances d'isolement et l'isolation solide supportent les surtensions transitoires.

La tension assignée de tenue aux chocs doit être supérieure ou égale aux valeurs spécifiées pour les surtensions transitoires qui apparaissent dans le ou les réseaux électriques auxquels le circuit est conçu pour être raccordé.

Les valeurs privilégiées de tension assignée de tenue aux chocs sont celles données dans le Tableau G.1.

5.3 Caractéristiques assignées de courant

5.3.1 Courant assigné d'un ensemble (I_{nA})

Le courant assigné d'un ensemble est la valeur la plus faible entre:

– le courant assigné total de groupe, I_{ng}, du ou des circuits d'arrivée, qui est soit le courant assigné de groupe du circuit d'arrivée individuel ou la somme des courants assignés de

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groupe des circuits d'arrivée utilisés en parallèle et simultanément à l'intérieur de l'ensemble;

– le courant total que le jeu de barres principal peut distribuer dans la configuration particulière de l'ensemble.

Ce courant doit passer sans que l'échauffement des différentes parties dépasse les limites spécifiées en 9.2.

NOTE 1 Le courant assigné de groupe d'un circuit d'arrivée peut être inférieur au courant assigné de l'appareil d'arrivée (conformément à la norme d'appareil applicable) installé dans l'ensemble.

NOTE 2 Dans ce contexte, le jeu de barres principal est un jeu de barres simple ou une combinaison de jeux de barres simples qui sont normalement raccordés en service, par exemple au moyen d'un dispositif de couplage de barres.

5.3.2 Courant assigné d'un circuit principal de départ (I_{nc})

Le courant assigné d'un circuit principal de départ est le courant pouvant être transporté par le circuit de départ lorsque tous les circuits principaux de départ dans une même colonne ne conduisent aucun courant (voir 10.10). Ce courant doit passer sans que l'échauffement des différentes parties de l'ensemble dépasse les limites spécifiées en 9.2.

La déclaration du courant assigné d'un circuit, I_{nc}, est volontaire si le courant assigné de groupe, I_{ng}, du circuit est déclaré. Si I_{nc} est déclaré, le courant de charge continue admissible maximal sur un circuit individuel dans une colonne faiblement chargée peut être évalué et la charge sur le circuit individuel peut éventuellement dépasser I_{ng}, mais il n'est jamais admis qu'elle dépasse I_{nc}.

NOTE I_{ng} représente le courant de charge continue admissible maximal dans un groupe entièrement chargé.

5.3.3 Courant assigné de groupe d'un circuit principal (I_{ng})

Le courant assigné de groupe d'un circuit principal est le courant pouvant être transporté par ce circuit lorsqu'il est chargé en continu et simultanément avec au moins un autre circuit dans le même ensemble ou la même colonne de l'ensemble, dans une configuration spécifique définie par le constructeur d'origine. Il doit être supporté sans que l'échauffement des différentes parties de l'ensemble ne dépasse les limites spécifiées en 9.2.

NOTE 1 Si le RDF pour une conception de l'ensemble a été établi conformément à des éditions précédentes de la série IEC 61439, I_{ng} peut être calculé par I_{nc} × RDF.

Si I_{ng} est déclaré, le constructeur d'origine doit indiquer les configurations spécifiques qui sont couvertes par le courant assigné de groupe en ce qui concerne:

- le ou les types, les caractéristiques assignées et le nombre maximal de circuits/d'unités fonctionnelles pouvant être installées dans le même ensemble ou la même colonne; et
- la ou les configurations d'unités fonctionnelles dans les colonnes et/ou ensembles.

NOTE 2 Pour une unité fonctionnelle présentant une valeur I_{ng} donnée, la configuration spécifique de l'ensemble ou de la section d'un ensemble peut également être déclarée en ce qui concerne la puissance dissipée.

NOTE 3 Dans la plupart des cas, le même type de colonne fourni par un constructeur d'origine peut être équipé d'un nombre variable et de différents types de circuits (unités fonctionnelles), en fonction des besoins d'un client spécifique. Il n'est généralement pas exigé que tous les circuits installés dans une colonne transportent leurs courants assignés de manière continue et simultanée. Par conséquent, la configuration spécifique définie par le constructeur d'origine clarifie les situations qui sont couvertes par une valeur déclarée de I_{ng}.

Le courant assigné de groupe des circuits principaux, qui sont chargés de manière continue et simultanée, doit être supérieur ou égal à la charge présumée des circuits de départ (égale au courant d'emploi, I_B, conformément à l'IEC 60364-1). Le courant assigné de groupe des circuits principaux, qui sont chargés de manière continue et simultanée, doit être supérieur ou égal à la charge présumée des circuits de départ (égale au courant d'emploi du circuit, I_B, conformément à l'IEC 60364-1).

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La charge présumée des circuits de départ doit être traitée par la norme d'ensemble applicable.

NOTE 4 La charge présumée des circuits de départ peut être un courant constant ou l'équivalent thermique d'un courant variable (voir Annexe I).

I_{ng} est obtenu par un essai conforme à 10.10.2.3.5, à 10.10.2.3.6 ou à 10.10.2.3.7, ou encore par calcul selon 10.10.4. En utilisant la méthode de 10.10.2.3.6 ou de 10.10.2.3.7, les valeurs de I_{ng} sont exigées pour calculer le RDF.

En variante à la déclaration de I_{ng} pour chaque type de circuit principal, il est possible de déclarer I_{nc} pour chaque type de circuit principal et le RDF approprié.

5.3.4 Courant assigné de crête admissible (I_{pk})

Le courant assigné de crête admissible doit être supérieure ou égal à la (aux) valeur(s) de crête spécifiée(s) du courant de court-circuit présumé du ou des réseau(x) d'alimentation auxquels le(s) circuit(s) sont conçus pour être raccordés (voir aussi 9.3.3).

5.3.5 Courant assigné de courte durée admissible (I_{cw}) (d'un circuit principal d'un ensemble)

Le courant assigné de courte durée admissible d'un circuit principal d'un ensemble doit être supérieur ou égal à la valeur du courant de court-circuit présumé, I_{cp}, à chaque point de raccordement du circuit à l'alimentation (voir aussi 3.8.10.3).

Différentes valeurs de I_{cw} peuvent être attribuées à un ensemble pour différentes durées (par exemple 0,2 s, 1 s, 3 s). La durée maximale ne dépasse généralement pas 1 s.

En courant alternatif, la valeur du courant est la valeur efficace de la composante alternative. En courant continu, la valeur du courant est la valeur moyenne arithmétique.

5.3.6 Courant conditionnel de court-circuit assigné (I_{cc}) (d'un ensemble ou d'un circuit d'un ensemble)

Le courant conditionnel de court-circuit assigné d'un ensemble ou d'un circuit d'un ensemble, déclaré par le constructeur d'ensembles, est le courant de court-circuit maximal que ce circuit, lorsqu'il est protégé par un DPCC comme spécifié par le constructeur, peut supporter de façon satisfaisante pendant le temps de fonctionnement du dispositif dans les conditions d'essai spécifiées au 10.11.

Le courant conditionnel de court-circuit assigné d'un ensemble ou d'un circuit d'un ensemble doit être supérieur ou égal à la valeur efficace du courant de court-circuit présumé (I_{cp}) pendant une durée limitée par le fonctionnement du dispositif de protection contre les courts-circuits qui protège le circuit ou l'ensemble. Le constructeur d'ensembles doit déclarer le pouvoir de coupure, les caractéristiques de limitation de courant, I^2t et I_{lt}, du dispositif de protection contre les courts-circuits spécifié, compte tenu des données fournies par le constructeur du dispositif.

5.4 Facteur de diversité assigné (RDF)

En variante à la déclaration du courant assigné de groupe, I_{ng}, de chaque circuit principal de départ, leur courant admissible dans les conditions de fonctionnement simultané peut être indiquée par rapport aux courants assignés, I_{nc}, et au facteur de diversité assigné.

Le facteur de diversité assigné est la proportion de la valeur de I_{nc} à laquelle les circuits de départ peuvent être chargés de manière continue et simultanée dans la même colonne de l'ensemble dans la (les) configuration(s) spécifiques définies par le constructeur d'origine, en tenant compte des influences thermiques mutuelles. Pour plus de précisions sur les configurations spécifiques, voir 5.3.3.

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NOTE 1 L'Annexe E fournit davantage d'informations sur le RDF.

Le facteur de diversité assigné multiplié par le courant assigné, I_{nc}, des circuits doit être supérieur ou égal à la charge présumée des circuits de départ, si le courant de charge présumé est égal au courant d'emploi, I_B, pour les circuits chargés de manière continue et simultanée. Si le courant d'emploi, I_B, n'est pas fourni, la charge présumée des circuits de départ doit être indiquée dans la norme d'ensemble applicable de l'IEC 61439 et suppose qu'un accord soit conclu entre l'utilisateur et le constructeur.

NOTE 2 La charge présumée des circuits de départ peut être un courant constant ou l'équivalent thermique d'un courant variable (voir Annexe I).

5.5 Fréquence assignée (f_n)

La fréquence assignée d'un circuit est la valeur de fréquence à laquelle les conditions d'exploitation font référence. Lorsque les circuits d'un ensemble sont prévus pour différentes valeurs de fréquence, la fréquence assignée de chaque circuit doit être précisée.

Il convient que la fréquence soit comprise dans les limites spécifiées dans les normes correspondantes de l'IEC relatives aux constituants incorporés. Sauf indication contraire du constructeur d'ensembles, les limites sont, par hypothèse, égales à 98 % et 102 % de la fréquence assignée.

5.6 Autres caractéristiques

Les caractéristiques suivantes doivent être fixées:

a) les exigences supplémentaires en fonction de l'utilisation d'une unité fonctionnelle (par exemple type de coordination, caractéristiques de surcharge);
b) le degré de pollution du macroenvironnement (voir 3.6.10.2);
c) les types de schéma des liaisons à la terre pour lesquels l'ensemble est conçu;
d) l'installation à l'intérieur et/ou à l'extérieur (voir 3.5.1 et 3.5.2);
e) fixe ou mobile (voir 3.5.3 et 3.5.4);
f) le degré de protection contre les contacts avec des parties actives dangereuses, contre la pénétration de corps étrangers solides et d'eau, code IP (voir 8.2.2);
g) si l'utilisation prévue vise des personnes ordinaires ou autorisées (voir 3.7.16 et 3.7.17);
h) la classification de compatibilité électromagnétique (CEM) (voir Annexe J);
i) les conditions spéciales d'emploi, le cas échéant (voir 7.2);
j) la conception extérieure (voir 3.3);
k) le degré de protection contre les impacts mécaniques, code IK, le cas échéant (voir 8.2.1);
l) le type de construction, fixe ou à parties amovibles (voir 8.5.1 et 8.5.2);
m) le type du ou des dispositifs de protection contre les courts-circuits (voir 9.3.2);
n) les mesures de protection contre les chocs électriques;
o) les dimensions hors-tout (y compris les saillies, par exemple poignées, panneaux, portes), si cela est exigé;
p) la masse, si cela est exigé.

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6 Informations

6.1 Marquage pour l'identification des ensembles

Le constructeur d'ensembles doit pourvoir chaque ensemble d'une ou plusieurs étiquettes, marquées d'une manière durable et disposées à un emplacement leur permettant d'être visibles et lisibles lorsque l'ensemble est installé et en exploitation. La conformité est vérifiée conformément à l'essai de 10.2.7 et par examen.

Les renseignements suivants concernant l'ensemble doivent être fournis sur l'étiquette ou les étiquettes d'identification:

a) le nom du constructeur d'ensembles ou sa marque de fabrique (voir 3.10.2);

b) la désignation du type ou un numéro d'identification, ou tout autre moyen d'identification, permettant d'obtenir du constructeur d'ensembles les renseignements appropriés;

c) les moyens d'identification de la date de fabrication;

d) le courant assigné de l'ensemble, I_{nA} (voir 3.8.10.7 et 5.3.1);

e) la tension assignée de l'ensemble, U_n (voir 3.8.9.1 et 5.2.1);

f) la fréquence assignée de l'ensemble, f_n (voir 3.8.12 et 5.5);

g) l'IEC 61439-X (la partie particulière "X" doit être identifiée).

NOTE La norme d'ensemble applicable peut spécifier si des renseignements supplémentaires doivent être indiqués sur l'étiquette d'identification.

6.2 Documentation

6.2.1 Renseignements concernant l'ensemble

Toutes les caractéristiques d'interface conformément à l'Article 5 doivent être, le cas échéant, fournies dans la documentation technique du constructeur d'ensembles, livrée avec l'ensemble.

6.2.2 Instructions de manutention, d'installation, d'exploitation et de maintenance

Le constructeur d'ensembles doit spécifier, dans ses documents ou ses catalogues, les conditions éventuelles de manutention, d'installation, d'exploitation et de maintenance de l'ensemble et du matériel qu'il contient. Le cas échéant, les instructions doivent indiquer que le constructeur d'ensembles doit être consulté lorsque la réparation d'un ensemble est exigée.

Si nécessaire, les instructions doivent indiquer les mesures qui sont d'une importance particulière pour que le transport, la manutention, l'installation et l'exploitation de l'ensemble soient sûrs, corrects et appropriés. La mise à disposition de renseignements détaillés concernant le poids est particulièrement importante en vue du transport et de la manutention des unités de transport. En outre, les instructions d'installation doivent fournir des détails suffisants pour que l'installateur assure de manière adéquate l'ensemble en service.

L'emplacement et l'installation corrects des moyens de levage et la taille des câbles des accessoires de levage, le cas échéant, doivent être donnés dans la documentation du constructeur d'ensembles ou dans les instructions sur la mode de manutention de l'unité de transport.

Les éventuelles mesures à prendre pendant l'installation, l'exploitation et la maintenance de l'ensemble en vue de la CEM doivent être spécifiées (voir Annexe J).

Si un ensemble prévu spécifiquement pour un environnement A est à utiliser dans un environnement B, un avertissement doit être inclus dans les instructions d'exploitation, conforme à ce qui suit:

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AVERTISSEMENT
Ce produit a été conçu pour un environnement A. L'utilisation de ce produit dans un environnement B peut engendrer des perturbations électromagnétiques indésirables qui peuvent exiger la prise de mesures d'atténuation appropriées de la part de l'utilisateur.

Lorsque cela est nécessaire, les documents mentionnés ci-dessus doivent indiquer la nature de la maintenance et sa périodicité recommandées.

Si les circuits à l'intérieur de l'ensemble ne sont pas évidents, par exemple s'il y a des connexions de plusieurs alimentations d'arrivée telles que les alimentations photovoltaïques, les générateurs, les batteries, des informations détaillant les montages des circuits doivent être fournies.

Lorsque des fusibles sont installés, le constructeur d'ensembles doit indiquer le type et les valeurs assignées des cartouches fusibles à utiliser.

6.3 Identification des appareils et/ou des composants

A l'intérieur de l'ensemble, il doit être possible d'identifier chacun des circuits et ses dispositifs de protection. Les marquages d'identification doivent être lisibles, permanents et appropriés à l'environnement physique. Toutes les identifications utilisées doivent être conformes à celles de l'IEC 81346-1:2009 et de l'IEC 81346-2:2019, et identiques à celles des schémas des circuits, qui doivent être conformes à l'IEC 61082-1:2014.

7 Conditions d'emploi

7.1 Conditions normales d'emploi

7.1.1 Conditions climatiques

Les ensembles conformes au présent document sont destinés à être utilisés dans les conditions normales d'emploi indiquées dans le Tableau 15.

Si des composants sont utilisés, par exemple des relais, des matériels électroniques, qui ne sont pas conçus pour ces conditions, l'environnement à l'intérieur de l'ensemble doit être adapté aux composants.

7.1.2 Degré de pollution

Le degré de pollution dont il est question à l'Annexe C est la condition de macroenvironnement pour laquelle l'ensemble est prévu.

Pour les appareils de connexion et les composants situés à l'intérieur d'une enveloppe, le degré de pollution des conditions d'environnement à l'intérieur de l'enveloppe, le microenvironnement, est applicable.

Pour évaluer les distances d'isolement et les lignes de fuite, les quatre degrés de pollution suivants sont établis au niveau du microenvironnement.

- Degré de pollution 1:

  Pas de pollution ou seulement une pollution sèche non conductrice. La pollution n'a aucune influence.

- Degré de pollution 2:

  Présence uniquement d'une pollution non conductrice. Occasionnellement, une conductivité temporaire provoquée par la condensation peut cependant, être prévue.

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- Degré de pollution 3:

  Présence d'une pollution conductrice ou d'une pollution sèche non conductrice, susceptible de devenir conductrice par suite de condensation.

- Degré de pollution 4:

  Il se produit une conductivité persistante causée par de la poussière conductrice, ou par de la pluie ou par d'autres conditions humides.

Le degré de pollution 4 n'est pas applicable au présent document pour un microenvironnement à l'intérieur de l'ensemble.

Le microenvironnement à l'intérieur de l'ensemble peut être différent du macroenvironnement à l'extérieur de l'enveloppe. Le degré de pollution pour un type d'ensemble spécifique est donné dans la norme d'ensemble applicable.

NOTE Le degré de pollution du microenvironnement de l'équipement peut être influencé par l'installation de celui-ci dans une enveloppe. Lorsqu'il est nécessaire d'ouvrir l'ensemble pour un service ou une opération normal, le macroenvironnement de l'installation peut avoir un impact sur le microenvironnement.

7.2 Conditions spéciales d'emploi

Lorsqu'il existe des conditions spéciales d'emploi, les exigences particulières applicables doivent être respectées ou des conventions particulières doivent intervenir entre l'utilisateur et le constructeur d'ensembles. L'utilisateur doit informer le constructeur d'ensembles de l'existence de telles conditions spéciales d'emploi.

Les conditions spéciales d'emploi comprennent, par exemple:

a) des valeurs de température, d'humidité relative et/ou d'altitude différentes de celles qui sont spécifiées en 7.1;
b) des applications où les variations des conditions climatiques sont susceptibles d'entraîner une condensation exceptionnelle à l'intérieur de l'ensemble;
c) une pollution importante de l'air par des poussières, fumées, particules corrosives ou radioactives, vapeurs ou sel;
d) une exposition à des champs électriques ou magnétiques élevés;
e) une exposition à des conditions climatiques extrêmes;
f) des attaques par des champignons ou de petits animaux;
g) une installation dans des emplacements exposés à des dangers d'incendie ou d'explosion;
h) une exposition à des vibrations, des chocs importants, des phénomènes sismiques;
i) une installation dans des conditions telles que le courant admissible est affecté, par exemple les matériels incorporés à des machines ou encastrés dans un mur;
j) une exposition à des perturbations conduites et rayonnées autres qu'électromagnétiques et aux perturbations électromagnétiques dans des environnements autres que ceux décrits en 9.4;
k) des conditions de surtension ou des fluctuations de tension exceptionnelles;
l) des harmoniques excessifs dans la tension d'alimentation ou le courant de charge;
m) l'exposition à un rayonnement (par exemple rayons X, micro-ondes, rayonnements ultraviolets autres que solaires, lasers).

7.3 Conditions au cours du transport, du stockage et de l'installation

Un accord spécial doit être conclu entre l'utilisateur et le constructeur d'ensembles si les conditions pendant le transport, le stockage et l'installation, par exemple les conditions de température et d'humidité, diffèrent de celles qui sont définies en 7.1.

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8 Exigences de construction

8.1 Résistance des matériaux et des parties

8.1.1 Généralités

Toutes les activités de conception doivent être réalisées ou surveillées par une personne compétente, sous la responsabilité du constructeur d'origine.

La forme extérieure de l'enveloppe de l'ensemble, le cas échéant, peut varier pour s'adapter à l'application et à l'utilisation. En voici quelques exemples:

- ensemble en armoire (voir 3.3.4);
- ensemble en armoires multiples (voir 3.3.5);
- ensemble en pupitre (voir 3.3.6);
- ensemble en coffret (voir 3.3.7);
- ensemble en coffrets multiples (voir 3.3.8);
- ensemble pour fixation en saillie sur mur (voir 3.3.9);
- ensemble à encastrer dans un mur (voir 3.3.10); et
- ensemble reposant sur le sol (voir 3.3.11).

Ces enveloppes peuvent être construites dans différents matériaux, par exemple isolants, métalliques ou une combinaison des deux.

Les ensembles doivent être construits avec des matériaux capables de supporter les contraintes mécaniques, électriques et thermiques, ainsi que les contraintes d'environnement susceptibles d'être rencontrées dans les conditions d'emploi spécifiées.

Dans le cas de conditions spéciales d'emploi pouvant être présentes dans l'environnement physique dans lequel l'ensemble est à installer (par exemple poussière, acides, gaz corrosifs, sels), les ensembles doivent être adéquatement protégés contre les agents contaminants (voir Annexe C). Lorsque l'ensemble est soumis à un rayonnement (par exemple rayons X, micro-ondes, rayonnements ultraviolets, lasers), des mesures supplémentaires doivent être prises pour éviter un dysfonctionnement de l'ensemble et une détérioration accélérée de l'isolation. Lorsque de telles mesures sont nécessaires, un accord est exigé entre le constructeur d'ensembles et l'utilisateur.

Lorsque l'ensemble est soumis à des effets indésirables des vibrations ou des chocs, causés par exemple par une machine et ses équipements associés, le choix d'un équipement approprié, son montage à distance de la source des vibrations, ou la fourniture de supports antivibrations doit être envisagé.

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8.1.2 Protection contre la corrosion

La protection contre la corrosion doit être assurée par l'utilisation de matériaux appropriés ou par des revêtements de protection des surfaces exposées, en tenant compte des conditions normales d'emploi (voir 7.1). La conformité à cette exigence est vérifiée par l'essai de 10.2.2.

8.1.3 Propriétés des matériaux isolants

8.1.3.1 Stabilité thermique

Les enveloppes ou les parties des enveloppes en matériau(x) isolant(s), et qui ne sont pas déjà certifiées selon leur propre norme de produit, par exemple les grilles à lames ou les treillis, doivent être en mesure de fonctionner à des températures d'au moins 70 °C. La stabilité thermique doit être vérifiée conformément à 10.2.3.1.

8.1.3.2 Résistance des matériaux isolants à la chaleur et au feu

8.1.3.2.1 Généralités

Les parties des matériaux isolants qui sont susceptibles d'être exposées à des contraintes thermiques résultant d'effets électriques internes, et dont la détérioration peut altérer la sécurité de l'ensemble, ne doivent pas être affectées défavorablement par la chaleur normale (en exploitation), par une chaleur anormale et par le feu.

8.1.3.2.2 Résistance des matériaux isolants à la chaleur normale

Le constructeur d'origine doit choisir les matériaux isolants adaptés aux températures maximales auxquelles ils sont exposés en service normal, conformément à 9.2 et au Tableau 6. La limite d'échauffement appliquée (voir 9.2) concernant les parties en matériaux isolants doit être justifiée en se basant, par exemple, sur les méthodes de l'IEC 60216 (toutes les parties), ou sur la classe thermique identifiée conformément à l'IEC 60085:2007.

NOTE En tenant compte des différences par rapport aux autres méthodes, des matériaux isolants peuvent aussi être choisis en se basant sur l'indice thermique relatif (RTI, Relative Thermal Index), voir l'UL 746B.

8.1.3.2.3 Résistance des matériaux isolants à une chaleur anormale et au feu dus aux effets électriques internes

Les matériaux isolants utilisés pour les parties nécessaires pour maintenir en position les parties transportant le courant et les parties pouvant être exposées à des contraintes thermiques résultant d'effets électriques internes, et dont la détérioration peut altérer la sécurité de l'ensemble, ne doivent pas être affectés défavorablement par une chaleur anormale ou le feu et doivent être vérifiés au moyen de l'essai au fil incandescent de 10.2.3.2. Pour les besoins de cet essai, un conducteur de protection (PE) n'est pas considéré comme une partie transportant le courant.

8.1.4 Résistance aux rayonnements ultraviolets (UV)

Les surfaces extérieures en matériau(x) isolant(s) et les enveloppes métalliques revêtues destinées à être utilisées à l'extérieur, avec une exposition aux rayonnements ultraviolets, ne doivent pas présenter de fissures ou d'autres détériorations telles qu'elles compromettent la sécurité de l'ensemble. La résistance aux rayonnements ultraviolets doit être vérifiée conformément à 10.2.4.

NOTE Pour les ensembles exposés aux rayons UV, autres que le rayonnement solaire, les moyens de vérification de la résistance des enveloppes et des parties extérieures en matériau isolant ou des parties métalliques extérieures revêtues sur leur(s) surface(s) exposée(s) par un matériau synthétique, sont soumis à un accord entre l'utilisateur et le constructeur.

8.1.5 Résistance mécanique

Toutes les enveloppes ou cloisons, y compris les moyens de fermeture et les charnières des portes, doivent avoir une résistance mécanique suffisante pour résister aux contraintes auxquelles elles peuvent être soumises en utilisation normale (voir également 10.2.8) et en conditions de court-circuit (voir aussi 10.11).

Le fonctionnement mécanique des parties amovibles, y compris tout verrouillage d'insertion, doit être vérifié par essai conformément à 10.2.8.

8.1.6 Dispositifs de levage

Si le constructeur recommande une opération de levage effectuée autrement que par des moyens manuels, par exemple au moyen d'une grue ou d'un chariot élévateur à fourche, les unités de transport doivent être dotées des dispositions appropriées pour le levage. La conformité est vérifiée conformément à 10.2.5.

8.2 Degré de protection procuré par l'enveloppe d'un ensemble

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8.2.1 Protection contre les impacts mécaniques (code IK)

Si nécessaire, le degré de protection minimum procuré par l'enveloppe d'un ensemble contre les impacts mécaniques doit être défini par les normes d'ensembles appropriées.

La conformité est vérifiée conformément à 10.2.6.

8.2.2 Protection contre les contacts avec des parties actives, contre la pénétration de corps étrangers solides et d'eau (code IP)

Le degré de protection procuré par un ensemble contre les contacts avec des parties actives, contre la pénétration de corps étrangers solides et d'eau est indiqué par le code IP conformément à l'IEC 60529:1989, l'IEC 60529:1989/AMD1:1999 et à l'IEC 60529:1989/AMD2:2013 et est vérifié conformément à 10.3.

Après installation conformément aux instructions du constructeur d'ensembles, le degré de protection d'un ensemble sous enveloppe doit être au moins égal à IP2X. Le degré de protection procuré par la face avant d'un ensemble ouvert à protection frontale doit être au moins égal à IPXXB.

Dans le cas des ensembles destinés à être utilisés à l'extérieur n'ayant pas de protection supplémentaire, le second chiffre caractéristique doit être au moins égal à 3.

NOTE Pour l'installation à l'extérieur, la protection supplémentaire peut être un toit ou une protection similaire.

Sauf spécification contraire, le degré de protection indiqué par le constructeur d'ensembles s'applique à l'ensemble complet lorsqu'il est installé conformément aux instructions du constructeur d'ensembles, par exemple avec obturation de la surface de montage de l'ensemble laissée ouverte, etc.

Lorsqu'un ensemble n'a pas le même code IP partout, le constructeur d'ensembles doit déclarer le code IP de chacune des parties.

Les différents codes IP ne doivent pas affecter l'utilisation prévue de l'ensemble.

EXEMPLES:

- face de service IP20, autres parties IP00;
- trous de vidange pratiqués dans la base IPXXD, autres parties IP43.

Les codes IP ne doivent pas être déclarés par le constructeur d'ensembles si les vérifications appropriées n'ont pas été réalisées conformément à 10.3.

Les ensembles sous enveloppe pour installation à l'extérieur et à l'intérieur, destinés à être utilisés dans des lieux où règnent une humidité élevée et des températures variant avec une grande amplitude, doivent comporter des configurations appropriées (ventilation et/ou chauffage intérieur, trous de vidange, etc.) afin d'empêcher toute condensation nuisible à l'intérieur de l'ensemble. Toutefois, dans le même temps, le degré de protection spécifié doit être maintenu.

8.2.3 Ensemble avec parties amovibles

Le degré de protection (IP) indiqué pour les ensembles s'applique normalement à la position raccordée (voir 3.2.3) des parties amovibles.

Si le degré de protection d'origine ne peut être maintenu après le retrait d'une partie amovible, par exemple par la fermeture d'une porte, le constructeur d'ensembles doit mettre à disposition des panneaux ou des parties analogues afin de rétablir le degré de protection d'origine. Si ces mesures ne sont pas disponibles, les essais IP doivent être réalisés sans la partie amovible.

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Lorsque des volets permettent d'assurer une protection adéquate contre l'accès aux parties actives, ils doivent être fixés de manière à ne pas pouvoir être démontés de façon non intentionnelle.

8.3 Distances d'isolement et lignes de fuite

8.3.1 Généralités

Les exigences applicables aux distances d'isolement et aux lignes de fuite sont fondées sur les principes de l'IEC 60664-1:2007 et sont destinées à assurer une coordination de l'isolement au sein de l'installation.

NOTE D'autres informations sont disponibles dans l'IEC TR 60664-2-1:2011.

Les distances d'isolement et les lignes de fuite des équipements qui font partie de l'ensemble doivent être conformes aux exigences de la norme de produit applicable.

Lorsque des équipements sont incorporés dans l'ensemble, les distances d'isolement et les lignes de fuite spécifiées doivent être maintenues dans les conditions normales d'emploi.

Pour dimensionner des distances d'isolement et des lignes de fuite entre des circuits distincts, les caractéristiques assignées de tension les plus élevées doivent être utilisées (tension assignée de tenue aux chocs pour les distances d'isolement et tension assignée d'isolement pour les lignes de fuite).

Les distances d'isolement et les lignes de fuite s'appliquent entre phases, entre phase et neutre et, sauf si un conducteur est directement raccordé à la terre, entre phase et terre et neutre et terre.

Pour les conducteurs actifs nus et les raccordements, les distances d'isolement et les lignes de fuite doivent être au moins équivalentes à celles spécifiées pour l'appareil auquel ils sont directement associés.

Un court-circuit inférieur ou égal à la (aux) caractéristique(s) assignée(s) déclarée(s) de l'ensemble ne doit pas réduire d'une manière permanente les distances d'isolement ou les lignes de fuite entre les jeux de barres et/ou les connexions en dessous des valeurs spécifiées pour l'ensemble. La déformation des parties de l'enveloppe ou des cloisons, des barrières et des obstacles internes due à un court-circuit ne doit pas réduire de manière permanente les distances d'isolement ou les lignes de fuite en dessous des valeurs spécifiées en 8.3.2 et 8.3.3 (voir aussi 10.11.5.5).

8.3.2 Distances d'isolement

Les distances d'isolement doivent être suffisantes pour satisfaire à la tension assignée de tenue aux chocs (U_{imp}) déclarée d'un circuit. Les distances d'isolement doivent être au moins telles que spécifiées dans le Tableau 1. Dans le cas contraire, un essai de vérification de conception et un essai individuel de série de la tension assignée de tenue aux chocs sont réalisés conformément à 10.9.3 et 11.3, respectivement.

La méthode de vérification des distances d'isolement par des mesures est donnée à l'Annexe F.

8.3.3 Lignes de fuite

Le constructeur d'origine doit choisir une ou des tensions assignées d'isolement (U_i) pour les circuits de l'ensemble à partir desquelles la ou les lignes de fuite doivent être déterminées. Pour tout circuit donné, la tension assignée d'isolement ne doit pas être inférieure à la tension assignée d'emploi (U_e).

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Dans tous les cas, les lignes de fuite ne doivent pas être inférieures aux distances d'isolement minimales associées.

Les lignes de fuite doivent correspondre à un degré de pollution tel que spécifié en 7.1.2 et au groupe de matériaux correspondant à la tension assignée d'isolement donnée dans le Tableau 2.

La méthode de vérification des lignes de fuite par des mesures est donnée à l'Annexe F.

Pour les matériaux isolants en matière non organique, par exemple le verre ou la céramique, qui ne cheminent pas, il n'est pas nécessaire que les lignes de fuite soient supérieures à leurs distances d'isolement associées. Il convient, toutefois, de tenir compte du risque de décharge disruptive.

En utilisant des nervures de 2 mm de hauteur minimale, la ligne de fuite peut être réduite, mais quel que soit le nombre de nervures, elle ne doit pas être inférieure à 0,8 fois la valeur du Tableau 2, ni inférieure à la distance d'isolement minimale associée. La largeur minimale de la base de la nervure est déterminée par des exigences mécaniques (voir Article F.2).

8.4 Protection contre les chocs électriques

8.4.1 Généralités

Les appareillages et les circuits de l'ensemble doivent être disposés de manière à faciliter leur exploitation et leur maintenance, avec la protection exigée contre les chocs électriques.

Les exigences suivantes sont destinées à assurer que les mesures de protection exigées sont obtenues après installation d'un ensemble dans un réseau électrique conforme à la série IEC 60364.

NOTE Pour les mesures de protection généralement acceptées, se reporter à l'IEC 61140:2016 et à l'IEC 60364-4-41:2005 et à l'IEC 60364-4-41:2005/AMD1:2017.

Les mesures de protection qui sont particulièrement importantes pour un ensemble sont reproduites de 8.4.2 à 8.4.6.

8.4.2 Protection principale

8.4.2.1 Généralités

La protection principale est destinée à assurer la protection contre les chocs électriques dans des conditions normales, en évitant le contact direct avec des parties actives dangereuses.

La protection principale peut être obtenue soit par des mesures appropriées de construction de l'ensemble à proprement parler, soit par des dispositions supplémentaires à prendre lors de son installation; ceci peut exiger que des renseignements soient fournis par le constructeur d'ensembles.

Un exemple de mesures supplémentaires à prendre est l'installation d'un ensemble ouvert, sans autres dispositions, dans un emplacement dont l'accès est réservé à la ou aux seules personnes autorisées.

Lorsque la protection principale est obtenue par des mesures de construction, une ou plusieurs des mesures de protection données en 8.4.2.2 et 8.4.2.3 peuvent être choisies. Le choix de la mesure de protection doit être déclaré par le constructeur d'ensembles, s'il n'est pas spécifié dans la norme d'ensemble applicable.

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8.4.2.2 Isolation principale assurée par des matériaux isolants

Les parties actives dangereuses doivent être complètement recouvertes d'une isolation qui ne puisse être enlevée que par destruction ou par l'emploi d'un outil.

Cette isolation doit être faite à l'aide de matériaux isolants appropriés capables de résister durablement aux contraintes mécaniques, électriques et thermiques auxquelles l'isolation peut être soumise en service.

EXEMPLES Dispositifs électriques enrobés dans un isolant et les conducteurs isolés.

Les peintures, vernis et laques seuls ne sont en général pas considérés comme satisfaisant aux exigences de l'isolation principale. Cela n'exclut pas l'utilisation de matériaux de revêtement isolants spécialement conçus satisfaisant aux exigences diélectriques spécifiées en 10.9.6.

8.4.2.3 Barrières ou enveloppes

Les parties actives à isolement dans l'air doivent se trouver à l'intérieur d'enveloppes ou derrière des barrières. Les enveloppes ou les barrières doivent assurer un degré de protection d'au moins IPXXB.

Les surfaces supérieures horizontales des enveloppes accessibles ayant une hauteur inférieure ou égale à 1,6 m au-dessus de l'aire de passage doivent fournir un degré de protection d'au moins IPXXD.

Les barrières et les enveloppes doivent être fixées solidement en place et présenter une stabilité et une durabilité suffisantes pour maintenir les degrés de protection exigés et la séparation appropriée avec les parties actives dans les conditions normales d'emploi, en tenant compte des influences externes concernées. La distance entre une barrière conductrice ou une enveloppe et les parties actives qu'elles protègent ne doit pas être inférieure aux valeurs spécifiées pour les distances d'isolement et les lignes de fuite en 8.3.

Lorsqu'il est nécessaire de retirer les barrières ou d'ouvrir les enveloppes ou de retirer des parties des enveloppes (voir 8.4.6), cela ne doit être possible que si l'une des conditions a) à c) est satisfaite.

a) A l'aide d'une clé ou d'un outil, c'est-à-dire d'une aide mécanique pour ouvrir la porte, le panneau ou débloquer un verrouillage.

b) Après sectionnement de l'alimentation appliquée aux parties actives, contre lesquelles les barrières ou les enveloppes assurent la protection principale, le rétablissement de l'alimentation étant possible uniquement après le remplacement ou la fermeture des barrières ou enveloppes. Dans les schémas TN-C et TN-C-S, le conducteur PEL, PEM ou PEN ne doit pas être coupé ou sectionné. Dans les schémas TN-S et TN-C-S, il n'est pas nécessaire de couper ou sectionner le conducteur de point milieu et le conducteur neutre (voir l'IEC 60364-5-53:2001, 536.1.2).

   EXEMPLE En verrouillant la ou les portes avec un sectionneur de telle sorte qu'elles ne puissent être ouvertes que si le sectionneur est en position isolé et qu'il ne soit pas possible de fermer le sectionneur si la porte est ouverte sauf à l'aide d'un outil.

c) Lorsqu'une barrière intermédiaire assurant un degré de protection d'au moins IPXXB empêche le contact avec les parties actives, une telle barrière ne pouvant être retirée qu'à l'aide d'une clé ou d'un outil.

8.4.3 Protection en cas de défaut

8.4.3.1 Conditions d'installation

L'ensemble doit comprendre des mesures de protection et convenir aux installations conçues pour être conformes à l'IEC 60364-4-41:2005 et à l'IEC 60364-4-41:2005/AMD1:2017.

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NOTE 1 Des mesures de protection appropriées pour des installations spécifiques peuvent faire l'objet d'exigences supplémentaires ou d'exigences différentes, par exemple pour l'installation à bord des navires, comme indiqué dans la série IEC 60092.

Lorsque le réseau électrique utilise une installation de mise à la terre TT, une des mesures de protection suivantes doit s'appliquer à l'ensemble:

a) isolation double ou renforcée de tous les conducteurs (câbles d'arrivée, bornes d'extension, etc.) du côté amont du ou des premiers dispositifs à courant différentiel résiduel (DDR) du réseau (ceci n'est pas une exigence lorsqu'un ensemble de classe II est utilisé); ou

b) protection par dispositif à courant différentiel résiduel (DDR) du circuit d'arrivée.

NOTE 2 Un équivalent à l'isolation renforcée peut être constitué par des connexions rigides, une lame d'air et une protection mécanique appropriée.

Ces dispositions sont soumises à un accord entre l'utilisateur et le constructeur.

8.4.3.2 Exigences pour le conducteur de protection pour faciliter la coupure automatique de l'alimentation

8.4.3.2.1 Généralités

Chaque ensemble doit posséder un conducteur de protection pour faciliter la coupure automatique de l'alimentation pour:

a) la protection contre les conséquences des défauts de mise à la terre à l'intérieur de l'ensemble de classe I;

b) la protection contre les conséquences des défauts de mise à la terre dans les circuits externes alimentés par l'ensemble de classe I et de classe II. Dans le cas d'un ensemble de classe II, le conducteur de protection peut ou non être incorporé dans l'ensemble: il est admis de le faire passer à l'extérieur.

NOTE L'enveloppe peut constituer le circuit de protection, ou faire partie du circuit de protection.

Les exigences à satisfaire sont données en 8.4.3.2.2 et en 8.4.3.2.3.

Les exigences d'identification du conducteur de protection (PE, PEN, PEM, PEL) sont données en 8.6.6.

8.4.3.2.2 Exigences pour la continuité à la terre des circuits assurant la protection contre les conséquences des défauts à l'intérieur de l'ensemble de classe I

Toutes les masses de l'ensemble doivent être raccordées entre elles et au conducteur de protection de l'alimentation ou par un conducteur de terre vers l'installation de mise à la terre.

Ces raccordements peuvent être effectués soit au moyen de connexions métalliques vissées, soit par soudage, soit par d'autres connexions conductrices, soit par un conducteur indépendant assurant la continuité à la terre.

Pour les parties métalliques de l'ensemble ayant un fini de surface résistant à l'abrasion, par exemple des plaques de presse-étoupe avec un revêtement de poudre polymérisée, les raccordements assurant la continuité à la terre exigent le retrait ou la pénétration du revêtement.

La méthode de vérification de la continuité à la terre entre les masses de l'ensemble et le conducteur de protection est donnée en 10.5.2.

Pour la continuité de ces connexions, les exigences suivantes doivent s'appliquer.

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a) Lorsqu'une partie de l'ensemble est retirée, par exemple pour la maintenance normale, la continuité à la terre du reste de l'ensemble ne doit pas être interrompue.

   Les moyens utilisés pour l'assemblage des diverses pièces métalliques d'un ensemble sont considérés comme suffisants pour assurer la continuité à la terre si les mesures de prévention prises garantissent en permanence une bonne conductivité.

   Les conduits métalliques souples ou flexibles ne doivent pas être utilisés comme conducteurs de protection sauf s'ils sont conçus à cet effet.

b) Pour les couvercles, portes, plaques de fermeture et autres pièces analogues, les connexions métalliques à vis et les charnières métalliques utilisées couramment sont considérées comme suffisantes pour assurer la continuité, à condition qu'aucun matériel électrique n'y soit fixé, à l'exception d'un équipement qui fait partie d'un système TBTP ou TBTS, suivant le cas.

Si des appareils ayant une tension dépassant les limites des systèmes TBTP ou TBTS, suivant le cas, sont fixés à des couvercles, des portes ou à des plaques de fermeture, des mesures supplémentaires doivent être prises pour assurer la continuité à la terre. Ces parties (couvercles, portes ou panneaux) doivent être équipées d'un conducteur de protection (PE) dont la section est conforme au Tableau 3, en fonction du courant assigné d'emploi I_e le plus élevé des appareils fixés. En variante, si le courant assigné d'emploi des appareils fixés est inférieur ou égal à 16 A, un raccordement électrique équivalent spécifiquement conçu et vérifié à cet effet doit être mis en place (par exemple contact glissant, charnières protégées contre la corrosion).

Les masses d'un appareil qui ne peuvent pas être raccordées pour la continuité à la terre par les moyens de fixation de l'appareil doivent être raccordées à l'installation de mise à la terre de l'ensemble par un conducteur dont la section est choisie conformément au Tableau 3.

Certaines masses d'un ensemble qui ne constituent pas un danger peuvent ne pas être raccordées à l'installation de mise à la terre, soit:

– parce qu'elles ne peuvent être touchées sur de grandes surfaces ni être saisies à la main; soit

– parce qu'elles sont de petites dimensions (environ 50 mm sur 50 mm) ou disposées de telle sorte que tout risque de contact avec les parties actives est exclu.

Cela s'applique aux vis, aux rivets et aux plaques signalétiques. Il en est de même pour les électroaimants de contacteurs ou de relais, les noyaux magnétiques de transformateurs, certaines pièces de déclencheurs, ou équivalents quelles que soient leurs dimensions.

Lorsque les parties amovibles comportent des surfaces portantes métalliques, ces surfaces doivent être considérées comme suffisantes pour assurer la continuité à la terre, sous réserve que la pression exercée sur celles-ci soit suffisamment élevée.

8.4.3.2.3 Exigences pour les conducteurs de protection assurant la protection contre les conséquences de défauts de mise à la terre dans les circuits externes alimentés par l'intermédiaire des ensembles de classe I ou de classe II

Un conducteur de protection à l'intérieur de l'ensemble doit être conçu de manière à pouvoir résister aux contraintes thermiques et dynamiques les plus élevées résultant des courants de défaut à la terre des circuits externes alimentés par l'ensemble dans son emplacement d'installation. Les parties conductrices de la structure peuvent être utilisées comme conducteur de protection ou comme une part de celui-ci. Les exigences supplémentaires pour les conducteurs de protection pour les ensembles de classe II sont données en 8.4.4 c).

Sauf dans le cas où la vérification de la tenue aux courts-circuits n'est pas exigée conformément à 10.11.2, la vérification doit être réalisée conformément à 10.5.3.

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En principe, à l'exception des cas mentionnés ci-dessous, les conducteurs de protection situés à l'intérieur d'un ensemble ne doivent pas comprendre de dispositif de sectionnement (interrupteur, sectionneur, etc.).

– Dans les circuits des conducteurs de protection, seules des barrettes pouvant être enlevées à l'aide d'un outil et accessibles seulement à la ou aux personnes autorisées doivent être admises (ces barrettes peuvent être exigées pour certains essais).
– Lorsque la continuité peut être interrompue au moyen de connecteurs ou de prises de courant, le circuit de protection ne doit être interrompu qu'après l'interruption des conducteurs actifs et la continuité doit être établie avant que les conducteurs actifs soient de nouveau raccordés.

Dans le cas d'un ensemble contenant des parties structurelles, des bâtis, des enveloppes, etc., en matériaux conducteurs, il n'est pas nécessaire qu'un conducteur de protection, s'il est prévu, soit isolé de ces pièces. Les conducteurs des dispositifs de détection de défauts sensibles à la tension, y compris les conducteurs qui les relient à une prise de terre distincte, doivent être isolés lorsque le constructeur le spécifie. Cela peut également s'appliquer à la connexion avec la terre du neutre du transformateur.

La section des conducteurs de protection (PE, PEL, PEM et PEN) dans un ensemble auquel des conducteurs externes sont destinés à être raccordés ne doit pas être inférieure à la valeur calculée avec la formule indiquée à l'Annexe B en utilisant le courant de défaut à la terre le plus élevé et la durée de défaut qui peuvent apparaître, en tenant compte de la limitation des DPCC qui protègent les conducteurs actifs correspondants. La tenue aux courts-circuits est vérifiée conformément à 10.5.3.

Pour les conducteurs PEL, PEM et PEN, les exigences supplémentaires suivantes s'appliquent.

– La section minimale doit être de 10 mm^2 pour le cuivre ou de 16 mm^2 pour l'aluminium.
– Les conducteurs PEN et PEM doivent avoir une section qui ne soit pas inférieure à celle exigée pour un conducteur neutre et un conducteur de point milieu (voir 8.6.1).
– Il n'est pas nécessaire d'isoler les conducteurs PEN, PEL et PEM dans un ensemble de classe I.
– Les éléments de structure ne doivent pas être utilisés comme conducteurs PEN, PEL et PEM; cependant, des rails de montage en cuivre ou en aluminium conformes à l'IEC 60947-7-2:2009, Annexe A, peuvent être utilisés.

Pour les détails des exigences concernant les bornes pour le raccordement des conducteurs de protection externes, voir 8.8.

8.4.3.3 Séparation électrique

La séparation électrique des différents circuits est destinée à empêcher les chocs électriques par contact avec des masses pouvant être mises sous tension par un défaut de l'isolation principale du circuit.

Pour ce type de protection, voir l'IEC 60364-4-41:2005 et l'IEC 60364-4-41:2005/AMD1:2017.

8.4.4 Exigences supplémentaires pour les ensembles de classe II

a) Pour assurer la protection principale et la protection en cas de défaut, par une isolation double ou renforcée, les exigences supplémentaires suivantes doivent être satisfaites. Les matériels électriques doivent être enveloppés dans un matériau isolant équivalent à une isolation double ou renforcée. L'enveloppe doit porter le symbole ⧈ qui doit être visible depuis l'extérieur de l'espace protégé.

NOTE 1 L'enveloppe peut être l'espace protégé ou l'espace protégé peut être derrière une barrière derrière la porte d'une enveloppe.

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NOTE 2 L'exigence d'un ensemble de classe II peut être satisfaite au moyen d'une enveloppe métallique séparée des parties actives dangereuses et des conducteurs de protection, PEL, PEM et PEN par une isolation double ou renforcée.

b) L'enveloppe ne doit être percée en aucun point par des parties conductrices de telle manière qu'il y ait possibilité qu'une tension de défaut soit transmise à l'extérieur de l'enveloppe.

Cela signifie que les parties métalliques, telles que les mécanismes des organes de commande qui doivent traverser l'enveloppe pour des raisons de construction, doivent être isolées des parties actives à l'intérieur ou à l'extérieur de l'enveloppe, pour la tension assignée d'isolement maximale et pour la tension assignée maximale de tenue aux chocs de tous les circuits de l'ensemble.

Si un organe de commande, ou équivalent, est réalisé en métal (qu'il soit ou non recouvert d'un matériau isolant), il doit être doté d'une isolation conçue pour la tension assignée d'isolement maximale et pour la tension assignée maximale de tenue aux chocs de tous les circuits de l'ensemble.

c) Si un organe de commande, ou équivalent, est principalement réalisé en matériau isolant, toutes ses parties métalliques susceptibles de devenir accessibles en cas de défaut d'isolement doivent aussi être isolées des parties actives, pour la tension assignée d'isolement maximale et pour la tension assignée maximale de tenue aux chocs de tous les circuits de l'ensemble. L'enveloppe ou l'espace protégé, lorsque l'ensemble de classe II est prêt à fonctionner et relié à l'alimentation, doit renfermer toutes les parties actives, les masses et toutes les parties appartenant à un circuit de protection de telle sorte qu'elles ne puissent pas être touchées. L'enveloppe doit au moins procurer le degré de protection IP2XC (voir l'IEC 60529:1989, l'IEC 60529:1989/AMD1:1999 et l'IEC 60529:1989/AMD2:2013).

Si un conducteur de protection externe PEL, PEM ou PEN traverse l'ensemble de classe II, il convient que l'ensemble soit équipé d'une borne d'identification appropriée.

d) A l'intérieur de l'enveloppe ou de l'espace protégé d'un ensemble de classe II, le conducteur de protection (conducteur PE, PEL, PEM ou PEN) et sa borne doivent être isolés des parties actives et des masses. Les masses à l'intérieur de l'ensemble ne doivent pas être raccordées au conducteur de protection. Cela s'applique aussi aux appareils incorporés, même s'ils ont une borne de connexion pour un conducteur de protection.

e) Si les portes ou les panneaux de l'enveloppe peuvent être ouverts sans l'aide d'une clé ou d'un outil, une barrière en matériau isolant doit être prévue, qui fournit une protection d'au moins IPXXB contre un contact fortuit non seulement avec les parties actives accessibles, mais également avec les masses qui ne le sont qu'après l'ouverture du panneau; cependant, cette barrière ne doit pas pouvoir être enlevée sans l'aide d'un outil.

8.4.5 Limitation du courant permanent et de la charge

Si l'ensemble contient des matériels qui peuvent conserver des charges électriques après avoir été mis hors tension (condensateurs sans protection principale interne, etc.), une étiquette d'avertissement est exigée.

De petits condensateurs tels que ceux qui sont utilisés pour l'extinction d'arcs, pour temporiser la réponse de relais, etc., ne doivent pas être considérés comme dangereux.

Un contact fortuit n'est pas considéré comme dangereux si les tensions provenant de charges statiques chutent au-dessous d'une tension continue de 60 V en moins de 5 s après coupure de l'alimentation.

Les courants de contact sont limités en s'assurant que les masses sont effectivement raccordées au conducteur de protection. Voir 10.5.2.

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8.4.6 Conditions d'exploitation et d'entretien

8.4.6.1 Appareils pouvant être utilisés ou composants pouvant être remplacés par des personnes ordinaires

La protection contre tout contact avec des parties actives doit être maintenue en cas d'intervention sur des appareils ou de remplacement de composants.

Le degré de protection minimal doit être IPXXC. Des ouvertures plus importantes que celles définies par le degré de protection IPXXC sont autorisées au cours du remplacement de certaines lampes ou de fusibles.

8.4.6.2 Exigences relatives à l'accessibilité en service par des personnes autorisées

8.4.6.2.1 Généralités

Selon l'application et l'accessibilité nécessaires en service par la ou les personnes autorisées, une ou plusieurs des exigences suivantes, données de 8.4.6.2.2 à 8.4.6.2.4, doivent être satisfaites. Ces exigences doivent s'ajouter à celles concernant la protection principale, spécifiées en 8.4.2.

Si les portes ou les panneaux de l'ensemble peuvent être ouverts par des personnes autorisées par déblocage d'un verrouillage permettant d'accéder aux parties actives, le verrouillage doit alors être rétabli automatiquement, au moment où la (les) porte(s) sont refermées ou le (les) panneau(x) sont remis en place.

Des obstacles peuvent être utilisés pour empêcher:

– toute approche involontaire des parties actives, ou
– tout contact fortuit avec des parties actives pendant l'exploitation des équipements sous tension en conditions normales d'emploi.

Les obstacles peuvent être retirés sans l'utilisation d'une clé ou d'un outil, mais ils doivent être fixés de manière à empêcher tout retrait involontaire. La distance entre un obstacle en matériau conducteur et les parties actives qu'il protège ne doit pas être inférieure aux valeurs spécifiées pour les distances d'isolement et les lignes de fuite en 8.3.

Lorsqu'un obstacle en matériau conducteur est séparé des parties actives dangereuses par une protection principale seulement, il constitue une masse et des dispositions pour les protections en cas de défaut doivent également être appliquées.

8.4.6.2.2 Exigences relatives à l'accessibilité en vue d'un examen ou d'opérations analogues

L'ensemble doit être construit de sorte que certaines opérations puissent être effectuées lorsque l'ensemble est en service et sous tension.

De telles opérations peuvent consister:

– à l'examen visuel:
  - des appareils de connexion et autres appareillages;
  - des réglages et indicateurs des relais et des déclencheurs;
  - des raccordements des conducteurs et du marquage;
– à régler et à réarmer des relais, des déclencheurs et des dispositifs électroniques;
– à remplacer les cartouches fusibles;
– à remplacer les lampes de signalisation;

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– à certaines opérations visant à localiser les défauts, par exemple les mesures de tension et de courant avec des dispositifs convenablement conçus et isolés.

8.4.6.2.3 Exigences relatives à l'accessibilité en vue de la maintenance

Pour permettre la maintenance d'une unité fonctionnelle sectionnée ou d'un groupe sectionné d'unités fonctionnelles de l'ensemble, alors que des unités ou groupes fonctionnels adjacents sont maintenus sous tension, les mesures nécessaires doivent être prises. Le choix dépend de facteurs tels que les conditions d'emploi, la fréquence de maintenance, la compétence du personnel autorisé ainsi que des règles locales d'installation. De telles mesures peuvent comprendre:

– une distance suffisante entre l'unité ou le groupe fonctionnel considéré et les unités ou les groupes fonctionnels adjacents. Il est recommandé que les parties susceptibles d'être retirées en vue de la maintenance aient, dans toute la mesure du possible, des moyens de fixation imperdables;
– l'utilisation de barrières ou d'obstacles conçus et disposés pour protéger contre tout contact direct avec les équipements situés dans les unités ou groupes fonctionnels adjacents;
– l'utilisation de cache-bornes;
– l'utilisation de compartiments pour chaque unité ou groupe fonctionnel;
– l'insertion de moyens supplémentaires de protection fournis ou spécifiés par le constructeur d'ensembles.

8.4.6.2.4 Exigences relatives à l'accessibilité en vue d'une extension alors que l'ensemble est sous tension

Lorsqu'il est exigé de permettre une extension future d'un ensemble avec des unités ou des groupes fonctionnels supplémentaires, alors que le reste de l'ensemble est maintenu sous tension, les exigences spécifiées en 8.4.6.2.3 doivent s'appliquer, sous réserve d'un accord entre le constructeur d'ensembles et l'utilisateur. Ces exigences s'appliquent également pour l'insertion et le raccordement de câbles de départ supplémentaires lorsque les câbles en place sont sous tension.

L'extension des jeux de barres et le raccordement d'unités supplémentaires à leur alimentation d'arrivée ne doivent pas être effectués sous tension, sauf si l'ensemble est conçu à cette fin.

8.5 Intégration des appareils de connexion et des composants

8.5.1 Parties fixes

Dans le cas de parties fixes (voir 3.2.1), les connexions des circuits principaux (voir 3.1.3) ne doivent être connectées ou déconnectées que lorsque l'ensemble est hors tension. L'enlèvement et l'installation de parties fixes exigent l'utilisation d'un outil.

Le débranchement d'une partie fixe doit exiger le sectionnement de l'ensemble complet ou d'une partie de celui-ci.

Afin d'empêcher une manœuvre non autorisée, l'appareil de connexion peut être équipé de moyens pour le maintenir dans une ou plusieurs de ses positions.

8.5.2 Parties amovibles

Les parties amovibles doivent être conçues de sorte que leur matériel électrique puisse être retiré du circuit principal ou raccordé à celui-ci en toute sécurité, même si ce circuit est sous tension. Les parties amovibles peuvent être équipées d'un verrouillage d'insertion (voir 3.2.5).

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Les distances d'isolement et les lignes de fuite (voir 8.3) doivent être respectées lors du passage d'une position à une autre.

Une partie amovible doit être munie d'un dispositif qui garantit à l'utilisateur qu'elle ne peut être retirée et insérée qu'après sectionnement de son circuit principal.

Si une opération non autorisée peut se produire, alors les parties amovibles doivent être dotées d'un moyen de fermeture afin de les bloquer dans au moins une de leurs positions.

8.5.3 Choix des appareils de connexion et des composants

Les appareils de connexion et les composants incorporés dans les ensembles doivent être conformes aux normes correspondantes de l'IEC.

Les appareils de connexion et les composants doivent convenir à leur application particulière en ce qui concerne la conception externe de l'ensemble (par exemple ouvert ou sous enveloppe), leurs tensions assignées, leurs courants assignés, leur fréquence assignée, leur durée de vie, leurs pouvoirs de fermeture et de coupure, leur tenue aux courts-circuits, etc.

La tension assignée d'isolement et la tension assignée de tenue aux chocs des appareils installés dans le circuit doivent être supérieures ou égales à la valeur de tension correspondante affectée à ce circuit. La protection contre les surtensions peut être nécessaire, par exemple pour les équipements de la catégorie de surtension II (voir 3.6.11). Les appareils de connexion et les composants dont la tenue aux courts-circuits et/ou le pouvoir de coupure sont insuffisants pour résister aux contraintes susceptibles de se produire sur le lieu de l'installation, doivent être protégés au moyen de dispositifs de protection ayant des caractéristiques de limitation de courant appropriées, par exemple des coupe-circuit à fusibles ou des disjoncteurs limiteurs de courant. Lors du choix des dispositifs de protection limiteurs de courant comme appareils de connexion incorporés, les valeurs maximales admissibles spécifiées par le constructeur de l'appareil doivent être utilisées, en tenant tout particulièrement compte de la coordination (voir 9.3.4).

La coordination des appareils de connexion et des composants doit satisfaire aux normes IEC appropriées. La coordination des démarreurs de moteur dotés de dispositifs de protection contre les courts-circuits doit satisfaire à l'IEC 60947-4-1:2018. Voir également 9.3.4.

NOTE Des recommandations sont fournies dans l'IEC TR 61912-1:2007 et l'IEC TR 61912-2:2009.

8.5.4 Installation des appareils de connexion et des composants

Les appareils de connexion et les composants doivent être installés et câblés dans l'ensemble conformément aux instructions données par leurs constructeurs et de telle sorte que leur bon fonctionnement ne soit pas compromis par les influences mutuelles, par exemple la chaleur, les émissions de coupure, les vibrations, les champs électromagnétiques, qui se produisent en service normal. Dans le cas de matériel électronique, il peut être nécessaire de séparer ou d'isoler par blindage tous les circuits électroniques de traitement des signaux.

Lorsque des fusibles sont installés, le constructeur d'origine doit indiquer le type et les valeurs assignées des cartouches fusibles à utiliser.

8.5.5 Accessibilité

Les dispositifs de réglage et de réarmement qui doivent être manœuvrés à l'intérieur de l'ensemble doivent être facilement accessibles.

Les unités fonctionnelles montées sur le même support (plaque de montage, cadre), ainsi que leurs bornes pour les conducteurs externes, doivent être disposées de manière à être accessibles pour le montage, le câblage, la maintenance et le remplacement.

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En prenant pour hypothèse que la base de l'ensemble et la zone de passage destinée au personnel d'exploitation se trouvent au même niveau, les exigences d'accessibilité suivantes associées aux ensembles reposant sur le sol doivent s'appliquer.

– Les bornes, à l'exception des bornes des conducteurs de protection, doivent être situées au moins à 0,2 m au-dessus de la base de l'ensemble et, de plus, elles doivent être placées de manière à ce que les câbles puissent leur être raccordés facilement et leur rayon de courbure respecté.
– Les appareils indicateurs nécessitant une lecture par l'opérateur doivent être placés à une hauteur comprise entre 0,2 m et 2,2 m au-dessus de la base de l'ensemble.
– Les organes de commande tels que poignées, boutons-poussoirs ou organes analogues doivent être installés à une hauteur telle qu'ils puissent être facilement manœuvrés; cela signifie que leur axe doit se trouver à une hauteur comprise entre 0,2 m et 2 m au-dessus de la base de l'ensemble. Les appareils utilisés peu souvent, par exemple moins d'une fois par mois, peuvent être installés à une hauteur jusqu'à 2,2 m.
– Les organes de commande des dispositifs de coupure d'urgence (voir 536.4.2 de l'IEC 60364-5-53:2001) doivent être accessibles à l'intérieur d'une zone située entre 0,8 m et 1,6 m au-dessus de la base de l'ensemble.

8.5.6 Barrières

Des barrières pour les appareils de connexion à commande manuelle doivent être conçues de telle sorte que les émissions de coupure ne présentent pas de danger pour l'opérateur.

Pour réduire le plus possible tout danger lors du remplacement des cartouches fusibles, des barrières entre phases doivent être installées, à moins que la conception et l'emplacement des coupe-circuit à fusibles ne rendent cette mesure de sécurité inutile.

8.5.7 Sens de manœuvre et indication des positions de commande

Les positions de fonctionnement des composants et des appareils doivent être clairement identifiées. Les positions de fonctionnement sont la position "I" (Marche (mise sous tension)) et la position "O" (Arrêt (mise hors tension)) (voir 8.1.6 de l'IEC 60947-1:2020). Une position correspondant à un déclenchement n'est pas considérée comme une position de fonctionnement et peut ne pas être indiquée. Si le sens de manœuvre n'est pas conforme à l'IEC 60447:2004, il doit être clairement identifié.

8.5.8 Voyants lumineux et boutons-poussoirs

Sauf spécification contraire dans la norme de produit applicable, les couleurs des voyants lumineux et des boutons-poussoirs doivent être conformes à l'IEC 60073:2002.

8.5.9 Batteries de compensation du facteur de puissance

Pour les batteries de compensation du facteur de puissance intégrées dans les ensembles, les exigences de l'IEC 61921:2017 doivent être satisfaites.

NOTE L'IEC 61439 constitue la principale référence pour la vérification exigée par l'IEC 61921:2017.

8.6 Circuits électriques internes et connexions

8.6.1 Circuits principaux

Les jeux de barres (nus ou isolés, voir 3.1.5) doivent être disposés de telle sorte qu'un court-circuit interne ne soit pas à craindre. Ils doivent être dimensionnés au moins conformément aux exigences concernant la tenue aux courts-circuits (voir 9.3) et doivent être conçus pour résister au moins aux contraintes de court-circuit limitées par le ou les dispositifs de protection situés en amont des jeux de barres.

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A l'intérieur d'une colonne, les conducteurs (jeux de barres de distribution inclus) entre les jeux de barres principaux et l'amont des unités fonctionnelles ou, dans le cas d'un ensemble à colonne unique, entre les bornes de charge de l'appareil d'arrivée et les bornes d'alimentation de chaque DPCC de départ, ainsi que leurs constituants peuvent être conçus sur la base des contraintes réduites de court-circuit se produisant en aval de chacun des dispositifs de protection contre les courts-circuits de chaque unité. Ceci sous réserve que la disposition des conducteurs soit telle qu'en exploitation normale un court-circuit interne entre parties actives et/ou entre parties actives et terre ne soit pas à craindre (voir 8.6.4).

La section minimale du conducteur neutre dans un circuit triphasé plus neutre doit être:

– pour les circuits avec une section du conducteur de ligne inférieure ou égale à 16 mm^2, 100 % de celle des phases correspondantes;
– pour les circuits avec une section du conducteur de ligne supérieure à 16 mm^2, 50 % de celle des phases correspondantes avec une valeur minimale de 16 mm^2.

NOTE Il existe des applications spécifiques pour lesquelles un conducteur neutre de plus faible section est acceptable pour l'utilisateur.

Par hypothèse:

a) le courant de neutre ne dépasse pas 50 % des courants de ligne;
b) le conducteur neutre est réalisé dans le même matériau que les conducteurs de ligne. Si ce n'est pas le cas, le conducteur neutre doit avoir au moins la même conductance ou le même courant admissible que celle/celui qui existe lorsque le conducteur neutre est réalisé dans le même matériau que les conducteurs de ligne.

Pour certaines réalisations qui génèrent des valeurs élevées d'harmoniques homopolaires (par exemple harmoniques de rang 3), des sections plus importantes du conducteur neutre peuvent être exigées dans la mesure où ces harmoniques des lignes s'additionnent dans le conducteur neutre et génèrent un courant élevé à des fréquences également plus élevées. Ces exigences sont soumises à accord particulier entre le constructeur d'ensembles et l'utilisateur.

Les conducteurs PEL, PEM et PEN doivent être dimensionnés tel que spécifié en 8.4.3.2.3.

8.6.2 Circuits auxiliaires

La conception des circuits auxiliaires doit prendre en compte l'installation de mise à la terre des circuits auxiliaires et assurer qu'un défaut de mise à la terre ne doit pas provoquer de fonctionnement intempestif dangereux.

En général, les circuits auxiliaires doivent être protégés contre les effets des courts-circuits. Cependant, un dispositif de protection contre les courts-circuits ne doit pas être fourni si son fonctionnement est susceptible de causer un danger. Dans ce type de cas, les conducteurs des circuits auxiliaires doivent être disposés de telle manière qu'un court-circuit ne soit pas à craindre (voir 8.6.4).

NOTE D'autres informations sur les exigences relatives aux circuits auxiliaires sont données dans l'IEC 60364-5-55:2011, l'IEC 60364-5-55:2011/AMD1:2012 et l'IEC 60364-5-55:2011/AMD2:2016, 557.3.4.

8.6.3 Conducteurs nus et isolés

Les connexions des parties transportant le courant ne doivent pas subir d'altérations excessives à la suite d'un échauffement normal, de vieillissement des matériaux isolants et de vibrations qui se produisent en exploitation normale. Les effets de la dilatation thermique; des couples électrochimiques dans le cas de métaux différents; du vieillissement dû aux températures atteintes, doivent être pris en considération.

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Les connexions aux dispositifs montés sur les portes ou d'autres parties mobiles doivent être réalisées à l'aide de câbles à âmes souples, par exemple de classe 5 ou de classe 6 selon l'IEC 60228:2004, pour permettre le mouvement de la partie. Les conducteurs doivent être ancrés sur la partie fixe et sur la partie mobile indépendamment des bornes de connexion électrique.

Les connexions entre les parties transportant le courant doivent être établies par des moyens qui assurent une pression de contact suffisante et durable.

Si la vérification de l'échauffement est effectuée sur la base d'essais (voir 10.10.2), le choix des conducteurs et de leurs sections utilisés à l'intérieur de l'ensemble doit relever de la responsabilité du constructeur d'origine. Si la vérification de l'échauffement est effectuée selon les règles d'évaluation de 10.10.4, les conducteurs doivent avoir une section minimale conforme à l'IEC 60364-5-52:2009. Des exemples sur la façon d'utiliser le présent document dans les conditions présentes à l'intérieur d'un ensemble sont donnés dans le Tableau H.1 et le Tableau H.2. Outre le courant admissible par les conducteurs, le choix tient compte:

– des contraintes mécaniques auxquelles l'ensemble peut être soumis;
– du mode de pose et de fixation des conducteurs;
– du type d'isolation;
– du type des composants raccordés (par exemple appareillage conforme à la série IEC 60947; dispositifs ou matériel électroniques).

Dans le cas de conducteurs isolés, à âme massive ou souple, les critères suivants s'appliquent.

– Ceux-ci doivent être dimensionnés au moins pour la tension assignée d'isolement (voir 5.2.3) du circuit considéré.
– Les conducteurs situés entre deux points de raccordement ne doivent pas posséder de raccordement intermédiaire, par exemple épissé ou soudé.
– Les conducteurs qui ne possèdent qu'une isolation principale ne doivent pas reposer sur des parties nues actives ayant des potentiels différents.
– Tout contact des conducteurs avec des arêtes vives doit être empêché.
– Les conducteurs d'alimentation des appareils et des instruments de mesure montés sur des panneaux ou des portes doivent être installés de telle manière qu'aucun dommage mécanique ne puisse être causé aux conducteurs à la suite d'un mouvement de ces panneaux ou de ces portes.
– Les connexions par brasage tendre à des appareillages ne doivent être autorisées dans les ensembles que dans le cas où les appareils sont prévus pour ce type de connexion et où le type spécifié de conducteur est utilisé.
– Pour les appareillages autres que ceux mentionnés ci-dessus, des pattes soudées ou des extrémités soudées de conducteurs multibrins ne sont pas acceptables dans des conditions de vibrations importantes. Dans les emplacements où de fortes vibrations se produisent en service normal, par exemple sur les dragues et les grues, les navires, les équipements de levage et les locomotives, il convient d'accorder une attention toute particulière à la fixation des conducteurs.
– Généralement, il convient de ne raccorder qu'un seul conducteur à un organe de serrage de borne; le raccordement de deux ou plusieurs conducteurs à un organe de serrage de borne est admis uniquement dans les cas où les organes de serrage de borne sont conçus à cet effet.
– Des conducteurs de circuits différents peuvent être posés côte à côte, occuper le même conduit (par exemple conduit, système de goulottes) ou se trouver dans le même câble multiconducteur si la disposition ne nuit pas au bon fonctionnement des circuits respectifs. Lorsque ces circuits fonctionnent à des tensions différentes, les conducteurs doivent être séparés par des barrières appropriées. En variante, tous les conducteurs d'un même conduit ou tous les conducteurs de câbles multiconducteurs doivent être isolés pour la tension la plus élevée à laquelle peut être soumis tout conducteur du même conduit, par

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exemple la tension entre phases pour les systèmes non mis à la terre et la tension entre ligne et terre pour les systèmes mis à la terre.

8.6.4 Choix et installation de conducteurs actifs non protégés pour réduire la possibilité de courts-circuits

Dans un ensemble, les conducteurs actifs qui ne sont pas protégés par des dispositifs de protection contre les courts-circuits (voir 8.6.1 et 8.6.2) doivent être choisis et installés dans tout l'ensemble conformément au Tableau 4. Les conducteurs actifs non protégés choisis et installés selon le Tableau 4 doivent avoir une longueur totale qui ne dépasse pas 3 m entre le jeu de barres principal et chaque DPCC respectif ou, dans le cas d'un ensemble à colonne unique, entre les bornes de charge de l'appareil d'arrivée et les bornes d'alimentation de chaque DPCC de départ.

8.6.5 Identification des conducteurs des circuits principaux et auxiliaires

A l'exception des cas mentionnés en 8.6.6, la méthode et les repères d'identification des conducteurs, par exemple par disposition, couleurs ou symboles, sur les bornes auxquelles ils sont raccordés ou sur l'extrémité ou les extrémités des conducteurs eux-mêmes, relèvent de la responsabilité du constructeur d'ensembles et doivent être conformes aux indications des schémas et plans de câblage. Le cas échéant, l'identification conformément à l'IEC 60445:2017 doit être appliquée.

8.6.6 Identification du conducteur de protection (PE, PEL, PEM, PEN), du conducteur neutre (N) et du conducteur de point milieu (M) des circuits principaux

Le conducteur de protection (PE, PEL, PEM ou PEN) doit pouvoir être facilement distingué par son emplacement et/ou son marquage ou sa couleur. Si l'identification se fait par la couleur ou le marquage, elle doit être conforme à l'IEC 60445:2017. Lorsque le conducteur de protection est un câble monoconducteur isolé, cette identification par la couleur doit être utilisée de préférence sur toute sa longueur.

Tout conducteur neutre ou de point milieu du circuit principal doit être facilement repérable par son emplacement et/ou son marquage ou sa couleur (voir l'IEC 60445:2017 qui exige le bleu).

8.6.7 Conducteurs dans des circuits à courant alternatif traversant des enveloppes ou des plaques ferromagnétiques

Lorsque des conducteurs présents dans des circuits à courant alternatif ayant un courant assigné supérieur à 200 A traversent des enveloppes, des parties ou des plaques ferromagnétiques, ils doivent:

– être disposés de telle sorte que les conducteurs ne soient entourés que collectivement par un matériau ferromagnétique, par exemple en passant par le même trou; ou
– les dispositions pour lesquelles les conducteurs passent dans des trous séparés doivent avoir été vérifiées par un ou plusieurs essais d'échauffement.

Il est permis qu'un conducteur de protection supplémentaire pénètre individuellement dans l'enveloppe en alliage ferreux.

8.7 Refroidissement

Si des précautions spéciales sont exigées concernant leur installation afin d'assurer un refroidissement convenable, le constructeur d'ensembles doit fournir les renseignements nécessaires (par exemple indication de la nécessité d'un espacement avec les pièces susceptibles d'empêcher la dissipation de chaleur ou de produire elles-mêmes de la chaleur).

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8.8 Bornes pour câbles externes

En se basant sur les informations du constructeur d'origine, le constructeur d'ensembles doit indiquer si les bornes conviennent pour des conducteurs en cuivre ou en aluminium, ou pour les deux. Les bornes doivent être telles que les conducteurs externes puissent être raccordés par un moyen (vis, connecteurs, etc.) assurant que la pression de contact nécessaire correspondant à la valeur assignée du courant et aux contraintes de courts-circuits de l'appareil et du circuit est maintenue.

En l'absence d'information spécifique stipulant l'utilisation de câbles de plus grande section, qui exigent des bornes de plus grandes dimensions, les bornes doivent être capables de recevoir des conducteurs en cuivre des plus petites jusqu'aux plus grandes sections correspondant au courant assigné du dispositif de protection du circuit, I_n, (voir Annexe A). Pour les dispositifs de protection réglables, le courant assigné correspond au réglage de courant choisi.

Pour l'utilisation de conducteurs en aluminium, le type, les dimensions et la méthode de raccordement des conducteurs doivent être tels que prévus dans l'accord entre le constructeur d'ensembles et l'utilisateur.

Dans le cas où des conducteurs externes destinés aux circuits électroniques à bas niveau de courant et de tension (moins de 1 A et moins de 50 V alternatif ou 120 V continu) doivent être raccordés à un ensemble, le Tableau A.1 ne s'applique pas.

L'espace disponible pour le branchement doit permettre le raccordement correct des conducteurs externes du matériau indiqué et l'épanouissement des conducteurs dans le cas de câbles multiconducteurs.

Les conducteurs ne doivent pas être soumis à des contraintes qui sont susceptibles de réduire leur espérance de vie normale. En l'absence d'information spécifique stipulant l'utilisation de câbles de plus grande section, qui exigent des bornes de plus grandes dimensions, sur les circuits triphasés plus neutre, les bornes du conducteur neutre doivent permettre de raccorder des conducteurs en cuivre présentant une section minimale:

– égale à la moitié de la section du conducteur de ligne, avec un minimum de 16 mm^2, si la dimension du conducteur de ligne dépasse 16 mm^2;
– égale à la section entière du conducteur de ligne, si la dimension de ce dernier est inférieure ou égale à 16 mm^2.

Pour les conducteurs autres que les conducteurs en cuivre, il convient que les sections mentionnées ci-dessus soient remplacées par des sections d'une conductance équivalente, ce qui peut exiger des bornes plus grandes.

Pour certaines réalisations qui génèrent des valeurs élevées d'harmoniques homopolaires (par exemple harmoniques de rang 3), des sections plus importantes du conducteur neutre peuvent être exigées dans la mesure où ces harmoniques des lignes s'additionnent dans le conducteur neutre et génèrent un courant élevé à des fréquences également plus élevées. Ces exigences sont soumises à accord particulier entre le constructeur d'ensembles et l'utilisateur.

Si des moyens de raccordement sont prévus pour les conducteurs neutres, de point milieu, de protection ou PEL, PEM et PEN d'arrivée et de départ, ils doivent être disposés près des bornes de conducteurs de ligne associés.

NOTE L'IEC 60204-1:2016 exige une section minimale du conducteur de protection et ne permet pas le raccordement du PEN au matériel électrique des machines.

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Les ouvertures pratiquées dans les entrées de câbles, plaques de fermeture, etc., doivent être conçues de telle sorte que, lorsque les câbles sont convenablement installés, les mesures indiquées de protection contre les contacts et le degré de protection soient obtenus. Cela implique le choix de dispositifs d'entrée de câbles adaptés à l'utilisation prévue par le constructeur d'ensembles.

Les bornes prévues pour les conducteurs de protection externes doivent être marquées selon l'IEC 60445:2017. A titre d'exemple, voir le symbole graphique ⏚ (IEC 60417-5019:2006-08-25). Ce symbole n'est pas exigé dans les cas où le conducteur de protection externe est destiné à être connecté à un conducteur de protection intérieur qui est clairement identifié par les couleurs verte et jaune.

Les bornes pour le raccordement des conducteurs de protection externes (PE, PEL, PEM, PEN) et des gaines métalliques des câbles de connexion (conduit en acier, gaine en plomb, etc.) doivent, lorsque cela est exigé, être nues et, sauf spécification contraire, permettre le branchement de conducteurs en cuivre. Une borne séparée de dimension appropriée doit être fournie pour chaque sortie de conducteur(s) de protection de chaque circuit.

En l'absence d'information spécifique stipulant l'utilisation de câbles de plus grande section, qui exigent des bornes de plus grandes dimensions, les bornes pour conducteurs de protection doivent permettre le raccordement de conducteurs en cuivre présentant une section qui dépend de la section des conducteurs de ligne correspondants selon le Tableau 5. Les bornes pour les conducteurs PEN doivent être identiques à celles pour les conducteurs neutres.

Dans le cas d'enveloppes et de conducteurs en aluminium ou en alliages d'aluminium, une attention particulière doit être accordée au danger de corrosion électrolytique. Les moyens de connexion prévus pour assurer la continuité des parties conductrices avec les conducteurs de protection externes ne doivent avoir aucune autre fonction.

Des mesures de prévention spéciales peuvent être nécessaires pour les parties métalliques de l'ensemble, en particulier les plaques de presse-étoupe, lorsqu'un fini de surface résistant à l'abrasion, par exemple un revêtement de poudre polymérisée, est utilisé.

L'identification des bornes doit être conforme à l'IEC 60445:2017 sauf indication contraire.

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9 Exigences relatives aux performances

9.1 Propriétés diélectriques

9.1.1 Généralités

Chaque circuit de l'ensemble doit être capable de résister:

– aux surtensions temporaires;

– aux surtensions transitoires.

La capacité à résister aux surtensions temporaires et l'intégrité de l'isolation solide sont vérifiées par la tension de tenue à fréquence industrielle, tandis que la capacité de l'ensemble à supporter les surtensions transitoires est vérifiée par la tension de tenue aux chocs.

Dans le cas de dispositifs d'entraînement ou de convertisseurs à fréquence variable, les ondes de tension réfléchies, les tensions de crête répétitives et la fréquence peuvent exiger une attention particulière.

9.1.2 Tension de tenue à fréquence industrielle

Les circuits de l'ensemble doivent être capables de supporter les tensions de tenue à fréquence industrielle appropriées données dans le Tableau 8 et le Tableau 9 (voir 10.9.2). La tension d'isolement assignée de tout circuit de l'ensemble doit être supérieure ou égale à sa tension assignée d'emploi maximale.

Les enveloppes et les poignées de manœuvre externes fabriquées dans des matériaux isolants ou recouvertes de ces matériaux doivent être capables de supporter les essais diélectriques à fréquence industrielle donnés en 10.9.4 et 10.9.5.

Les conducteurs recouverts d'un matériau isolant pour offrir une protection contre les chocs électriques doivent être capables de supporter l'essai diélectrique à fréquence industrielle donné en 10.9.6. Cet essai n'est pas exigé pour les conducteurs isolés dont l'isolement approprié a été vérifié d'après leur norme de produit (par exemple les câbles).

9.1.3 Tension de tenue aux chocs

9.1.3.1 Tensions de tenue aux chocs des circuits principaux

Les distances d'isolement entre les parties actives et les masses, ainsi qu'entre les parties actives de potentiel différent, doivent pouvoir supporter la tension d'essai donnée dans le Tableau 10 en fonction de la tension assignée de tenue aux chocs.

La tension assignée de tenue aux chocs pour une valeur donnée de la tension assignée d'emploi ne doit pas être inférieure à celle qui correspond, dans l'Annexe G, au type de réseau d'alimentation et à la tension nominale du réseau d'alimentation du circuit à l'endroit où l'ensemble doit être utilisé, et à la catégorie de surtension appropriée.

9.1.3.2 Tensions de tenue aux chocs des circuits auxiliaires

a) Les circuits auxiliaires qui sont raccordés au circuit principal et qui fonctionnent à la tension assignée d'emploi sans aucun dispositif de réduction de la surtension, doivent être conformes aux exigences de 9.1.3.1.

b) Les circuits auxiliaires qui ne sont pas raccordés au circuit principal peuvent avoir une tenue aux surtensions différente de celle du circuit principal. Les distances d'isolement de ces circuits, alternatifs ou continus, doivent pouvoir résister à la tension assignée de tenue aux chocs appropriée conformément à l'Annexe G.

9.1.4 Protection des parafoudres

Lorsque les conditions de surtension exigent que des parafoudres soient raccordés au circuit principal, ces parafoudres doivent être protégés pour empêcher les conditions de court-circuit non contrôlées, tel que spécifié par le constructeur des parafoudres.

L'installation du parafoudre doit respecter les instructions du constructeur de parafoudres, par exemple, la longueur totale des conducteurs entre les bornes du parafoudre et celles de la ligne et de la terre, suivant le cas.

9.2 Limites d'échauffement

9.2.1 Généralités

L'ensemble et ses circuits doivent pouvoir conduire leurs courants assignés dans les conditions spécifiées (voir 5.3.1, 5.3.2, 5.3.3 et 5.4), en tenant compte des caractéristiques assignées des composants, de leur disposition et application, sans dépasser les limites données dans le Tableau 6, lorsqu'ils sont vérifiés conformément à 10.10. Les limites d'échauffement données dans le Tableau 6 s'appliquent pour une température moyenne de l'air ambiant journalière de 35 °C.

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L'échauffement d'un élément ou d'une partie est la différence entre la température de cet élément ou de cette partie mesurée conformément à 10.10.2.3.3 et la température de l'air ambiant à l'extérieur de l'ensemble. Si la température moyenne de l'air ambiant est supérieure à 35 °C, les limites d'échauffement doivent alors être adaptées à cette condition spéciale d'emploi, de sorte que la somme de la température de l'air ambiant et des limites d'échauffement individuelles demeure identique. Si la température moyenne de l'air ambiant est inférieure à 35 °C, la même adaptation des limites d'échauffement est admise sous réserve d'un accord entre l'utilisateur et le constructeur d'ensembles.

Dans certains cas, par exemple les organes manuels de commande, ou les enveloppes et panneaux externes accessibles, des températures supérieures sont admises, sans qu'elles ne dépassent les limites fixées dans le Tableau 6. Voir Tableau 6, note h.

L'échauffement ne doit pas causer de dommage aux parties transportant le courant ou aux pièces adjacentes de l'ensemble. En particulier, pour les matériaux isolants, le constructeur d'origine doit démontrer la conformité soit par référence à l'indice de température, par exemple par les méthodes définies dans l'IEC 60216 (toutes les parties), soit conformément à l'IEC 60085:2007.

9.2.2 Ajustement des courants assignés pour d'autres températures de l'air ambiant

Si les limites d'échauffement ont été modifiées pour couvrir une température de l'air ambiant différente, il peut se révéler nécessaire de modifier en conséquence les courants assignés de tous les jeux de barres, toutes les unités fonctionnelles, etc. Le constructeur d'origine doit indiquer les mesures à prendre, s'il y a lieu, afin d'assurer la conformité avec les limites de température. Si une adaptation est effectuée pour des températures de l'air ambiant plus basses, les courants assignés des appareils, publiés par les constructeurs des appareils, ne doivent pas être dépassés.

Si un essai d'échauffement a été préalablement réalisé par l'application des limites d'échauffement pour une température moyenne de l'air ambiant journalière de 35 °C, alors, jusqu'à une température moyenne de l'air ambiant journalière de 50 °C, les courants assignés vérifiés par essai peuvent être ajustés par calcul, comme indiqué en 10.10.3.6.

9.3 Protection contre les courts-circuits et tenue aux courts-circuits

9.3.1 Généralités

Les ensembles doivent être capables de résister aux contraintes thermiques et dynamiques résultant de courants de court-circuit ne dépassant pas les valeurs assignées.

NOTE 1 Il est possible de réduire les contraintes de court-circuit par l'utilisation de dispositifs limiteurs de courant, par exemple inductances, fusibles limiteurs de courant ou autres appareils de connexion limiteurs de courant.

NOTE 2 Lorsqu'un court-circuit résulte du fonctionnement d'un dispositif d'extinction d'arc (AQD, Arc Quenching Device) conformément à l'IEC 60947-9-1 ou de tout autre dispositif de mise en court-circuit intentionnelle, il en résulte une contrainte maximale sur les circuits concernés.

Les ensembles doivent être protégés contre les courants de court-circuit au moyen, par exemple de disjoncteurs, de coupe-circuit à fusibles ou d'une combinaison des deux, qui peuvent être soit incorporés à l'ensemble, soit disposés à l'extérieur de celui-ci.

Pour les ensembles destinés à être utilisés dans les réseaux IT, il convient que le dispositif de protection contre les courts-circuits ait un pouvoir de coupure suffisant sur chaque pôle sous la tension entre phases pour éliminer un double défaut à la terre. (Voir l'IEC 60364-5-53:2001, l'IEC 60364-5-53:2001/AMD1:2002 et l'IEC 60364-5-53:2001/AMD2:2015).

Sauf spécification contraire dans les instructions d'utilisation et de maintenance du constructeur d'ensembles, les ensembles qui ont subi un court-circuit peuvent ne pas être adaptés à une remise en service ultérieure sans un examen et/ou une maintenance par une ou des personnes qualifiées.

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9.3.2 Indications concernant la tenue aux courts-circuits

Pour les ensembles dans lesquels un DPCC est incorporé à l'unité d'arrivée, le constructeur d'ensembles doit déclarer la valeur maximale admissible du courant de court-circuit présumé aux bornes d'arrivée de l'ensemble. Cette valeur ne doit pas être supérieure à la (aux) caractéristique(s) assignée(s) appropriée(s) (voir 5.3.4, 5.3.5 et 5.3.6). Le facteur de puissance et les valeurs de crête correspondants doivent être ceux qui sont indiqués en 9.3.3.

Si un disjoncteur à déclenchement temporisé est utilisé comme dispositif de protection contre les courts-circuits, le constructeur d'ensembles doit spécifier la temporisation maximale et le réglage correspondant au courant de court-circuit présumé.

Pour les ensembles dont le dispositif de protection contre les courts-circuits n'est pas intégré à l'unité d'arrivée, le constructeur d'ensembles doit indiquer la tenue aux courts-circuits selon l'une des deux manières suivantes, ou selon les deux à la fois:

a) courant assigné de courte durée admissible (I_{cw}), ainsi que la durée correspondante (voir 5.3.5), et la valeur de crête du courant assigné admissible (I_{pk}) (voir 5.3.4);

b) courant conditionnel de court-circuit assigné (I_{cc}) comprenant les caractéristiques de limitation de courant du DPCC situé en amont (voir 3.1.11).

Pour les durées n'excédant pas une durée maximale de 3 s, la relation entre le courant assigné de courte durée et la durée est donnée par la formule I^2t = constante, sous réserve que la valeur de crête ne dépasse pas la valeur de crête du courant assigné admissible.

Pour un ensemble ayant plusieurs unités d'arrivée non susceptibles de fonctionner simultanément, la tenue aux courts-circuits peut être indiquée pour chacune des unités d'arrivée conformément à ce qui précède.

Pour un ensemble ayant plusieurs unités d'arrivée susceptibles de fonctionner simultanément, et pour un ensemble ayant une unité d'arrivée et une ou plusieurs unités de départ de grande puissance susceptibles de contribuer au courant de court-circuit, il est nécessaire de déterminer les valeurs du courant de court-circuit présumé en tenant compte de tous les modes de fonctionnement, dans chaque unité d'arrivée, dans chaque unité de départ et dans les jeux de barres. Les courants de court-circuit présumés qui sont déterminés doivent être basés sur des données fournies par l'utilisateur.

9.3.3 Relation entre le courant de crête et le courant de courte durée

Pour déterminer les contraintes électrodynamiques, la valeur du courant de crête doit être obtenue en multipliant la valeur efficace, pour les applications en courant alternatif, et la valeur moyenne, pour les applications en courant continu, du courant de court-circuit par le facteur n. Les valeurs du facteur n et le facteur de puissance correspondant pour les applications en courant alternatif sont donnés dans le Tableau 7. Le facteur de crête pour les applications en courant continu fait l'objet d'un accord entre le constructeur et l'utilisateur.

NOTE Pour les applications en courant continu, si l'utilisateur n'a pas indiqué de valeur de courant de crête, la valeur n = 1,42 est généralement utilisée.

9.3.4 Coordination des dispositifs de protection

La coordination des dispositifs de protection à l'intérieur de l'ensemble avec ceux destinés à être utilisés à l'extérieur de l'ensemble doit faire l'objet d'un accord entre le constructeur d'ensembles et l'utilisateur. Les indications données dans le catalogue du constructeur d'ensembles peuvent tenir lieu d'un tel accord.

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Si les conditions de service exigent une continuité maximale d'alimentation, il convient que les réglages ou le choix des dispositifs de protection contre les courts-circuits à l'intérieur de l'ensemble soient, si possible, fixés de telle sorte qu'un court-circuit se produisant dans tout circuit de départ soit éliminé par le DPCC installé dans le circuit, sans affecter les autres circuits de départ, assurant ainsi la sélectivité du système de protection.

Lorsque les dispositifs de protection contre les courts-circuits sont raccordés en série et sont prévus pour fonctionner simultanément pour atteindre le pouvoir de coupure en court-circuit exigé (protection d'accompagnement), le constructeur d'ensembles doit informer l'utilisateur (par exemple par une étiquette d'avertissement située dans l'ensemble ou par les instructions d'exploitation, voir 6.2) qu'aucun des dispositifs de protection ne peut être remplacé par un autre appareil, sauf si cet appareil est de type et de caractéristiques assignées identiques et s'il a été soumis à essai et validé conjointement avec l'appareil d'accompagnement, dans le cas contraire le pouvoir de coupure de la combinaison complète d'appareils serait compromis.

D'autres recommandations sont fournies dans l'IEC/TR 61912-1:2007 et l'IEC/TR 61912-2:2009. Voir également 8.5.3.

9.4 Compatibilité électromagnétique (CEM)

Pour les exigences de performance liées à la CEM, voir J.9.4.

10 Vérification de la conception

10.1 Généralités

Toutes les vérifications de conception doivent être réalisées ou surveillées par une personne compétente, sous la responsabilité du constructeur d'origine.

La vérification de la conception est destinée à vérifier la conformité de la conception d'un ensemble ou d'un système d'ensembles avec les exigences de la série IEC 61439.

Les vérifications de conception doivent couvrir toutes les orientations de montage déclarées.

Lorsque des essais sur l'ensemble ont été réalisés conformément à la série IEC 60439 (supprimée) ou aux éditions précédentes de la série IEC 61439, et que les résultats d'essai satisfont aux exigences de l'édition actuelle de la partie appropriée de la série IEC 61439, il n'est pas nécessaire de répéter la vérification de ces exigences.

La répétition des vérifications selon les normes de produit des appareils de connexion ou des composants comprenant des conducteurs incorporés à l'intérieur de l'ensemble, qui ont été choisis conformément à 8.5.3 et installés conformément aux instructions de leur constructeur, n'est pas exigée. Les essais propres aux appareils et composants, y compris les conducteurs selon leurs normes de produit respectives, ne constituent pas une alternative aux vérifications de la conception selon le présent document, pour l'ensemble.

Si des modifications sont apportées à l'ensemble vérifié, les spécifications de l'Article 10 doivent être utilisées pour vérifier si ces modifications sont de nature à affecter les performances de l'ensemble. De nouvelles vérifications doivent être effectuées si un effet défavorable est probable.

Les différentes méthodes comprennent:

– des essais de vérification;
– une comparaison de vérification avec une ou plusieurs conceptions de référence;
– une évaluation de vérification, c'est-à-dire la vérification de l'application correcte des calculs et des règles de conception, y compris l'emploi de marges de sécurité appropriées.

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Voir l'Annexe D pour consulter la liste complète des vérifications de conception à couvrir.

Lorsqu'il existe plusieurs méthodes pour une même vérification, ces méthodes sont considérées comme équivalentes et le choix de la méthode appropriée relève de la responsabilité du constructeur d'origine.

Les essais doivent être effectués sur un échantillon représentatif d'un ensemble, dans un état propre et neuf.

Les performances de l'ensemble peuvent être affectées par les essais de vérification (par exemple essai de court-circuit). Il convient de ne pas réaliser ces essais sur un ensemble qui est destiné à être mis en service.

Il n'est pas exigé qu'un ensemble qui est vérifié conformément au présent document par un constructeur d'origine (voir 3.10.1) et qui est fabriqué ou assemblé par un autre constructeur subisse à nouveau les vérifications de conception d'origine si toutes les exigences et instructions spécifiées et fournies par le constructeur d'origine sont satisfaites dans leur intégralité. Lorsque le constructeur d'ensembles incorpore ses propres dispositions, non comprises dans la vérification du constructeur d'origine, il est réputé être le constructeur d'origine en ce qui concerne ces dispositions et est responsable de la vérification de ces dispositions alternatives.

La vérification de conception doit comprendre ce qui suit:

a) Construction:
   - 10.2 Résistance des matériaux et des parties,
   - 10.3 Degré de protection des ensembles (code IP),
   - 10.4 Distances d'isolement et lignes de fuite,
   - 10.5 Protection contre les chocs électriques et intégrité des circuits de protection,
   - 10.6 Intégration des appareils de connexion et des composants,
   - 10.7 Circuits électriques internes et connexions,
   - 10.8 Bornes pour conducteurs externes.

b) Performances:
   - 10.9 Propriétés diélectriques,
   - 10.10 Echauffement,
   - 10.11 Tenue aux courts-circuits,
   - 10.12 Compatibilité électromagnétique.

Les conceptions de référence, le nombre d'ensembles ou de pièces d'ensembles utilisés pour la vérification, le choix de la méthode de vérification le cas échéant, et l'ordre dans lequel les vérifications sont réalisées, doivent être laissés à l'initiative du constructeur d'origine.

Les données utilisées, les calculs effectués et les comparaisons réalisées dans le cadre de la vérification des ensembles doivent être consignés dans des rapports de vérification.

10.2 Résistance des matériaux et des parties

10.2.1 Généralités

Les capacités mécaniques, électriques et thermiques des matériaux de construction et des pièces de l'ensemble doivent être réputées prouvées par la vérification des caractéristiques de construction et de performance.

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Lorsqu'une enveloppe vide conforme à l'IEC 62208:2011 est utilisée et qu'elle n'a pas été modifiée d'une manière pouvant dégrader ses performances, aucun essai supplémentaire de cette dernière selon 10.2 n'est exigé.

10.2.2 Tenue à la corrosion

10.2.2.1 Vérification par essai

La résistance à la corrosion d'échantillons représentatifs des enveloppes en métal ferreux et des pièces de construction internes et externes en métal ferreux de l'ensemble doit être vérifiée.

L'essai doit être réalisé sur:

– une enveloppe ou un échantillon d'enveloppe représentatif équipés de pièces internes représentatives dont la (les) porte(s) sont fermées comme en utilisation normale;
– des parties d'enveloppe et des parties internes représentatives séparées.

Dans tous les cas, les charnières, les dispositifs de blocage et les moyens de fixation doivent également être soumis à essai, à moins d'avoir subi au préalable un essai équivalent et que leur résistance à la corrosion n'ait pas été affectée par leur mise en œuvre.

Lorsque l'enveloppe est soumise à l'essai, elle doit être montée comme en usage normal conformément aux instructions du constructeur d'origine.

Les éprouvettes doivent être neuves et propres et doivent par ailleurs être soumises à l'essai de sévérité A ou B, tel qu'indiqué en 10.2.2.2 et 10.2.2.3.

NOTE L'essai au brouillard salin fournit une atmosphère qui accélère la corrosion et n'implique pas que l'ensemble soit adapté à une atmosphère saline.

10.2.2.2 Essai de sévérité A

Cet essai s'applique:

– aux enveloppes en métal ferreux pour installation à l'intérieur;
– aux parties externes en métal ferreux des ensembles pour installation à l'intérieur;
– aux parties internes en métal ferreux des ensembles pour installation à l'intérieur et à l'extérieur dont le fonctionnement mécanique prévu peut dépendre.

L'essai se compose de:

six cycles de 24 h chacun pour l'essai cyclique de chaleur humide, conformément à l'IEC 60068-2-30:2005 (Essai Db) à (40 ± 2) °C. Variante 1 ou 2 à choisir selon les recommandations de l'Annexe A de l'IEC 60068-2-30:2005;

suivis de:

deux cycles de 24 h chacun pour l'essai au brouillard salin, conformément à l'IEC 60068-2-11:1981 (Essai Ka: brouillard salin), à une température de (35 ± 2) °C.

10.2.2.3 Essai de sévérité B

Cet essai s'applique:

– aux enveloppes en métal ferreux pour installation à l'extérieur,
– aux parties externes en métal ferreux des ensembles pour installation à l'extérieur.

L'essai comprend deux périodes identiques de 12 jours.

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