CEI EN IEC 61439-1:2022

Verifiche di progetto ed individuali

Certifico S.r.l. IT | Rev. 0.0 2024

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Documento di approfondimento sulle verifiche di progetto e le verifiche individuali sui quadri elettrici in accordo ai capitoli 10 e 11 della CEI EN IEC 61439-1:2022.

Verifica di progetto: verifica eseguita su un quadro campione o su parti di quadro per dimostrare che il progetto soddisfa le prescrizioni della relativa norma del quadro.

Verifica individuale: verifica eseguita su ciascun quadro durante e/o dopo la fabbricazione per confermare che il quadro soddisfi le prescrizioni della relativa norma del quadro.

La verifica di progetto è prevista per verificare la conformità del progetto di un quadro o di un sistema di quadri con le prescrizioni di questa serie di norme.

Un quadro che è stato verificato in accordo con la CEI EN IEC 61439-1:2022 dal costruttore originale ed è stato realizzato o assemblato da un altro costruttore non richiede la ripetizione delle verifiche originarie di progetto se tutte le prescrizioni e le istruzioni specificate e fornite dal costruttore originale sono state pienamente soddisfatte. Se il costruttore del quadro installa delle proprie disposizioni che non sono comprese nelle verifiche fatte dal costruttore originale, il costruttore del quadro, per quanto riguarda queste disposizioni, diventa il costruttore originale.

La verifica individuale ha lo scopo di individuare i difetti nei materiali e nella fabbricazione e di accertare il corretto funzionamento del quadro assemblato. Essa è eseguita su ogni quadro. Il costruttore del quadro deve stabilire se la verifica individuale è effettuata durante e/o dopo l'assemblaggio. Se del caso, la verifica individuale deve confermare che la verifica di progetto sia documentata.

La CEI EN IEC 61439-1:2022 (Ed. 3a) sostituisce l'edizione 2012 che resta applicabile fino al 21.05.2024.

A partire dal 22.05.2024 è in vigore solo la norma CEI EN IEC 61439-1:2022 (Ed. 3a).

Verifiche di progetto

1. Costruzione:

- Robustezza dei materiali e delle parti del quadro;
- Grado di protezione IP del quadro;
- Distanze d'isolamento (in aria e superficiali);
- Protezione contro la scossa elettrica ed integrità dei circuiti di protezione;
- Installazione degli apparecchi di manovra e dei componenti;
- Circuiti elettrici interni e collegamenti;
- Terminali per conduttori esterni.

2. Prestazioni:

- Proprietà dielettriche;
- Sovratemperatura;
- Resistenza al cortocircuito;
- Compatibilità elettromagnetica (EMC).

Verifiche individuali

1. Costruzione:

- grado di protezione contro il contatto con parti attive pericolose e dell'involucro;
- distanze di isolamento in aria e superficiali;
- protezione contro la scossa elettrica ed integrità dei circuiti di protezione;
- installazione degli apparecchi di manovra e dei componenti;
- circuiti elettrici interni e collegamenti;
- terminali per conduttori esterni;
- funzionamento meccanico.

2. Prestazioni:

- proprietà dielettriche;
- cablaggio, prestazioni in condizioni operative e funzionalità.

Estratto CEI EN IEC 61439-1:2022

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10 Design verification

10.1 General

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

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

Design verifications shall cover all declared mounting orientations.

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

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

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

The various methods include:

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

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

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

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

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

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

Design verification shall comprise the following.

a) Construction:

10.2 Strength of materials and parts;
10.3 Degree of protection of assemblies (IP Code);
10.4 Clearances and creepage distances;
10.5 Protection against electric shock and integrity of protective circuits;

10.6 Incorporation of switching devices and components;
10.7 Internal electrical circuits and connections;
10.8 Terminals for external conductors.

b) Performance:

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

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

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

10.2 Strength of materials and parts

10.2.1 General

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

Where an empty enclosure in accordance with IEC 62208:2011 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.

The test consists of:

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

followed by,

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

10.2.2.3 Severity test B

This test is applicable to:

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

The test comprises two identical 12-day periods. Each 12-day period comprises:

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

followed by:

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

10.2.2.4 Results to be obtained

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

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

10.2.2.5 Verification by comparison to reference design

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

10.2.3 Properties of insulating materials

10.2.3.1 Thermal stability

10.2.3.1.1 Verification of thermal stability of enclosures by test

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

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

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

The use of an electrically heated cabinet is recommended.

Natural circulation may be provided by holes in the walls of the cabinet. The enclosure or sample shall show no crack visible to normal or corrected vision without additional magnification nor shall the material have become sticky or greasy, this being judged as follows:

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

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

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

10.2.3.1.2 Verification of thermal stability of enclosures by comparison

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

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

10.2.3.2.1 Verification by test

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

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

The test shall be carried out on material with the minimum thickness used for the parts in a) or b). For a description of the test, see Clause 8 of IEC 60695-2-11:2014. The apparatus to be used shall be as described in Clause 5 of IEC 60695-2-11:2014.

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

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

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

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

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

10.2.3.2.2 Verification by comparison to a reference design

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

10.2.3.2.3 Verification by assessment

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

10.2.4 Resistance to ultraviolet (UV) radiation

10.2.4.1 Verification by test

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

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

Test samples:

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

shall be prepared.

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

Test sequence:

a) UV test on all twelve samples according to ISO 4892-2:2013, Method A, Cycle 1 providing a total test period of 500 h.
b) Verification of the flexural strength in accordance with ISO 178 (method A) with six of the samples. The surface of the sample exposed to UV radiation shall be turned face down and the pressure applied to the non-exposed surface.
c) Verification of the Charpy impact in accordance with ISO 179 on the other six samples. No notches shall be cut into the sample and the impact shall be applied to the exposed surface. Results to be obtained:

i) Samples shall not show cracks or deterioration visible to normal or corrected vision without additional magnification.
ii) The flexural strength according to ISO 178 shall have 70% minimum retention.
iii) The Charpy impact according to ISO 179 shall have 70% minimum retention. For materials whose impact bending strength cannot be determined prior to exposure because no rupture has occurred, not more than three of the exposed test specimens shall be allowed to break.

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

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

Test sequence:

a) UV test on all three samples according to ISO 4892-2 :2013, Method A, Cycle 1 providing a total test period of 500 h.
b) Verification of the retention of the coating according to ISO 2409.

Results to be obtained:

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

10.2.4.2 Verification by comparison to a reference design

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

10.2.4.3 Verification by assessment

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

10.2.5 Lifting

10.2.5.1 Verification by test

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

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

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

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

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

10.2.5.2 Verification by comparison to a reference design

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

10.2.6 Verification of 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.

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. I n true life a slow pollution takes place which is removed by regular maintenance.

The test device for IPX3 and IPX4 as well as the type of support for the enclosure during the IPX4 test shall be stated in the test report.

The IPX1 test may be carried out by moving the drip box instead of rotating the assembly. If the dimensions of the surface of the assembly to be tested are larger than the dimensions of the drip box, the test shall be repeated as often as necessary to cover all relevant surfaces of the assembly. Each separate test shall take 10 min.

Ingress of water in the IPX1 to IPX6 tests on an assembly is permissible only if its route of entry is obvious and the water is only in contact with the enclosure at a location where it will not reduce the clearance and creepage distances. If clearances and creepage distances are reduced, they shall not be below the minimum specified in Table 1 and Table 2, respectively.

The IP5X test is deemed to be a failure if dust is visible on creepage paths housed within the enclosure and creepage distances are reduced below the minimum specified in Table 2, see IEC 60529:1989, 13.5.2.

10.4 Clearances and creepage distances

It shall be verified that the clearances and creepage distances comply with the requirements of 8.3.

The creepage distances shall be measured in accordance with Annex F. Clearances are verified by measurement according to Annex F or by test according to 10.9.3.

10.5 Protection against electric shock and integrity of protective circuits

10.5.1 General

The effectiveness of the earth continuity and the protective circuit is verified for the following functions:

1) protection against the consequences of a fault within the class I assembly (internal faults) as outlined in 10.5.2; and
2) protection against the consequences of faults in external circuits supplied through the assembly (external faults) as outlined in 10.5.3.

10.5.2 Effective earth continuity between the exposed-conductive-parts of the class I assembly and the protective circuit

It shall be verified that the different exposed-conductive-parts of the assembly are effectively connected to the terminal for the incoming external protective conductor.

Verification shall be made using a resistance-measuring instrument that is capable of driving a current of at least 10 A (AC or DC). The current is passed between each exposed-conductive-part and the terminal for the external protective conductor. The resistance shall not exceed 0,1 Ω.

It is recommended to limit the duration of the test where low-current equipment is used; otherwise it can be adversely affected by the test.

10.5.3 Short-circuit withstand strength of the protective circuit

10.5.3.1 General

The rated short-circuit withstand strength shall be verified. Verification may be carried out by a comparison to a reference design(s) (see 10.5.3.3 or 10.5.3.4) or with a test as detailed in 10.5.3.5.

The original manufacturer shall determine the reference design(s) that will be used in 10.5.3.3and 10.5.3.4.

10.5.3.2 Protective circuits that are exempted from short-circuit withstand verification

Where a separate protective conductor is provided in accordance with 8.4.3.2.3, short-circuit testing is not required if one of the conditions of 10.11.2 is fulfilled.

10.5.3.3 Verification by comparison with reference designs - Using a checklist

Verification is achieved when the comparison of the assembly to be verified with already tested designs using items 1 to 6 and 8 to 10 of the checklist given in Table 13 shows no deviations.

To ensure the same current-carrying capacity for that portion of the fault current that flows through the exposed-conductive-parts, the design, number and arrangement of the parts that provide contact between the protective conductor and the exposed-conductive-parts shall be the same as in the reference design.

10.5.3.4 Verification by comparison with reference designs - Using calculation

Verification by comparison with reference designs based on calculation is to be carried out in accordance with 10.11.4.

To ensure the same current-carrying capacity for that portion of the fault current that flows through the exposed-conductive-parts, the design, number and arrangement of the parts that provide contact between the protective conductor and the exposed-conductive-parts shall be the same as in the reference design.

10.5.3.5 Verification by test

Subclause 10.11.5.6 applies.

10.6 Incorporation of switching devices and components

10.6.1 General

Compliance with the design requirements of 8.5 for the incorporation of switching devices and components shall be confirmed by the original manufacturer's inspection.

NOTE If the assembly manufacturer carries out a modification to the original manufacturer's design, then the assembly manufacturer assumes the responsibility of the original manufacturer for that design change and is responsible for carrying out the original manufacturer's inspection. See 10.1.

10.6.2 Electromagnetic compatibility

The performance requirements of J.9.4 for electromagnetic compatibility shall be confirmed by inspection or, where necessary, by testing (see 10.12).

10.7 Internal electrical circuits and connections

Compliance with the design requirements of 8.6 for internal electrical circuits and connections shall be confirmed by the original manufacturer's inspection.

NOTE If the assembly manufacturer carries out a modification to the original manufacturer's design, then the assembly manufacturer assumes the responsibility of the original manufacturer for that design change and is responsible for carrying out the original manufacturer's inspection. See 10.1.

10.8 Terminals for external conductors

Compliance with the design requirements of 8.8 for terminals for external conductors shall be confirmed by the original manufacturer's inspection.

NOTE If the assembly manufacturer carries out a modification to the original manufacturer's design, then the assembly manufacturer assumes the responsibility of the original manufacturer for that design change and is responsible for carrying out the original manufacturer's inspection. See 10.1.

10.9 Dielectric properties

10.9.1 General

For this test, all the electrical equipment of the assembly shall be connected, except those items of apparatus which, according to the relevant specifications, are designed for a lower test voltage; current-consuming apparatus (e.g. windings, measuring instruments, voltage surge suppression devices) in which the application of the test voltage would cause the flow of a current, shall be disconnected.

Such apparatus shall be disconnected at one of their terminals unless they are not designed to withstand the full test voltage, in which case all terminals may be disconnected.

For test voltage tolerances and the selection of test equipment, see IEC 61180:2016.

10.9.2 Power-frequency withstand voltage

10.9.2.1 Main and auxiliary circuits

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

Auxiliary circuits, whether AC or DC, that are not connected to the main circuit shall be subjected to the test voltage according to Table 9. This test is not carried out on auxiliary circuits:

- which contain only insulated conductors with the appropriate insulation strength as stated by their manufacturers; and
- which are protected by short-circuit protective devices with the rating not exceeding 16 A; and
- if an electrical function test has been carried out previously at the rated operational voltage for which the auxiliary circuits are designed.

10.9.2.2 Test voltage

Circuits intended for AC applications shall preferably be tested with an AC test voltage. Substitution of an AC voltage test by a DC voltage test should only be considered when the specimen does not allow testing with AC, e.g. in the case of filters, capacitors and similar, (see IEC 60664-1:2007, 6.1.3.4.1, fifth paragraph).

NOTE A test with a DC test voltage of a value equal to the peak value of the AC test voltage will be less stringent than the AC voltage test.

Circuits for DC applications shall be tested with AC or DC test voltages corresponding to the rated insulation voltage U_i.

Where an AC test voltage is used, it shall have a substantially sinusoidal waveform and a frequency equal to the rated frequency of the assembly with a tolerance of ±25%. A DC test voltage shall have negligible ripple.

The high-voltage source used for the test shall be so designed that, when the output terminals are short-circuited after the output voltage has been adjusted to the appropriate test voltage, the output current is sufficient to trip the overcurrent relay and it is greater than 100 mA.

The overcurrent relay shall not trip when the output current is less than 100 mA. The value of the test voltage shall be that specified in Table 8 or Table 9 as appropriate with a permitted tolerance of ±3%.

10.9.2.3 Application of the test voltage

The test voltage at the moment of application shall not exceed 50% of the full test value. It shall then be increased progressively to this full value and maintained for 60^{+2}_{0} sas 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
- other circuits;
- exposed-conductive-parts.

This test is not carried out on auxiliary circuits:

- which contain only insulated conductors with the appropriate insulation strength as stated by their manufacturers; and
- which are protected by short-circuit protective devices with a rating not exceeding 16 A; and
- if an electrical function test has been made previously at the rated operational voltage for which the auxiliary circuits are designed.

For an acceptable result, there shall be no disruptive discharge during the impulse voltage tests.

Some conductor arrangements retain a considerable charge after an impulse test, and for these cases care should be taken when reversing the polarity. To allow the arrangement to discharge, the use of appropriate methods, such as the application of three impulses at about 80% of the test voltage in the reverse polarity before the test, is recommended.

10.9.3.3 Alternative power-frequency voltage test

The test voltage shall have a substantially sinusoidal waveform at the rated frequency with a tolerance of ±25%.

The high-voltage source used for the test shall be so designed that, when the output terminals are short-circuited after the output voltage has been adjusted to the appropriate test voltage, the output current is sufficient to trip the overcurrent relay and it is greater than 100 mA.

The overcurrent relay shall not trip when the output current is less than 100 mA.

The value of the test voltage shall be that specified in 9.1.3 and Table 10 as appropriate with a permitted tolerance of ±3%.

The power-frequency voltage shall be applied once, at full value, for three cycles (see IEC 60664-1:2007, 6.1.2.2.2.2). It shall be applied to the assembly in the manner described in 10.9.3.2 a), b) and c) above.

For an acceptable result, the overcurrent relay shall not operate and there shall be no disruptive discharge during the tests.

10.9.3.4 Alternative DC voltage test

The test voltage shall have negligible ripple.

The high-voltage source used for the test shall be so designed that, when the output terminals are short-circuited after the output voltage has been adjusted to the appropriate test voltage, the output current is sufficient to trip the overcurrent relay and it is greater than 100 mA.

The overcurrent relay shall not trip when the output current is less than 100 mA.

The value of the test voltage shall be that specified in 9.1.3 and Table 10 as appropriate with a permitted tolerance of ± 3%.

The DC voltage shall be applied three times for each polarity for a duration of 10 ms (see IEC 60664-1:2007, 6.1.2.2.2.3)

It shall be applied to the assembly in the manner described in 10.9.3.2 a) and b) above.

For an acceptable result the overcurrent relay shall not operate and there shall be no disruptive discharge during the tests.

10.9.3.5 Verification assessment

Clearances shall be verified by measurement, or verification of measurements on design drawings, employing the measurement methods stated in Annex F. The clearances shall be at least 1,5 times the values specified in Table 1.

NOTE The 1,5 factor applied to the values in Table 1 is to avoid impulse withstand voltage tests for design verification. It is a safety factor that takes into consideration manufacturing tolerances.

It shall be verified by assessment of the device manufacturer’s data that all incorporated devices are suitable for the specified rated impulse withstand voltage (U_{imp}).

10.9.4 Testing of enclosures made of insulating material

For assemblies with enclosures made of insulating material, an additional dielectric test shall be carried out by applying an AC test voltage between a metal foil laid on the outside of the enclosure over openings and joints, and the interconnected live and exposed-conductive-parts within the assembly located next to the openings and joints. For this additional test, the test voltage shall be equal to 1,5 times the values indicated in Table 8.

10.9.5 External door or cover mounted operating handles of insulating material

In the case of handles made of or covered by insulating material, a power-frequency withstand voltage test shall be carried out by applying a test voltage equal to 1,5 times the test voltage indicated in Table 8 between the live parts and a metal foil wrapped round the whole surface of the representative handle. During this test, the exposed-conductive-parts shall not be earthed or connected to any other circuit.

10.9.6 Testing of conductors and hazardous live parts covered by insulating material to provide protection against electric shock

Conductors and hazardous live parts covered by insulating material in direct contact with the conductor so as to provide protection against electric shock, excluding those previously verified to their own product standard (e.g. cables), shall be subjected to an additional dielectric test. This test shall be carried out by applying an AC test voltage between a metal foil laid on the outside of the conductor insulation including openings and joints in the insulation, and the interconnected conductive parts within the insulation. For this additional test, the test voltage shall be equal to 1,5 times the values indicated in Table 8.

10.10 Temperature-rise

10.10.1 General

It shall be verified that the temperature-rise limits specified in 9.2 for the different parts of the assembly or assembly system will not be exceeded.

Verification shall be made with one or more of the following methods (see Annex L for guidance):

a) testing (10.10.2);
b) comparison with a reference design (10.10.3);
c) 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 capacity of the circuits to be verified is determined by;

- the group rated current of a main circuit I_{ng} (see 5.3.3); or
- the rated current of the main circuit I_{nc} (see 5.3.2) and the RDF (see 5.4).

NOTE In addition to I_{ng}, I_{nc} can be stated to allow assessment of the current-carrying capacity in lightly loaded sections, see 5.3.2. For assemblies incorporating power factor correction banks, verification of temperature-rise shall meet the additional requirements of IEC 61921:2017.

10.10.2 Verification by testing

10.10.2.1 General

Verification through testing consists of the following

a) If the assembly system to be verified comprises a number of variants, the most onerous arrangement(s) for the assembly system shall be selected according to 10.10.2.2.
b) The assembly variant(s) selected shall be verified by one of the following methods(see Annex L):

1) considering individual functional units, the main and distribution busbars and the assembly collectively according to 10.10.2.3.5;
2) considering individual functional units separately, and the complete assembly including the main and distribution busbars according to 10.10.2.3.6;
3) considering individual functional units and the main and distribution busbars separately as well as the complete assembly according to 10.10.2.3.7.

c) When the assembly variant(s) tested are the most onerous variants of an assembly system, then the test results can be used to establish the ratings of similar variants without further testing. Comparison rules for such derivations are given in 10.10.3.

10.10.2.2 Selection of the representative arrangement

10.10.2.2.1 General

The test shall be made on one or more representative arrangements loaded with one or more representative load combinations chosen to determine with reasonable accuracy the maximum temperature-rise under normal operating and installation conditions. The selection of the representative arrangements to be tested is given in 10.10.2.2.2 and 10.10.2.2.3 and is the responsibility of the original manufacturer. The original manufacturer shall take into consideration in the selection for testing the configurations to be derived from the tested arrangements according to 10.10.3.

10.10.2.2.2 Busbars

For busbar systems consisting of single or multiple rectangular sections of conductor, where the variants differ only in the reduction of one or more of;

- height,
- thickness,
- quantity of bars per conductor, and have the same;
- geometric arrangement of bars,
- centre line spacing of conductors,
- enclosure, and
- busbar compartment (if any),

the busbars with the greatest cross-sectional area shall be selected as the representative arrangement as a minimum for the test. For ratings of smaller busbar size variants or other materials, see 10.10.3.3.

10.10.2.2.3 Functional units

a) Selection of comparable functional unit groups

Functional units intended to be used at different rated currents can be considered to have a similar thermal behaviour and form a comparable range of units if they fulfil the following conditions:

1) the function and basic wiring diagram of the main circuit is the same (e.g. incoming unit, reversing starter, cable feeder);
2) the devices are of the same frame size and belong to the same series;
3) the mounting structure is of the same type;
4) the mutual arrangement of the devices is the same;
5) the type and arrangement of conductors is the same;
6) the cross-section of the main circuit conductors within a functional unit shall have a rating at least equal to that of the lowest rated device in the circuit. Selection of cables shall be as tested or in accordance with IEC 60364-5-5:2009. Examples on how to adapt this document for conditions inside an assembly are given in Table H.1 and Table H.2. The cross-section of bars shall be as tested or as given in Annex K.

b) Selection of a critical variant out of each comparable group as a specimen for test

The maximum possible current rating for each variant of functional unit is established. For functional units containing only one device, this is the rated current of the device. For functional units with several devices, it is that of the device with the lowest rated current. For each functional unit, the power loss is calculated at the maximum possible current using the data given by the device manufacturer for each device together with the power losses of the associated conductors.

For functional units with currents up to and including 630 A, the critical unit in each range is the functional unit with the highest total power loss.

For functional units with currents above 630 A, the critical unit in each range is that which has the highest rated current. This ensures that additional thermal effects relating to eddy currents and current displacement are taken into consideration.

The critical functional unit shall at least be tested:

- inside the smallest compartment (if any) which is intended for this functional unit; and
- with the worst variant of internal separation (if any) with respect to size of ventilation openings; and
- with the enclosure with the highest installed power loss per volume; and
- with the worst variant of ventilation of the enclosure with respect to the kind of ventilation (natural or forced convection) and size of ventilation openings.

If the functional unit can be arranged in different orientations (horizontal, vertical), then the most onerous arrangement shall be tested.

Additional tests may be made at the discretion of the original manufacturer for less critical arrangements and variants of functional units, if any.

10.10.2.3 Methods of test

10.10.2.3.1 General

In 10.10.2.3.5 to 10.10.2.3.7, three methods of testing are given, which differ in the number of tests needed and in the range of applicability of the test results. 10.10.2.3.5 provides a means of testing a complete assembly where the group rated current Ing is the test result. 10.10.2.3.6 provides a means of testing an assembly where additionally the rated current I_{nc} of the outgoing circuits is determined with fewer tests than specified in 10.10.2.3.7. An explanation is provided in Annex L.

The temperature-rise test on the individual circuits shall be made with the type of current for which they are intended, and at the design frequency. Any convenient value of the test voltage may be used to produce the desired current. Current consuming items such as, electronic components, coils of relays, contactors, releases, etc. shall be supplied with their rated operational voltages.

For assemblies with active cooling, the cooling equipment shall be operational, as in normal service.

The assembly shall be mounted as in normal use, with all covers including bottom cover plates, etc. in place.

If the assembly includes fuses, it shall be fitted for the test with fuse-links as specified by the manufacturer.

Details of the fuse-links used for the test, i.e. the manufacturer's name and reference, the rated current, the power loss of the fuse-link, and the breaking capacity, shall be given in the test report. The type test with the specified fuse-links shall be deemed to cover the use of any other fuse-link having a power loss, at the conventional thermal current of the combination unit, not exceeding the power loss of the fuse-link used for the test.

The size and the disposition of external conductors used for the test shall be stated in the test report.

The test shall be carried out for a time sufficient for the temperature-rise to reach a constant value. In practice, this condition is reached when the variation at all measured points (including the ambient air temperature) does not exceed 1 K/h.

To shorten the test, if the devices allow it, the current may be increased during the first part of the test, with it being reduced to the specified test current afterwards.

When a control electro-magnet is energized during the test, the temperature is measured when thermal equilibrium is reached in both the main circuit and the control electro-magnet.

The average value of the actual incoming test currents shall be between 100% and 103% of the intended value. Each phase shall be within ±5% of the intended value.

Tests on an individual section of the assembly are acceptable. To make the test representative, the external surfaces at which additional sections may be connected shall be thermally insulated with a covering to prevent any undue cooling.

When the performance of a single functional unit in one compartment is being tested as part of a complete assembly (or part of an assembly) as required by 10.10.2.3.7 d) taking into account the influence of other functional units in their own compartments, these other functional units can be replaced by heating resistors if the rating of each does not exceed 630 A and their rating is not to be verified with this test.

In assemblies where there is a possibility that additional auxiliary circuits or devices may be incorporated, heating resistors shall simulate the power dissipation of these additional items.

To reduce the testing required to determine the rated current of a circuit I_1 at the maximum permissible temperature-rise ΔT_1, the current rating may be calculated from the actual test current I_2 if the measured temperature-rise ΔT_2 of the current carrying parts (e.g. busbars and terminals) deviates from the permissible value by not more than ±5 K, using the following formula:

$$\frac{I_1}{I_2} = (\frac{\Delta T_1}{\Delta T_2})^{0,61}$$

[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.
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.

Where the fully-loaded circuits do not distribute exactly the total incoming current, the remaining current shall be distributed via any other appropriate circuit. This test shall be repeated until all types of outgoing circuit have been verified at their group rated currents.

Change in the arrangement of functional units within a verified assembly, or section of an assembly, may necessitate additional tests as the thermal influence of the adjacent units may differ significantly.

10.10.2.3.6 Verification considering individual functional units separately and the complete assembly

The group rated currents, I_{ng}, according to 5.3.3 and the rated currents, I_{nc}, of the outgoing main circuits according to 5.3.2 shall be verified in two stages:

- The rated current, I_{nc}, of each critical variant of outgoing functional unit as defined in 10.10.2.2.3 b) shall be verified separately in accordance with 10.10.2.3.7 c).
- The assembly is verified by loading the incoming circuit and all outgoing functional units collectively to their estimated group rated currents, I_{ng}.

If the group rated current, I_{ng}, of the incoming circuit or distribution busbar system is less than the sum of the currents, I_{ng}, of all outgoing circuits, then the outgoing circuits shall be split into test sets corresponding to the group rated current of the incoming circuit or distribution busbar system. The test sets shall be formed in a manner so that the highest possible temperature-rise is obtained. Sufficient test sets shall be formed and tests undertaken to include all different variants of functional units in at least one test set.

Where the fully loaded circuits do not distribute exactly the total incoming current, the remaining current shall be distributed via any other appropriate circuit. This test shall be repeated until all types of outgoing circuit have been verified at their test current.

Change in the arrangement of functional units within a verified assembly, or section of an assembly, may necessitate additional tests as the thermal influence of the adjacent units may differ significantly.

If I_{nc} and I_{ng} are verified, the RDF is calculated by dividing I_{ng} by I_{nc} for the individual circuits being considered.

10.10.2.3.7 Verification considering functional units and the main and distribution busbars separately as well as the complete assembly

Assemblies shall be verified by separate verification of standard elements a) to c) as selected in accordance with 10.10.2.2.2 and 10.10.2.2.3, and verification of a complete assembly d) under worst case conditions as detailed below.

a) Main busbars shall be tested separately. They shall be mounted in the assembly enclosure as in normal use with all covers and all partitions that separate the main busbars from other compartments in place. If the main busbar has joints, then they shall be included in the test. The test shall be carried out at the rated current. The test current shall pass through the full length of the busbars. Where the design of the assembly permits, and, to minimize the influence of the external test conductors on the temperature-rise, the length of the main busbar within the enclosure for the test shall be a minimum of 2 m and include a minimum of one joint when the busbars are extendable.
b) Each distribution busbar shall be tested separately from the outgoing units. They shall be mounted in the enclosure as in normal use with all covers and all partitions that separate the busbar from other compartments in place. Distribution busbars shall be connected to the main busbar. No other conductors (e.g. connections to functional units) shall be connected to the distribution busbar. In order to consider the most onerous condition, the test shall be carried out at the rated current, and the test current shall pass

through the full length of the distribution busbar. If the rated current of the main busbar is higher than the test current, it shall be fed with additional current so that it carries its rated current to its junction with the distribution busbar.
c) If the manufacturer declares I_{nc}, the relevant functional units shall be tested individually.
The functional unit shall be mounted in the enclosure as in normal use with all covers and all internal partitions in place. If it can be mounted at different places, the most unfavourable place shall be used. It shall be connected to the main or the distribution busbar as in normal use. If the main busbar and/or the distribution busbar (if any) are intended to supply other circuits and they are rated for a higher current, they shall be fed with additional currents so that they carry their individual rated currents to the respective junction points. The test shall be carried out at the estimated rated current I_{nc} for the functional unit.
d) The complete assembly shall be verified by temperature-rise testing of the most onerous arrangement(s) possible in service and as defined by the original manufacturer. For this test the incoming circuit and each outgoing functional unit are loaded to their group rated current I_{ng} where I_{ng} is equal to I_{nc} multiplied by RDF when I_{nc} is declared. If the group rated current of the incoming circuit or distribution busbar system is less than the sum of the test currents of all outgoing circuits (i.e. their group rated currents), then the outgoing circuits shall be split into test sets corresponding to the rated current of the incoming circuit or distribution busbar system. If the main busbar and/or the distribution busbar (if any) are rated for a higher current, they shall be fed with additional currents so as to maintain the rating achieved in a) and b). The test sets shall be formed in a manner so that the highest possible temperature-rise is obtained. Enough test sets shall be formed and tests undertaken to include all different variants of functional units in at least one test set.

If I and I_{ng}, are verified the RDF is calculated by dividing I_{ng} by I_{nc} for the individual circuits being considered.

10.10.2.3.8 Results to be obtained

The estimated rated currents in 10.10.2.3.5, 10.10.2.3.6 and 10.10.2.3.7, as verified by test(s), determine the final I_{nc} and/or I_{ng}, as applicable. At the end of the test, the temperature-rise shall not exceed the values specified in Table 6. If tests according to 10.10.2.3.6 or 10.10.2.3.7 have been carried out to verify I_{nc} in addition to I_{ng}, for the outgoing circuits, then the rated diversity factor may be calculated (see 3.8.11 and 5.4).

10.10.3 Verification by comparison

10.10.3.1 General

The following subclauses define how the rated currents of variants can be verified by derivation from similar arrangements verified by testing.

Tests carried out at a particular frequency are applicable at the same current rating to lower frequencies including DC.

Temperature-rise tests on the circuit(s) carried out at 50 Hz are applicable to 60 Hz for rated currents up to and including 800 A. In the absence of tests at 60 Hz for currents above 800 A, the rated current at 60 Hz shall be reduced to 95% of that at 50 Hz. Alternatively, where the maximum temperature-rise at 50 Hz does not exceed 90% of the permissible value, then de-rating for 60 Hz is not required.

10.10.3.2 Assemblies

Assemblies verified by derivation from a similar tested arrangement shall comply with the following:

a) the functional units shall belong to the same group(s) as the functional unit(s) selected for test (see 10.10.2.2.3);
b) the same type of construction as used for the test;
c) the same or increased overall dimensions as used for the test;
d) the same or increased cooling conditions as used for the test (forced or natural convection, same or larger ventilation openings);e) the same or reduced internal separation as used for the test (if any);
f) the same or reduced power losses in the same section as used for the test.

The assembly being verified may comprise all or only part of the electrical circuits of the assembly previously verified. Alternative arrangement(s) of functional units within the assembly or section compared to the tested variant is allowed as long as the thermal influences of the adjacent units are not more severe.

Thermal tests performed on 3-phase, 3-wire assemblies are considered as representing 3-phase, 4-wire and single-phase, 2-wire or 3-wire assemblies, provided that the neutral conductor is sized equal to or greater than the line conductors and arranged in the same manner.

10.10.3.3 Busbars

Ratings established for aluminium busbars are valid for copper busbars with the same cross-sectional dimensions and configuration. However, ratings established for copper busbars shall not be used to establish ratings of aluminium busbars.

The ratings of variants not selected for test according to 10.10.2.2.2 shall be determined by multiplying their cross-section with the current density of a larger cross-section busbar of the same design that has been verified by testing.

If, additionally, a smaller cross-section than the one to be derived has been tested, which also fulfils the conditions of 10.10.2.2.2, then the rating of the intermediate variants may be established by interpolation.

Modification of the connection between main and distribution busbar is permissible if the modification is verified by a test in which the temperature-rise in the new arrangement is not higher than in a comparable test on the reference design.

10.10.3.4 Functional units

After the critical variant of each group of comparable functional units (see 10.10.2.2.3 a)) has been subjected to a test for verification of temperature-rise, the actual rated currents Ing, and if determined, Inc, of all other functional units in the group shall be calculated using the results of these tests.

For each functional unit tested, a de-rating factor (rated current, I_{nc} or I_{ng}, resulting from the test divided by the maximum possible current of this functional unit, see 10.10.2.2.3 b)) shall be calculated.

The rated current, I_{nc} or I_{ng}, of each non-tested functional unit in the range shall be the maximum possible current of the functional unit multiplied by the de-rating factor established for the variant tested in the range.

Modification of the connection between functional unit and the main or distribution busbar is permissible if the modification is verified by a test in which the temperature-rise in the new arrangement is not higher than in a comparable test on the reference design.

10.10.3.5 Functional units - Temperature-rise considerations for device substitution

A device with a rated current I_n not exceeding 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 I1;

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. In 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.

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, Ing, 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, Ing. 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.

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 1600 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:

a) assemblies having a rated short-time withstand current (see 5.3.5) or rated conditional short-circuit current (see 5.3.6) not exceeding 10 kA RMS for AC and 10 kA mean average for DC;
b) assemblies, or circuits of assemblies, protected by current-limiting devices having a cut-off current not exceeding 17 kA with the maximum allowable prospective short-circuit current at the terminals of the incoming circuit of the assembly;
c) auxiliary circuits of assemblies intended to be connected to transformers whose rated power does not exceed 10 kVA for a rated secondary voltage of not less than 110 V, or 1,6 kVA for a rated secondary voltage less than 110 V, and whose short-circuit impedance is not less than 4%;
d) circuits protected by frequency converters where the outputs are provided with electronic short-circuit protection that limits the cut-off current to not more than 17 kA, as declared by the manufacturer.

All other circuits shall be verified.

10.11.3 Verification by comparison with a reference design - Using a checklist

The verifications are undertaken by comparison of the assembly to be verified with a reference design(s) using the checklist provided in Table 13.

Should any elements identified in the checklist not comply with the requirements of the checklist and be marked ‘NO’, one of the following means of verification shall be used (see 10.11.4 and 10.11.5).

A fuse link used in the reference design can be replaced by a fuse link of another make or series without any further testing if:

– the rating of the fuse links shall be the same;
– the utilization category is the same (e.g. gG);
– the fuse system is the same (e.g. NH); and
– power loss is the same or lower.

10.11.4 Verification by comparison with a reference design(s) - Using calculation

Assessment of the rated short-time withstand current of an assembly and its circuits, by calculation, shall be undertaken by a comparison of the assembly to be assessed with an assembly already verified by testing. The assessment to verify the main circuits of an assembly shall be in accordance with Annex M. In addition, each of the circuits of the assembly to be assessed shall meet the requirements of items 6, 8, 9 and 10 in Table 13.

The data used, calculations made and the comparison undertaken shall be stated in the verification documentation.

If the assessment in accordance with Annex M does not pass or any of the items listed above are not fulfilled, then the assembly and its circuits shall be verified by test in accordance with 10.11.5.

10.11.5 Verification by test

10.11.5.1 Test arrangements

The assembly or its parts as necessary to complete the test shall be mounted as in normal use. It is sufficient to test a single functional unit if the remaining functional units are of the same construction. Similarly, it is sufficient to test a single busbar configuration if the remaining busbar configurations are of the same construction. Table 13 provides clarification on items not requiring additional tests.

10.11.5.2 Performance of the test

If the test circuit incorporates fuses, fuse-links with the maximum let-through current and, if required, of the type indicated by the original manufacturer as being acceptable, shall be used.

The supply conductors and the short-circuit connections required for testing the assembly shall have sufficient strength to withstand short-circuits and be so arranged that they do not introduce any additional stresses on the assembly.

Unless otherwise agreed, the test circuit shall be connected to the input terminals of the assembly. Three-phase assemblies shall be connected on a three-phase basis.

All parts of the equipment intended to be connected to the protective conductor in service, including the enclosure, shall be connected as follows:

a) for assemblies suitable for use on three-phase four-wire systems with an earthed star point and marked accordingly, to the neutral point of supply or to a substantially inductive artificial neutral permitting a prospective fault current of at least 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).

NOTE In some cases, where protective functions of the device can be disabled, this can result in higher peak currents and let through energy.

One of each type of circuit shall be subject to a short-circuit test as described in 10.11.5.3.2 to 10.11.5.3.5.

10.11.5.3.2 Outgoing circuits

The outgoing terminals of outgoing circuits shall be provided with a bolted short-circuit connection. When the protective device in the outgoing circuit is a circuit-breaker, the test circuit may include a shunting resistor in accordance with 9.3.4.1.2 b) of IEC 60947-1:2020 in parallel with the reactor used to adjust the short-circuit current.

For circuit-breakers having a rated current up to and including 630 A, a conductor 0,75 m in length having a cross-sectional area corresponding to the rated current (see Table 11 and Table 12) shall be included in the test circuit. At the original manufacturer's discretion, a shorter connection than 0,75 m may be used.

The switching device shall be closed and held closed in the manner normally used in service. The test voltage shall then be applied once for a magnitude and duration as given in 10.11.5.4. In the case of outgoing circuits which do not include an SCPD, the magnitude and duration shall be as specified for the main busbars by the original manufacturer. Testing of outgoing circuits may also result in the operation of the incoming SCPD.

10.11.5.3.3 Incoming circuit and main busbars

Assemblies containing main busbars shall be tested to prove the short-circuit withstand strength of the main busbars and the incoming circuit including at least one joint where the busbars are intended to be extendable. The short-circuit shall be placed such that the length of main busbar included in the test is (2 ± 0,4) m. For the verification of rated short-time withstand current (see 5.3.5) and rated peak withstand current (see 5.3.4), this distance may be increased and the test conducted at any convenient voltage providing the test current is the rated value (see 10.11.5.4 b)). Where the design of the assembly is such that the length of the busbars to be tested is less than 1,6 m and the assembly is not intended to be extended, then the complete length of busbar shall be tested, the short-circuit being established at the end of these busbars. If a set of busbars consists of different sections (as regards cross-sections, centre line spacing of the conductors, type and number of supports per metre), each section shall be tested separately or concurrently, provided that the above conditions are met.

10.11.5.3.4 Connections to the supply side of outgoing units

Where an assembly contains conductors, including any distribution busbars, between a main busbar and the supply side of outgoing functional units that do not fulfil the requirements of 8.6.4, one circuit of each type shall be subjected to an additional test.

A short-circuit is obtained by bolted connections on the conductors connecting the busbars to a single outgoing unit, as near as practicable to the terminals on the busbar side of the outgoing unit. The value and duration of the short-circuit current shall be the same as that for the main busbars.

10.11.5.3.5 Neutral or mid-point conductor

10.11.5.3.5.1 Neutral conductor

If a neutral conductor exists within a circuit, it shall be subjected to one test to prove its short-circuit withstand strength in relation to the nearest line conductor of the circuit under test including any joints. Line to neutral short-circuit connections shall be applied as specified in 10.11.5.3.3.

Unless otherwise agreed between the original manufacturer and the user, the value of the test current in the neutral conductor shall be at least 60% of the line current during the three-phase test.

The test need not be executed if the test is intended to be made with a current of 60% of the line current and if the neutral conductor is:

- the same shape and cross-section as the line conductors;
- supported in an identical manner as the line conductors and with support centres along the length of the conductor not greater than that of the phases;
- spaced at a distance from the nearest phase(s) not less than that between phases;
- spaced at a distance from earthed metalwork not less than the line conductors.

If a 4-pole busbar system is sectioned by a three pole device, the short-time withstand current test including the neutral need not be executed if the test is intended to be made with a current of 60% of the line current and:

a) the criteria listed above are met; and
b) the neutral pole is part of a 4-pole busbar system that includes a 3- pole device, and
c) the 3- pole device does not result in any changes to the support system that would be necessary to support the line and neutral conductors if the 3- pole device were not present.

10.11.5.3.5.2 Mid-point conductor

The mid-point conductor shall be subjected to one test to prove its short-circuit withstand strength in relation to the line conductor of the circuit under test including any joints. Mid-point to line short-circuit connections shall be applied as specified in 10.11.5.3.3.

Unless otherwise agreed between the original manufacturer and the user, the value of the test current in the mid-point conductor shall be 100% of the line to line test current.

The test need not be executed if the mid-point conductor is not positioned between the line conductors if the following are fulfilled:

- it is the same shape and cross-section as the line conductors;
- it is supported in an identical manner as the line conductors and with support centres along the length of the conductor not greater than that of the line conductors;
- it is spaced at an equal or greater distance than the distance between the line conductor(s). In the case of a short-time withstand current, the test need not be executed if:

a) the criteria listed above are met; and
b) the mid-point pole is part of a 3-pole busbar system that includes a device; and
c) the device does not result in any changes to the support system that would be necessary to support the line and mid-point conductors if the device were not present.

10.11.5.4 Value and duration of the short-circuit current

For all short-circuit withstand ratings, the dynamic and thermal stresses shall be verified with a prospective current at the supply side of the specified protective device, if any, equal to the value of the rated short-time withstand current, rated peak withstand current or rated conditional short-circuit current.

For the verification of all the short-circuit withstand ratings (see 5.3.4 to 5.3.6 inclusive), the value of the prospective short-circuit current shall be within a tolerance of 0% to +5% at a test voltage equal to 1,05 times the rated operational voltage U_e of the circuit. The value of the short-circuit current shall be determined from a calibration oscillogram, which is taken with the supply conductors to the assembly short-circuited by a connection of negligible impedance placed as near as possible to the input supply of the assembly. The oscillogram shall show that there is a constant flow of current such that it is measurable at a time equivalent to the operation of the protective device incorporated in the assembly or for the specified duration (see 9.3.2 a)).

The value of current during the calibration is:

- for a test with AC, the RMS value of the AC component and the average of currents of all phases in a poly-phase system; or
- for a test with DC, the mean value in sustained conditions.

When making the tests at maximum operational voltage, the calibration current shall be equal to the rated short-circuit current with a tolerance of 0% to +5%. In poly-phase systems, this tolerance applies to the average of all line currents, while each individual line current may have a tolerance of ±5% of the rated value. For AC tests, the power factor shall be within a tolerance of 0,00 and −0,05.

The peak current and power factor in the case of an AC test shall be in accordance with 9.3.3. All tests for AC applications shall be carried out at the rated frequency of the assembly with a tolerance of ± 25%. With the following exception, tests for DC applications shall be carried out with DC.

An AC short-time current test may be used to verify a rated DC short-time withstand current and a rated DC peak withstand current providing the test with AC has a peak current equal to the rated DC peak withstand current and the RMS value of the short-time current is at least equal to the rated DC short-time withstand current. When substituting a DC test by an AC test, it should be recognized that the thermal and dynamic stresses of the AC test are higher than those of the equivalent DC test.

a) For a test at the rated conditional short-circuit current I_{cc}, whether the protective devices are in the incoming circuit of the assembly or elsewhere, the test voltage shall be applied for a time sufficiently long to enable the short-circuit protective devices to operate to clear the fault and, in any case, for not less than 10 cycles for AC and 200 ms for DC. The test shall be conducted at 1,05 times the rated operational voltage with prospective short-circuit currents, at the supply side of the specified protective device, equal to the value of the rated conditional short-circuit current. Tests at lower voltages are not permitted.
b) For a test at the rated short-time withstand current and at the rated peak withstand current, the dynamic and thermal stresses shall be verified with a prospective current equal to the value of rated short-time withstand current and rated peak withstand current declared. The current shall be applied for the specified time during which the RMS value of its AC component in the case of a test with AC, or the DC value in the case of a test with DC, shall remain constant. In the event of difficulties in carrying out the short-time or peak withstand tests at the maximum operational voltage with the test station, the tests according to 10.11.5.3.3, 10.11.5.3.4 and 10.11.5.3.5 may be carried out at any convenient voltage with the original manufacturer’s agreement, the actual test current being in this case equal to the rated short -time current or peak withstand current. This shall be stated in the test report. If, however, any momentary contact separation occurs in a contact arrangement (e.g. within a switching device or a plug-in contact), during the test, the test shall be repeated at the maximum operational voltage.

If necessary, due to test limitations, a different test period is permissible; in such a case, the test current should be modified in accordance with the formula I2t = 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 I2t 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 1000 V shall be performed in accordance with 10.9.2.

There shall be no loosening of parts used for the connection of conductors and the conductors shall not separate from the outgoing terminals.

Distortion of the busbars or supporting structure of the assembly that impairs its normal use shall be deemed a failure.

Any distortion of the busbars or supporting structure of the assembly that impairs normal insertion or removal of the removable parts shall be deemed a failure.

Deformation of the enclosure or of the internal partitions, barriers and obstacles due to the short-circuit current is permissible to the extent that the degree of protection is not apparently impaired and the clearances or creepage distances are not reduced to values that are less than those specified in 8.3.

Additionally, after the tests of 10.11.5.3 incorporating short-circuit protective devices, the tested equipment shall be capable of withstanding the power-frequency withstand voltage test of 10.9.2 at a voltage value for the "after-test" condition prescribed in the relevant short-circuit protective device standard for the appropriate short-circuit test, as follows:

a) between all live parts and the exposed-conductive-parts of the assembly, and
b) between each pole and all other poles connected to the exposed-conductive-parts of the assembly.

If tests a) and b) above are conducted, they shall be carried out with any fuses replaced and with any switching device closed.

In case of any doubt, it shall be checked that the equipment incorporated in the assembly is in a condition as prescribed in the relevant product standards and/or device manufacturer’s information, e.g. can be manually opened and closed. The fusible element (see 10.11.5.2), if any, shall not indicate a fault current. There shall be neither arcing nor flashover between poles of the protective device, or between poles and enclosure.

10.11.5.6 Testing of the protective circuit

10.11.5.6.1 General

This test does not apply for circuits according to 10.11.2.

A single-phase test supply shall be connected to the incoming terminal of one phase and to the terminal for the incoming protective conductor. When the assembly is provided with a separate protective conductor, the nearest line conductor shall be used. Where the assembly is extendable, the protective circuit tested shall include at least one joint. For each representative outgoing unit, a separate test shall be carried out with a bolted short-circuit connection between the corresponding outgoing phase terminal of the unit and the terminal for the relevant outgoing protective conductor.

Each outgoing unit on test shall be fitted with its intended protective device. Where alternative protective devices can be incorporated in the outgoing unit, the protective device which lets through the maximum values of peak current and I^2t shall be used.

For this test, the frame of the assembly shall be insulated from the earth. The test voltage shall be equal to 1,05 times the single-phase value of the rated operational voltage. Unless otherwise agreed between the original manufacturer and the user, the value of the test current in the protective conductor shall be at least 60% of the line current during the three-phase test of the assembly.

All other conditions of this test shall be analogous to 10.11.5.2 to 10.11.5.4 inclusive.

10.11.5.6.2 Results to be obtained

The continuity and the short-circuit withstand strength of the protective circuit, whether it consists of a separate conductor or the frame or enclosure of the assembly, shall not be significantly impaired. Besides visual inspection, this may be verified by measurements with a current of the order of the rated current of the relevant outgoing unit. The earth continuity between the exposed-conductive-parts of a class I assembly and the protective circuit shall remain effective. If in doubt, measurements according to 10.5.2 shall be carried out. Deformation of the enclosure or of the internal partitions, barriers and obstacles due to the short-circuit current is permissible to the extent that the degree of protection is not apparently impaired and the clearances or creepage distances are not reduced to values that are less than those specified in 8.3.

Where the frame or enclosure of the assembly is used as a protective conductor, sparks and localized heating at joints are permitted, provided they do not impair the electrical continuity and provided that adjacent flammable parts are not ignited.

NOTE A comparison of the resistances measured before and after the test, between the terminal for the incoming protective conductor and the terminal for the relevant outgoing protective conductor, gives an indication of conformity with this condition.

10.12 Electromagnetic compatibility (EMC)

For EMC tests, see J.10.1

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 b y a competent person.

Routine verification is intended to detect faults in materials and workmanship and to ascertain proper functioning of the manufactured assembly. It is made on every assembly. The assembly manufacturer shall determine if routine verification is carried out during and/or after manufacture. Routine verification shall confirm that the assembly manufacturing instructions have been adhered to.

Routine verification is not required to be carried out on devices and self-contained components incorporated in the assembly when they have been selected in accordance with 8.5.3 and installed in accordance with 8.5.4.

Verification shall comprise the following categories:

a) Construction (see 11.2 to 11.8):

1) degree of protection against contact with hazardous live parts, ingress of solid foreign bodies and water of enclosures;
2) clearances and creepage distances;
3) protection against electric shock and integrity of protective circuits;
4) incorporation of built-in components;
5) internal electrical circuits and connections;
6) terminals for external conductors;
7) mechanical operation.

b) Performance (see 11.9 to 11.10):

1) dielectric properties;
2) wiring, operational performance and function.

NOTE This verification includes the proper connection and operation of any communicating devices.

c) Confirmation that documents that are intended to be supplied with the assembly are provided and include those required in 6.2.1.

11.2 Degree of protection against contact with hazardous live parts, ingress of solid foreign bodies and water of enclosures

A visual inspection is necessary to confirm that the assembly meets the prescribed measures to achieve the designated degree of protection.

11.3 Clearances and creepage distances

Where the clearances are:

– less than the values given in Table 1, an impulse voltage withstand test in accordance with 10.9.3 shall be carried out;
– not evident by visual inspection to be larger than the values given in Table 1 (see 10.9.3.5), verification shall be by physical measurement or by an impulse voltage withstand test in accordance with 10.9.3;
– evidently larger by visual inspection than the values given in Table 1, verification may be carried out only by visual inspection.

The prescribed measures with regard to creepage distances (see 8.3.3) shall be subject to a visual inspection. Where it is not evident by visual inspection, verification shall be by physical measurement. No reduction on the values given in Table 2 is acceptable.

11.4 Protection against electric shock and integrity of protective circuits

The prescribed protective measures with regard to basic protection and fault protection (see 8.4.2 and 8.4.3) shall be subject to a visual inspection.

The protective circuits shall be checked by inspection to ascertain that the measures prescribed in the manufacturer's instructions are adhered to and verified. When it is not obvious by inspection that the earth continuity of the protective circuits meets the requirement of 8.4.3.2, a continuity test according to 10.5.2 shall be made.

Screwed and bolted connections shall be checked for the correct tightness on a random basis.

11.5 Incorporation of built-in components

The installation and identification of built-in components shall be in accordance with the assembly's manufacturing instructions.

11.6 Internal electrical circuits and connections

The connections, especially screwed and bolted connections, shall be checked for the correct tightness on a random basis.

Conductors shall be checked in accordance with the assembly's manufacturing instructions.

11.7 Terminals for external conductors

The number, type and identification of terminals shall be checked in accordance with the assembly's manufacturing instructions.

11.8 Mechanical operation

The effectiveness of mechanical actuating elements, interlocks and locks, including those associated with removable parts, shall be checked.

Where a device's operating handle is used to indicate the switching position of the device, and it detaches from the device when the door is open, it shall be confirmed that, when the door is closed, the handle provides positive and unambiguous indication of the device's open and closed positions.

11.9 Dielectric properties

A power-frequency withstand test shall be performed on all circuits in accordance with 10.9.1and 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.

Table 1 - Minimum clearances in air (8.3.2)

Rated impulse withstand voltage, U_{imp} kV	Minimum clearance[a] mm
≤ 2,5	1,5
4,0	3,0
6,0	5,5
8,0	8,0
12,0	14,0
a Based on inhomogeneous field conditions and pollution degree 3.	

Table 2 - Minimum creepage distances (8.3.3)

Rated insulation voltage, Ui V[b]	Minimum creepage distance mm							
	Pollution degree							
	1	2			3			
	Material group[c]	Material group[c]			Material group[c]			
	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
1000	3,2	5	7,1	10	12,5	14	16	
1250	4,2	6,3	9	12,5	16	18	20	
1600	5,6	8	11	16	20	22	25	

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 830V, 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 III a175 ≤ CTI < 400
− Material group III b100 ≤ CTI <17

NOTA 1 The CTI values in footnote c refer to the values obtained in accordance with IEC 6 0112:2003 and IEC 6 0112:2003/AMD1:2009, test solution A, for the insulating material used.
NOTA 2 Values taken from IEC 6 0664-1 :2007, but maintaining a minimum value of 1,5 mm.

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

<table>
<tr><th>Type of conductor</th><th>Requirements</th></tr>
<tr><td>Bare conductors or single-core conductors with basic insulation, for example cables according to IEC 60227-3:1993 and IEC 60227-3:1993/AMD1:199.</td><td>Mutual contact or contact with conductive parts shall be avoided, for example by use of spacers.</td></tr>
<tr><td>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.</td><td>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.</td></tr>
<tr><td>Conductors with basic insulation, for example cables according to IEC 6 0227-3 :1993 and IEC 6 0227-3:1993/AMD1:1997, having additional secondary insulation, for example individually covered cables with shrink sleeving or individually run cables in plastic conduits.</td><td rowspan="3">No additional requirements.</td></tr>
<tr><td>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 6050.</td></tr>
<tr><td>Single or multicore sheathed cables, for example cables according to IEC 6 0245-4 :2011 or IEC 6 0227-4 :1992 and IEC 6 0227-4 :1992/AMD1:1997.</td></tr>
</table>

Table 5 - Minimum terminal capacity for copper protective conductors (PE)

Cross-sectional area of line conductors, S mm^2	Minimum cross-sectional areaof the corresponding protectiveconductor (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

Table 6 - Temperature-rise limits

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 control gear; - 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 control gear.

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 105K for copper busbars and conductors shall not be exceeded. The 105 K relates to the temperature above which annealing of copper is likely to occur. In the absence of a declaration from the original manufacturer, regarding the reliability and stability of the ageing behaviour of the electrical contact or joint, a maximum temperature-rise of 55 K for bare (uncoated) aluminium busbars and conductors is applicable.

h Where an assembly is installed in an ambient air temperature exceeding a daily average of 35 °C, a higher absolute temperature (°C) may be permitted. Temperature-rise (K) shall not exceed the values given in this table. See also 9.2. In such a case warning label according to ISO 7010 W017 shall be provided.

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

RMS value of the short-circuit current kA	Cos φ	n
I ≤ 5	0,7	1,5
5 < I ≤ 10	0,5	1,7
10 < I ≤ 20	0,3	2
20 < I ≤ 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 curren.		

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
$U_i \leq 60$	1000	1415
$60 < U_i \leq 300$	1500	2120
$300 < U_i \leq 690$	1890	2670
$690 < U_i \leq 800$	2000	2830
$800 < U_i \leq 1000$	2200	3110
$1000 < U_i \leq 1500$[a]	2700	3820
a For DC only		

Table 9 - Power-frequency withstand voltage for auxiliary circuits (10.9.2)

Rated insulation voltage U_i (line to line) V	Dielectric test voltage AC RMS V	Dielectric test voltage DC V
$U_i \le 12$	250	355
$12 < U_i \le 60$	500	710
$60 < U_i$	See Table 8	See Table 8

Table 10 - Impulse withstand test voltages (10.9.2)

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	1000 m	2000 m	Sea level	200 m	500 m	1000 m	2000 m
2,5	2,95	2,8	2,8	2,7	2,5	2,1	2,0	2,0	1,9	1,8
4,0	4,8	4,8	4,7	4,4	4,0	3,4	3,4	3,3	3,1	2,8
6,0	7,3	7,2	7,0	6,7	6,0	5,1	5,1	5,0	4,7	4,2
8,0	9,8	9,6	9,3	9,0	8,0	6,9	6,8	6,6	6,4	5,7
12,0	14,8	14,5	14,0	13,3	12,0	10,5	10,3	9,9	9,4	8,5

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

Range of rated current[a] A		Conductor cross-sectional area[b, c]	
		mm²	AWG/MCM
0	8	1,0	18
8	12	1,5	16
12	15	2,5	14
15	20	2,5	12
20	25	4,0	10
25	32	6,0	10
32	50	10	8
50	65	16	6
65	85	26	4
85	100	35	3
100	115	35	2
115	130	50	1
130	150	50	0
150	175	70	00
175	200	95	000
200	225	95	0000
225	250	120	250
250	275	150	300
275	300	185	350
300	350	185	400
350	400	240	500

a The value of the rated current shall be greater than the first value in the first column and less than or equal to the second value in that column.

b For convenience of testing and with the manufacturer's consent, smaller test conductors than those given for a stated rated current may be used.

c Either of the two conductors specified may be used.

Table 12 - Copper test conductors for rated currents from 400 A to 7000 A

Range of rated current[a] A	Test conductors			
	Cables[a]		Copper bars[b]	
	Quantity	Cross-sectional area mm²	Quantity	Dimensions mm (W X D)
400 < I ≤ 500	2	150	2	30 x 5
500 < I ≤ 630	2	185	2	40 x 5
630 < I ≤ 800	2	240	2	50 x 5
800 < I ≤ 1000	3	185	2	60 x 5
1000 < I ≤ 1250	3	240	2	80 x 5
1250 < I ≤ 1600	4 o 5	240 300	2	100 x 5
1600 < I ≤ 2000			3	100 x 5
2000 < I ≤ 2500			4	100 x 5
2500 < I ≤ 3150			3	100 x 10
3150 < I ≤ 4000			4	100 x 10
4000 < I ≤ 5000			5	100 x 10
5000 < I ≤ 6000			6	100 x 10
6000 < I ≤ 7000			7	100 x 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 1600 A and when the terminals are designed to be connected to a cable system, cables in parallel, with a total cross-section not exceeding that of the copper bars in this table, can be used as test conductors.

Table 13 - Short-circuit verification by comparison with reference designs: checklist (10.5.3.3, 10.11.3 and 10.11.4)

Item n°	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 with stand 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 require. "NO" to any one requirement - further verification is require.			
a Short-circuit protective devices of the same manufacturer, but of a different series, may be considered equivalent where the device manufacturer declares the performance characteristics to be the same or better in all relevant respects compared to the series used for verification, e.g. limitation characteristics (I^2t, I_{lt}), and critical distances.			

Table 14 - Relationship between prospective fault current and diameter of copper wire

Diameter of copper wire mm	Prospective fault current in the fusible element circuit A
0,1	50
0,2	150
0,3	300
0,4	500
0,5	800
0,8	1500

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	2000 (orresponding to an air pressure of the site of installation not less than 80 kPa)[d, e]	Not specified	2000 (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 2000 m. For some electronic equipment to be used at altitudes above 1000 m, it may be necessary to take into account the reduction of the cooling effect of the air.

Fonte:
CEI EN IEC 61439-1:2022

Collegati
CEI EN IEC 61439-1:2022
CEI EN IEC 61439-2:2021
CEI EN IEC 61439-1:2022 e CEI EN IEC 61439-1:2021: validità Ed. 2012 fino al 21 Maggio 2024
Certifico Quadri Elettrici
Manuale Quadro elettrico bordo macchina: EN 61439-1/2 e EN 60204-1*
Guida pratica Organizzare la Documentazione Quadri elettrici | CEI 121-5
Guida normativa quadri elettrici | CEI 121-5
Focus Quadri elettrici EN 61439-1: Verifiche e Prove previste

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Note Documento e legali