IEC TR 62271-307

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TECHNICAL REPORT

colour inside

High- voltage switchgear and controlgear –
Part 307: Guidance for the extension of validity of type tests of AC metal and solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV

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INTERNATIONAL
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FOREWORD

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IEC TR 62271-307 has been prepared by subcommittee 17C: Assemblies, of IEC technical committee 17: High-voltage switchgear and controlgear. It is a Technical Report.

This second edition cancels and replaces the first edition published in 2015. This edition constitutes a technical revision.

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

a) Structure of document updated.
b) Updated references to IEC 62271-200:2021 and IEC 62271-1:2017.

c) Addition of criteria for the extension of validity of type tests from functional unit(s) with a different insulating gas to the functional unit to be validated.
d) Figure 5 for the validation of a design modification was added.
e) Clause B.7 for the extension of validity of type test for a GIS with insulation gas A to insulation gas B was added.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
17C/939/DTR	17C/957/RVDTR

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

The language used for the development of this Technical Report is English.

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

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

This Technical Report is to be used in conjunction with IEC 62271-1:2017, IEC 62271-200:2021, and IEC 62271-201:2014 to which it refers and which are applicable unless otherwise specified.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

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

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 307: Guidance for the extension of validity of type tests of AC metal and solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV

1 Scope

This part of IEC 62271, which is a Technical Report, refers to prefabricated metal-enclosed and solid-insulation enclosed (both hereinafter called enclosed) switchgear and controlgear assemblies for alternating current of rated voltages above 1 kV and up to and including 52 kV as specified in IEC 62271-200 and IEC 62271-201, and to other equipment included in the same enclosure with any possible mutual influence.

This document can be used for the extension of the validity of type tests performed on one test object with a defined set of ratings to another switchgear and controlgear assembly of the same family with a different set of ratings or different arrangements of components or insulating fluids. It supports the selection of representative test objects composed of functional units of a family of switchgear and controlgear aimed at the optimization of type tests in order to perform a consistent conformity assessment.

The extension of validity, as this is the case for type tests, does not cover ageing, material compatibility, human health toxicity or impact on the environment, among others. It is the task of the manufacturer and the user to check those aspects are covered for the technical validation of an assembly design.

The extension of validity of type tests according to a component standard is outside the scope of this document.

This document utilises a combination of sound technical and physical principles, manufacturer and user experience, and calculations to establish guidance for the extension of validity of type tests, covering various design and rating aspects.

2 Normative references

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

IEC 60050-151:2001, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices*

IEC 60050-441:1984, *International Electrotechnical Vocabulary (IEV) – Part 441: Switchgear, controlgear and* fuses
IEC 60050-441:1984/AMD1:2000

IEC 62271-1:2017, *High-voltage switchgear and controlgear – Part 1: Common specifications for alternating current switchgear and* controlgear
IEC 62271-1:2017/AMD1:2021

IEC 62271-200:2021, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62271-201:2014, *High-voltage switchgear and controlgear – Part 201: AC solid-insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-151, IEC 60050-441, IEC 62271-1, IEC 62271-200, IEC 62271-201 and the following apply.

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

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

NOTE Some standard terms and definitions are recalled here for ease of reference.

3.1
family of switchgear and controlgear
functional units designed to be physically combined in assemblies and providing a range of ratings and characteristics (e.g. current, voltage, degree of protection)

3.2
functional unit
<of an assembly> part of an assembly comprising the main circuits, earthing circuit and auxiliary circuits that contribute to the fulfilment of a single function

Note 1 to entry: Functional units can be distinguished according to the function for which they are intended, e.g. incoming unit, through which electrical energy is normally fed into the assembly, outgoing unit, through which electrical energy is normally supplied to one or more external circuits.

[SOURCE: IEC 62271-200:2021, 3.5.103]

3.3
assembly
<of switchgear and controlgear> a combination of switchgear and/or controlgear completely assembled with all internal electrical and mechanical interconnections

Note 1 to entry: An assembly is comprised of one or more functional units.

[SOURCE: IEC 60050-441:1984, 441-12-01, modified – addition of a note to entry.]

3.4
component
<of an assembly> essential part of the high-voltage or earthing circuits of an assembly which serves a specific function (e.g. circuit-breaker, disconnector, switch, fuse, earthing switch, instrument transformer, bushing, busbar)

[SOURCE: IEC 62271-200:2021, 3.5.104]

3.5
main circuit
<of an assembly> all the high-voltage conductive parts of an assembly included in a circuit which is intended to carry the rated continuous current

[SOURCE: IEC 62271-200:2021, 3.5.105]

3.6
test object
item submitted to a test, including any accessories, unless otherwise specified

[SOURCE: IEC 60050-151:2001, 151-16-28]

3.7
extension (of validity) criterion
criterion based on the design parameters, which can be applied to validate the performance of an untested assembly based on the positive results of test(s) performed on another assembly for a specific characteristic

3.8
homogeneous group
group of functional units of a family of switchgear and controlgear having design parameters which allows for a specific characteristic extending the validity of the result of a type test performed on one member of the group to the rest of the group

3.9
clearance
the distance between two conductive parts along a string stretched the shortest way between these conductive parts

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

3.10
clearance between phases
the clearance between any conductive parts of adjacent phases

3.11
clearance to earth
clearance between any conductive parts and any parts which are earthed or intended to be earthed

[SOURCE: IEC 60050-441:1984, 441-17-33]

3.12
centre distance between phases
distance between the centres of adjacent phase conductors

3.13
continuous current performance
<of insulation fluid> ability of the gas or gas mixture to carry heat losses from inner components to the walls of the gas filled compartment for identical construction design

4 Use of extension criteria

4.1 General

Because of the variety of types of functional units, ratings and possible combinations of components, it is not practical to perform type tests with all the possible assemblies of enclosed switchgear and controlgear. Therefore, the performance of a particular assembly can be evaluated by reference to type test reports of other assemblies of the same family of switchgear and controlgear. Subclauses 5.1 to 5.7 provide for each kind of type test (or characteristic) a non-exhaustive list of design parameters, to be analysed for extension of validity.

The analysis is intended to be based on sound technical and physical principles and can also be supported by calculations, if applicable.

Each design parameter of the assembly to be assessed listed in the respective column of the tables in 5.1 to 5.7 is intended to be compared with the design parameter of the already type tested assembly applying the acceptance criteria provided in the same tables. The affirmation of every extension criterion allows a test performed on one assembly having specific characteristics to be applied to another assembly of the same family with different characteristics (e.g. some of the ratings or dimensions). For example, the affirmation of item (1) in Table 2 reads: the clearance between phases of the assessed assembly is larger than or equal to the clearance between phases of the tested assembly.

If any of the extension criteria cannot be affirmed, further evidence is required, for example by technical arguments, calculation/simulation or specific tests. Calculations are applied in a comparative sense as indicated in 4.3.

4.2 Parameters for extension criteria

The criteria for the extension of type tests available for a family of switchgear and controlgear depend on a number of design parameters such as the ones listed in Table 1. Every assembly is characterized by its own set of design parameters.

Component parameters are design and operating parameters that influence the capability of the component with respect to its own ratings. These parameters are controlled and specified by the manufacturer of the component. All applications of a component within a family of switchgear and controlgear are expected to meet the manufacturer's specified tolerances for component parameters.

NOTE Some switching devices, such as earthing switches, can be unavailable as a separate component and will be tested inside an assembly according to their relevant component standards.

Table 1 – Examples of design parameters

Design parameter	Related to
Raw material of a contact in a switching device	Component
Geometry of a contact in a switching device	Component
Opening and closing speed of a switching device	Component
Allowable rebound time of a switching device	Component
Clearance between phases	Component / assembly
Clearance to earth	Component / assembly
Pressure of insulating gas in a compartment	Component / assembly
Insulation gas or gas mixture	Component / assembly
Insulation class of all insulation parts in contact with conductors	Component / assembly
Length of unsupported section of busbar	Assembly
Arrangement of components	Assembly
NOTE This table includes examples only; it is not intended to be complete.	

Assembly parameters are those parameters that are directly influenced by the design of an assembly of a family of switchgear and controlgear, however, they can depend on component parameters. Assembly parameters are considered within the scope of this document.

4.3 Use of calculations

4.3.1 General

For the purpose of this document, calculations and simulations can only be applied in a comparative sense using calculation results available for a type tested assembly and results obtained for another assembly that is under investigation. The comparison is always based on the design parameters and the acceptance criteria in Table 2 to Table 7.

In many cases the performance of a given assembly, with respect to a particular type test, cannot be evaluated by a single value of a design parameter due to the complexity of the design. For example, the clearance between phase conductors might vary considerably along the current path. Calculations have the potential to compare the respective design parameter with spatial resolution supporting a comparison using technical arguments and expertise.

Depending on the type test and the particular design parameter, sometimes a simple model of the relevant switchgear and controlgear might be sufficient using an analytical or empirical formula, and sometimes a complete three-dimensional simulation model might be required using a complex numerical tool provided the results of the simulation tool are consistent and repeatable.

The validation of software tools and calculation methods themselves is outside the scope of this document. Some of these calculation methods are briefly mentioned below with their particular characteristics.

4.3.2 Temperature rise calculations

IEC TR 60890 [1][1] provides calculation procedures for low-voltage assemblies, which could also be applied to high-voltage switchgear and controlgear assemblies having regard to the particular limitations of this calculation method. The calculation is done in dependence of the total power generated inside, the area of enclosure walls and their mounting conditions, the number of horizontal partitions, and the area of ventilation openings. The temperature of air inside the tested compartment is the parameter to compare.

For complex geometries, a comparison can be performed by thermal networks, where the whole assembly with all components is divided into discrete elements built from heat generating resistors and heat conducting and convection elements. Also, more complex computational fluid dynamics (CFD) tools can be applied requiring a complete three-dimensional model of the switchgear and controlgear.

CIGRE TB 830 [2] provides guidelines for state-of-the-art temperature rise modelling of medium- and high-voltage switchgear and controlgear.

4.3.3 Electric field calculations

The dielectric withstand performance of two assemblies can be assessed by an electric field simulation of both designs comparing the resulting electric field strengths. Finite element (FE) or finite volume (FV) software tools exist, which allow simulating even complex three-dimensional geometries. A CIGRE publication [3] concludes in particular with respect to electric field calculations: "Simulation is an excellent and instructive tool… to predict performance, where performance is proven by tests on similar designs (interpolation)".

This document does not provide information for extrapolation but only for interpolation of characteristics, for example extending validity to higher values of electric field strengths is not covered.

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1 Numbers in square brackets refer to the Bibliography.

4.3.4 Mechanical stress calculations

Simulation software for operating mechanisms exists and can give information on the mechanical stress on parts of the mechanism. However, it is not feasible to assess the mechanical endurance by these programs. Therefore, at the present state of available simulation software, it is better if simulations for the extension of validity of mechanical type tests are not used. Nevertheless, the strength of single parts or mechanical supports can be assessed by such calculations.

4.3.5 Short-circuit current calculations

With respect to the short-time current withstand performance, guidance and calculation formulas for bus-bar designs can be found in the guideline on short-circuit withstand of low-voltage assemblies IEC TR 61117 [4], and on the calculation of the short-circuit current effects in IEC 60865-1 [5] and IEC TR 60865-2 [6]. This includes the determination of mutual electromagnetic forces between phase conductors and the resulting mechanical stress which is able to bend bus-bar conductors and damage insulators. The mechanical stress on busbars and forces on the supports can be assessed through stress analysis programs, when applying the calculated electromagnetic forces. Additionally, a calculation of the thermal stress using $I_k^2 t_k$ can be done when the assessment is made for a lower I_k and higher t_k than the ones tested.

4.3.6 Internal arc pressure rise calculations

The comparison of the pressure withstand performance of two assemblies can be substantiated by pressure rise calculations for the compartments under investigation. CIGRE TB 602 [7] provides some guidance on simulation tools for this purpose. The calculations are able to provide the pressure rise in the compartments under investigation, taking into account the opening of pressure relief devices. An assessment of the strength of the enclosure walls under the pressure stress can be made for simple geometries using calculation formulae, otherwise using finite element mechanical stress analysis.

The flow of hot gases expelled from the compartment can be simulated by CFD programs, however, it is, at the time of the publication of this document, not possible to simulate the ignition of indicators, which is an important acceptance criterion in the type test.

Therefore, such programs have limited applications for the extension of type test validity. CIGRE TB 686 [8] provides some examples of pressure rise calculations.

4.4 Information needed for extension of type test validity

For the extension of type test validity, similar information on the assembly under evaluation are collected as it is required for type test objects according to IEC 62271-200:2021, 7.1.3 or IEC 62271-201:2014, 6.1.3. In addition, Table 2 to Table 7 given in Clause 5 can be used to provide for each characteristic, i.e. type test relevant information on design parameters of the tested object and of the functional units under evaluation. Only the tables that are relevant for the characteristic under evaluation need to be used.

The applicable type test reports of the tested assembly are to be considered as far as they concern the comparison of the two assemblies.

Ideally, the manufacturer will provide relevant information on design parameters of the tested object as listed in Table 2 to Table 7 of Clause 5 to be included in any type test report in addition to the information required by the product standards.

Most often single value design parameters are not sufficient to perform the evaluation. In this case relevant drawings of both objects can be necessary.

If a comparison is substantiated by calculations, numerical data or by formula, the type of software used, the reference number of the calculation report and short summary of the results will be provided.

Documents proving traceability of the analysis performed are provided. Such documents are part of the report for extending the validity of performed type tests to the whole family or part of the family of switchgear and controlgear.

4.5 Extension of validity when using different insulating gas or gas mixture

Apart from SF_6 other insulation gases or gas mixtures are used in assemblies. These gases can, for example, differ in dielectric and thermal performance and in the behaviour during internal arc failures. It can happen, that identical assembly designs could be used with several insulation gases or gas mixtures depending on service conditions. It can be of interest to test only the gas or gas mixture with the lowest performance or highest stress to the design, covering other gases or gas mixtures for the same construction design assembly.

For this purpose, reference tests for direct comparison can be performed on the same construction design. Test object(s) with the different insulation gases or gas mixtures can be used to demonstrate which of the gas or gas mixture can be used as base for the transfer of each specific type test. The reference test(s) to be performed under type test conditions and the comparison test(s) are documented as well for later reference.

Then the transfer of test reports can follow a two-step approach as shown in Figure 1:

1) transfer of test for different construction design 1 to design 2 using the same gas;
2) transfer of test for an identical construction design from gas A to gas B.

The order of the transfer steps can be swapped.

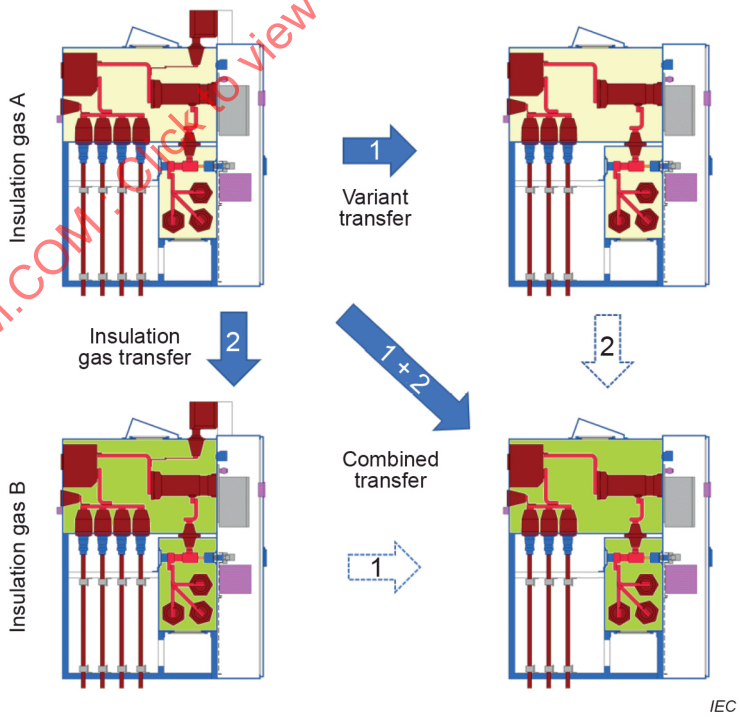

Figure 1 – Example for extension of validity of test report for dielectric testing with regard to different construction design variants and insulation gases of the same family of switchgear and controlgear

5 Application of extension criteria

5.1 General

Clause 5 to be read in conjunction with Annex A where the rationale behind is given for the guidance given in 5.2 to 5.7.

5.2 Dielectric tests

The criteria listed in Table 2 can be taken into consideration for all parts of the switchgear and controlgear assembly. The evaluation is applicable to the extension of validity of dielectric withstand tests from one functional unit or assembly to another belonging to the same family of switchgear and controlgear having the same or a lower rated insulation level.

If necessary for dielectric performance, insulating barriers and supplementary insulation can have been included in type tested objects according to IEC 62271-1:2017, 7.2.4, and therefore extension of the type test validity can only be performed on functional units or assemblies having the same arrangement and design of such insulation.

The test object is expected to contain suitable items or replicas that reproduce the field configuration of, for example, the high-voltage connections of instrument transformers or fuses posing the most onerous test conditions (refer to IEC 62271-200:2021, 7.2.7.2 and 7.2.7.3). This allows extending the validity of type tests to the use of components with different technical specification provided they have the same external electric field configuration. The same considerations can be made for other high and low-voltage accessories like surge arresters and heaters.

Table 2 – Extension criteria for dielectric withstand tests

Item	Design parameter	Acceptance criterion	Condition
(1)	(2)	(3)	(4)
1	Clearance between phases	≥	
2	Clearance to earth	≥	
3	Creepage distance	≥	NOTE 1
4	Electrical properties of insulating material	≥	A comparative result between two materials might be required (e.g. comparative tracking index according to IEC 60112 [9])
5	Surface roughness of live parts	≤	
6	Radius of conductive parts	≥	Not only the radius of live parts, but also the radius of all other conductive parts facing live parts (e.g. earthing devices, enclosure, LV wiring, supporting structures) need to be considered. NOTE 2
7	Open contact gap	≥	If influenced by the switchgear and controlgear assembly
8	Isolating distance	≥	If influenced by the switchgear and controlgear assembly
9	Minimum functional pressure for insulation	≥	If same gas or gas mixture for gas insulated switchgear and controlgear
10	Minimum ambient temperature in service	≥	If partial liquefaction of insulation gas can happen at service conditions
11	Minimum dielectric properties of insulation gas or gas mixture	≥	If different gas or gas mixture are used for identical construction designs at defined minimum functional pressure for insulation NOTE 3

NOTE 1 The field distribution along the insulating surface is also relevant.

NOTE 2 The geometry of parts made of insulating materials changes the electric field as well.

NOTE 3 The dielectric performances of different insulation gas or gas mixture for identical construction design can be verified using the procedure below Table 2.

To cover a different insulation gas or gas mixture, the dielectric performance difference between one gas and another gas or gas mixture or between two gas mixtures with different mixing ratios can be verified by reference tests, which are:

- lightning impulse voltage test (BIL),
- power-frequency voltage test (PFV),
- DC voltage test on cable testing circuits.

However, regarding the partial discharge (PD) type test, extension from one gas to another gas is not possible due to the following conflicting conditions:

- for the comparison of PD results in ideal circumstances the same test object is used;
- BIL and PFV to be carried out prior to PD measurement requires two separate but identical test samples.

Therefore, no extension of validity from one gas to another can be done for products according to IEC 62271-201.

Testing to the limit can demonstrate which gas or gas mixture has the lowest dielectric performance and would cover gases with higher performance on the identical construction design.

The minimum dielectric performance of a gas or gas mixture is assessed at a defined minimum functional pressure (density) for insulation and a defined gas composition for gas mixtures.

NOTE 1 The use of a minimum gas composition can be appropriate in case of different gas losses of the components of the mixture or significant decomposition of single gas components.

It needs to be taken into account, that for some gases or gas mixtures the dielectric behaviour is non-linear with the pressure, especially at higher pressures (see CIGRE brochure 730 [10] and CIGRE brochure 849 [11]). Solid insulated parts need to be identical and tested in the most onerous electric field configuration.

Test objects with identical construction and design for the reference test are preferably used. But it is better not to use the same test object, as the removal of all traces of previous tested gas or gas mixture being in practice impossible, except if the second gas mixture consists of the first with additional gas components providing a better performance.

After verification of higher dielectric properties at filling pressure compared to those at minimum functional pressure, this process will imply:

- to test to the limit the lowest dielectric performing gas or gas mixture at defined minimum functional pressure;
- to test the expected highest dielectric performing gas or gas mixture at same gas pressure and at a higher voltage level according to the procedure defined below.

As the impact of flash-over of lightning impulse voltage tests compared with power frequency voltage tests is normally low, lightning impulse voltage source is preferably used for the first comparison.

NOTE 2 The risk of surface damages and resulting weakening of the dielectric performance of the tests object is usually higher in case of disruptive discharges during power frequency voltage tests than during lighting impulse voltage tests due to a higher energy of the power frequency source. A current limiting resistor can be added to limit the breakdown current.

Lightning impulse voltage tests to be performed at increasing test voltage values by steps as follows:

- starting at rated lightning impulse withstand voltage;
- the voltage is increased stepwise by voltage steps of 5 % of the rated lightning impulse withstand voltage (e.g. 4 kV (75 kV); 7 kV (125 kV); 9 kV (170 kV)).

NOTE 3 Values are rounded up to next full digit.

The tests are started with the gas or gas mixture with the lowest expected performance:

- 15 impulses with positive polarity, followed by 15 impulses with negative polarity;
- when not more than 2 discharges occur, the voltage level is passed, and the test voltage is increased by a voltage step as described above;
- when 3 discharges occur, the voltage level is not passed, and the former passed voltage level is taken as the limit value for this gas or gas mixture;
- the same sequence is repeated for the other gases and gas mixtures at the same starting point with the same voltage steps.

NOTE 4 In case of damages on the test sample it can be necessary to change to a new test sample

During power frequency voltage tests the test voltage values are increased as follows:

- starting at rated power frequency withstand voltage;
- the voltage is increased stepwise by voltage steps, of 5 % of the rated power frequency withstand voltage (e.g. 2 kV (28 kV); 3 kV (50 kV); 4 kV (70 kV)).

NOTE 5 Values are rounded up to next full digit.

The tests are performed as follows, starting with the gas or gas mixture with the lowest expected performance:

- the test voltage is kept for 1 min;
- when no disruptive discharge occurs, the voltage level is passed, and the test voltage is increased by a voltage step as described above;
- when a disruptive discharge occurs, the voltage level is not passed, and the former passed voltage level is taken as the limit value for this gas or gas mixture at defined gas pressure;
- the same sequence is repeated for the other gases at the same starting point with the same voltage steps.

The DC voltage test on cable testing circuits are performed and passed according to IEC 62271-200:2021, 7.2.101, for each gas being compared.

Evidence of higher performance for a switchgear and controlgear construction design is given in case the limit value of the gas or gas mixture at defined gas pressure compared to the lowest dielectric performing gas or gas mixture at defined gas pressure is at least 3 voltage steps higher. If this is not the case, no evidence is given, and it is not possible to assess.

5.3 Continuous current tests

The extension criteria for continuous current type tests at rated continuous current equal to or smaller than assigned to the type tested functional unit are summarised in Table 3. The table does not consider forced ventilation.

The current carrying capacity of a functional unit is also dependent on the design of the bus-bar connection and on the distribution of current in adjacent functional units. Since the continuous current test is performed under the most severe conditions as required by the standard (e.g. IEC 62271-200:2021, 7.5), it is assumed that the impact of surrounding functional units on the continuous current performance is equal to or lower than the impact during the type test.

Where a functional unit includes different members of a family of components such as instrument transformers or fuses, these components need to be compared one by one with respect to power dissipation in order to extend the validity of the type test to the whole family of components.

For extension of rated frequency from 50 Hz to 60 Hz refer to IEC 62271-1:2017, 7.5.3.1.

Current transformers are type tested and verified according to their own product standard. Where current transformers are fitted in a functional unit, they can be considered acceptable if they have a power dissipation of the primary and secondary windings at the rated continuous current of the functional unit that is equal to or less than that installed in the type tested functional unit. Current transformers with lower current rating that have a higher primary resistance can only be applied in the switchgear and controlgear at lower continuous currents, where they have the same or lower primary and secondary power dissipation. The same will be considered for other components such as transformers supplying auxiliary and control circuits.

Table 3 – Extension criteria for continuous current performance

Item	Design parameter	Acceptance criterion	Condition
(1)	(2)	(3)	(4)
1	Centre distance between phases	≥	Only to be validated for rated continuous currents above 1250 A (see IEC 62271-1:2017, 7.5.2)
2	Phase to earth distance	≥	Only to be validated if an influence on the surrounding elements due to currents cannot be excluded, e.g. eddy currents and magnetising currents NOTE 1
3	Enclosure/compartment dimensions (L, H, W) and volume	≥	The enclosure and compartments are of the same construction NOTE 1
4	Minimum pressure of insulating gas	≥	If same gas or gas mixture; for gas insulated switchgear and controlgear
5	Current density of conductors	≤	The conductors have the same physical arrangement
6	Main circuit electrical resistance	≤	Resistance per unit length of conductors and contact resistance
7	Contact surface area of connections / joints	≥	Same or better contact material NOTE 2
8	Contact force of connections / joints	≥	Same or better contact material
9	Permissible temperature of contact materials of connections / joints	≥	Including metallic coatings having the same or lower resistivity
10	Effective ventilation area of partitions and enclosure	≥	NOTE 3
11	Power dissipation of components	≤	Here the main switching devices, fuses and current transformers are considered NOTE 4
12	Area of insulating barriers	≤	Barriers have the same physical arrangement

Item	Design parameter	Acceptance criterion	Condition
(1)	(2)	(3)	(4)
13	Thickness of insulating coating of conductors	≤	Thermal resistivity and emission coefficient of the coating are expected to be the same NOTE 5
14	Total coated surface area of enclosure for heat transfer	≥	The emission coefficient of the coating is expected to be the same
15	Temperature class of insulating material in contact with conductors	≥	Lower temperature classes can be applied with regard to margins obtained during the continuous current tests
16	Thermal performance of gas or gas mixture	≥	If different gas or gas mixture is used for gas insulated switchgear and controlgear NOTE 6

NOTE 1 The use of non-ferromagnetic material for enclosure and partitions will reduce heat generated by alternating magnetic fields compared with for example mild steel, when the conductors cross them.

NOTE 2 The lubrication of contacts is expected to be the same.

NOTE 3 The degree of protection (IP code) can be relevant.

NOTE 4 The power dissipation of both primary and secondary windings of current transformers is relevant.

NOTE 5 Coating of busbar, for example with paint, improves the heat transfer to the surrounding medium. The colour of the paint has no significant effect on the thermal radiation.

NOTE 6 The thermal performances of different insulation gas or gas mixture for identical construction design can be verified using the procedure below Table 3.

To cover a different insulation gas or gas mixture, the performance difference between one gas and another gas or gas mixture or between two gas mixtures with different mixing ratio can be demonstrated by reference tests. In case of thermal performance, continuous current tests with different gases in the identical design and test object at the same gas pressure and test current can be used to demonstrate which gas or gas mixture has the lowest thermal performance and would cover gases with higher thermal performance on the identical construction design at the same gas pressure.

The minimum thermal performance of a gas or gas mixture is assessed at a defined minimum functional pressure (density) for insulation.

It is preferable that the tests are carried out in the order of the expected thermal performance from lowest to highest performance. The tests will be carried out on the same test object filled with the different insulation gas or gas mixture at defined gas pressure. It is preferable to perform the continuous current tests as follows:

- measure the resistance of main circuit before test;
- perform the continuous current test as described in IEC 62271-200 or IEC 62271-201 at defined pressure(s) and measure the temperature rise inside the gas compartment, taking care of temperature limits defined in IEC 62271-1:2017, Table 14, related to the nature of conducting parts and of the insulation gas or gas mixture;
- let the test object cool down and repeat the test with the other gas or gas mixture;
- the same sequence can be repeated with other gases or gas mixtures, if any.

Evidence of the extension criteria from the lowest thermal performing gas or gas mixture to the expected highest thermal performing gas or gas mixture, at defined gas pressure, is given in case the temperature rise on all measurement points inside the gas compartment of the lowest thermal performing gas or gas mixture are higher than on those of the highest thermal performing gas or gas mixture and below the defined acceptable temperature limits for each measurement point and related gas or gas mixture.

5.4 Mechanical tests

The switching devices used in a family of switchgear and controlgear have to be type tested with respect to functionality and mechanical endurance according to the relevant component standard. This is applicable to the operating mechanisms of the switching devices, as well as to the shafts and interfaces used for manual or power operation. Mechanical position indicators are also covered by the component standards.

The mechanical parts being assessed in the switchgear and controlgear assembly, which are not covered by a dedicated component standard, are:

– shutter systems,
– contacts of the removable part,
– interlocks and kinematic chain of operating linkages.

Any changes in the design of the functional unit affecting the mounting / support of the switching device and the above-mentioned parts need to be carefully checked with respect to their impact on the mechanical behaviour. An extension of validity can only be carried out when the type tested arrangement of components is considered to operate under equal or more onerous conditions. Table 4 provides extension criteria for parts not covered by component standards provided that the number of assigned operations of the involved parts is equal or less than those of the type tested assembly.

Table 4 – Extension criteria for mechanical performance

Item	Part	Design parameter	Acceptance criterion	Condition
(1)	(2)	(3)	(4)	(5)
1	Shutter systems	1. Strength of locked mechanical linkage, including shutter	≥	The principal design of the shutter system is the same, but dimensions can be different.
		2. Mass of shutter	≤	See NOTE
2	Contacts of removable part	1. Number of contact points	≤	The designs of contacts, including base and coating material, and supports of movable and fixed contacts are the same
		2. Contact force per contact	≤	
		3. Roughness of contact surface	≤	
3	Interlocking-system directly operated on the mechanical chain	1. Strength of locked mechanical linkage	≥	The principal design of the interlocking system is the same, but dimensions can be different.
		2. Torque applied during operation attempt	≤	See NOTE
4	Interlocking- system preventing access to the operating devices	1. Strength of locked mechanical linkage	≥	The principal design of the interlocking system is the same, but dimensions can be different.
		2. Normal operating force	≤	See NOTE

NOTE Enclosure/compartment frame is part of the assessment when fixing and/or mounting of interlocking parts or mechanical devices is made on that structure.

5.5 Short-time withstand current and peak withstand current tests

Extension of validity of the short-time and peak withstand current type tests obtained on the main and earthing circuits of assemblies of functional units in accordance with IEC 62271-200 or IEC 62271-201 to other assemblies of the same family can be made using the criteria given in Table 5 provided that they have equal or smaller short-circuit current ratings (I_k and I_p) regardless of the value of the frequency (50/60 Hz). The short-circuit duration t_k can be longer as long as the condition for $I_k^2 t_k$ given in IEC 62271-1:2017, 7.6.3, is respected.

In order to extend the validity of a type test performed on a bus-bar compartment, it is assumed that the type test has been performed with at least two sections in series with identical bus-bar cross-section. This also allows for the evaluation of different bus-bar joints by affirmation of the items in Table 5.

Table 5 – Extension criteria for short-time and peak withstand current performance

Item	Design parameter	Acceptance criterion	Condition
(1)	(2)	(3)	(4)
1	Centre distance between phases	≥	
2	Electro-dynamic forces due to current path	≤	The conductors have the same physical arrangement. NOTE 1
3	Mechanical strength of insulating conductor supports	≥	NOTE 2 and NOTE 3
4	Length of unsupported sections of conductors	≤	
5	Cross-section of conductors	≥	Connections of the conductors are scaled and have the same or greater clamping force and contact area. NOTE 4 and NOTE 5
6	Material of conductors	Same	NOTE 4 and NOTE 5
7	Temperature class of insulating material in contact with conductors	≥	
8	Mechanical strength of the enclosure /partitions/ bushings	≥	NOTE 2 and NOTE 3
9	Contacts of removable part	Same	Consider complete design of contact sub-assembly and the fixing / mounting of the removable part.

NOTE 1 The effect of different paths can be assessed by calculation of electro-dynamic forces.

NOTE 2 Strength includes mechanical resistance to compression, traction, and bending loads.

NOTE 3 The enclosure can provide the base for the mechanical supports.

NOTE 4 In case of earthing circuits: in some designs, conductors can include parts of the metallic enclosure being used as earthing circuit.

NOTE 5 Conductors include connections in the main circuit and in the earthing circuit up to the earthing terminal.

5.6 Making and breaking tests

Switching devices forming part of the main and earthing circuit of enclosed switchgear and controlgear are supposed to have their rated making and breaking capacities verified according to the relevant component standards. IEC 62271-200:2021, 7.101.1, expresses that additional "tests are not necessary if making and breaking tests have been performed on the switching devices installed in assembly with identical or more onerous conditions." It already provides a note with respect to which effects might influence the performance of the switching devices such as mechanical forces due to the short circuit, the venting of arc products, the possibility of disruptive discharges, etc., and also recognizes that, in some cases, such influence can be negligible.

The rules for the extension of validity of breaking and making tests are described in IEC 62271-200:2021, 7.101, and equivalent in IEC 62271-201:2014. Table 6 lists the relevant design parameters that need to be considered to establish the same or less onerous conditions. All parameters in Table 6 are assembly parameters. Table 6 also applies to removable parts.

Table 6 – Extension criteria for making and breaking capacity

Item	Design parameter	Acceptance criterion	Condition
(1)	(2)	(3)	(4)
1	Clearance between phases	≥	See NOTE 1
2	Clearance to earth	≥	
3	Enclosure/compartment volume	≥	Only to be validated, if the fluid (gas or liquid) in the volume is involved in the making and breaking process.
4	Minimum functional pressure for insulation of insulating gas	≥	The travel characteristic is within the permissible tolerances.
5	Cross-section of conductors	≥	See NOTE 2
6	Electro-dynamic forces due to the current in the connection paths to the switching device	≤	Only to be validated, if there is an impact of the current path on the making and breaking performance
7	Mechanical strength of insulating supports	≥	Here, the supports of the phase conductors need to be considered see NOTE 3
8	Mechanical strength of the enclosure/ partitions / bushings	≥	See NOTE 3
9	Length of unsupported section of conductors	≤	See NOTE 3
10	Dielectric withstand capability of insulating gas or gas mixture	≥	The required dielectric properties are verified during the dielectric tests or extension of validity studies. Extension only possible in case the gas is not involved in the making and breaking process.
11	Contacts of removable part	Same	Consider complete design of contact sub-assembly and the fixing / mounting of the removable part.

NOTE 1 Extensions of type test validity with respect to the centre distance between phases inside the switching device are possibly treated by the relevant component standards.

NOTE 2 The contacts of a removable part do not affect the making and breaking capacity of the associated switching device and therefore are not considered here.

NOTE 3 It is assumed that the mechanical strength is already validated by a short-time withstand current and peak withstand current test. Not applicable for capacitive or any other load switching currents.

In case the identical design is used with different insulation gases or gas mixtures and the arc is not in the insulation gas, but for example in a vacuum interrupter, the test can be transferred from one insulation gas to another. Precondition is that the dielectric test is available for all gases or gas mixtures or a transfer of the dielectric tests for a gas or gas mixture to another gas or gas mixture was possible and proven by reference tests. The gas or gas mixture with the lowest dielectric performance Is intended to be used during making and breaking tests.

5.7 Internal arc fault tests

5.7.1 General

Switchgear and controlgear for which an internal arc classification (IAC) has been assigned has been subjected to internal arc tests for verification as specified in IEC 62271-200 or in IEC 62271-201. Depending on the purpose of the extension, criteria need to be considered with respect to the switchgear and controlgear design or with respect to the ratings and installation conditions or both.

5.7.2 Extension criteria with respect to the switchgear and controlgear design

Since internal arc tests are performed on individual compartments, the extension criteria provided in Table 7 are applied for each high-voltage compartment. The complete assessment of a functional unit or assembly is achieved after all the associated high-voltage compartments have been assessed. It is possible to combine different internal arc tests carried out on compartments in different functional units to extend the validity of type tests to the assembly under investigation. Details about design parameters and acceptance criteria for a compartment having arc fault current and duration equal to or smaller than assigned to the type tested compartment are given in Table 7.

Table 7 – Extension criteria for internal arc fault withstand performance

Item	Design parameter	Acceptance criterion	Condition
(1)	(2)	(3)	(4)
1	Clearance between phases	≤	
2	Clearance to earth	Same	This concerns the region where the arc is initiated. See NOTE 1
3	Net compartment volume	≥	
4	Filling pressure of insulating gas	≤	For fluid insulated switchgear and controlgear NOTE 2
5	Cross-section of conductors	≥	This concerns the region where the arc is initiated.
6	Raw material of conductors (Al or Cu or their alloys)	Same	This concerns the region where the arc is initiated. See NOTE 1
7	Location of the point of arc initiation	Same	Applying the rules of IEC 62271-200 or IEC 62271-201
8	Insulating material exposed to the arc	Same	See NOTE 3
9	Exhaust cross sectional area	≥	The position of the exhaust in the compartment and the gas flow path are the same. Larger cross-sectional areas are only acceptable, if an exhaust duct is used
10	Exhaust opening pressure	≤	Applicable to fluid tight compartments
11	Mechanical strength of elements to let open the relief device (flap)	≤	Applicable to non-tight compartments. The relief device and its retaining elements have the same design.
12	Mechanical strength of the enclosure and compartment	≥	This also includes the strength of partitions and bushings See NOTE 4
13	Thickness of the enclosure walls	≥	Same material See NOTE 4
14	Mechanical strength of the doors and covers	≥	See NOTE 4
15	Degree of protection (IP-code) of enclosure	≥	Where relevant for indicator ignition criterion

NOTE 1 The arc could move from the point of initiation.

NOTE 2 For SF_6 insulated switchgear and controlgear the test is performed with air (see IEC 62271-200:2021, 7.105.3, or IEC 62271-201:2014, 6.105.3) at the same filling pressure as for SF_6.

NOTE 3 For details refer to the first item of IEC 62271-200:2021, 7.105.3, or IEC 62271-201:2014, 6.105.3.

NOTE 4 An assessment of the strength can require calculations or stress analysis by finite element methods. The assessment considers the location, strength and number of all fixing points (bolts, hinges and latches).

5.7.3 Extension criteria with respect to ratings and installation conditions

The installation instructions supplied by the manufacturer are the base for the selection of test conditions during the laboratory test as defined in IEC 62271-200:2021, Annex A, or IEC 62271-201:2014, Annex AA. These test conditions comprise positioning of the switchgear and controlgear in the simulated room, determination of the ceiling height and location of accessible or non-accessible sides. It can be possible to accept a change of the installation instructions by a closer evaluation of the installation conditions in a previously performed type test. For this purpose, additional rules can be considered to extend the validity of an internal arc test performed on one switchgear and controlgear assembly under specified installation instructions to a different installation of the same assembly giving the same or less onerous conditions. Details about test ratings, installation conditions and extension criteria are given in Table 8. Most of the information provided in Table 8 is contained in IEC 62271-200 or IEC 62271-201. The table aims to summarize all the relevant information for easier use.

Table 8 – Extension criteria for internal arc fault classification with respect to installation conditions

Item	IAC test ratings and installation conditions	Extension criterion	Condition (Reference to a: IEC 62271-200:2021 or b: IEC 62271-201:2014)
(1)	(2)	(3)	(4)
1	Rated arc fault current	≤	a: A.4.1; b: AA.4.1
2	Rated arc fault duration	≤	a: A.4.1; b: AA.4.1
3	Rated voltage	≤	a: A.4.2; b: AA.4.2; see NOTE 1
4	Frequency	Type tests performed at 50 Hz or 60 Hz can prove both frequencies	a: A.4.4 and A.4.3.2 concerning the peak current; b: AA.4.4 and AA.4.3.2 concerning the peak current
5	Distance between the assembly and ceiling	≥	a: Clause A.1; b: Clause AA.1; and, if the test was performed with a clearance of at least 200 mm; see NOTE 2
6	Distance between assembly and lateral wall	≥	a: Clause A.1; b: Clause AA.1; if hot gases are not directed to the walls
7	Distance between assembly and rear wall	Depending on accessibility	Validation criteria are specified in a: Clause A.1; b: Clause AA.1
8	Indoor/outdoor condition	Type test performed for indoor application covers outdoor application with the same accessibility	a: A.1.2; b: AA.1.2
9	Accessibility type (A, B)	Type test performed for accessibility B covers accessibility A	
10	Accessible sides (F, L, R)	Classification FLR covers classification F, FR, FL (and theoretically LR, L, R)	Applicable to accessibility type A and B, if distances to all walls are larger than 300 mm and 100 mm, respectively.

NOTE 1 According to IEC 62271-200:2021, A.4.2, or IEC 62271-201:2014, AA.4.2, the test voltage can be any voltage equal to the rated voltage or lower. Respectively, A.4.3 or AA.4.3 specifies the actual test current conditions to be met in order to accept a test performed at a voltage lower than the rated voltage.

NOTE 2 The criterion is not applicable in case of an exhaust duct that carries the hot gases outside the room. In such case the distance between the test object and ceiling is not relevant, but only that between the exhaust duct and ceiling.

6 Typical processes for the application of the extension of the validity of type tests

6.1 General

The guidance for the extension of validity of type tests can be applied, but is not limited to the following situations:

a) when the validity of a type test performed on one test object for one characteristic of a functional unit (FU) is extended to other functional units within the family of switchgear and controlgear, (Figure 2);

b) when, for a family of switchgear and controlgear, test objects are selected for each characteristic, the results of which validate the complete family with a minimum number of test objects and type tests (Figure 3);

c) when for an untested assembly, an analysis is carried out using available type test reports of the same family of switchgear and controlgear to determine if the test results validate the assembly with respect to the specified characteristics (Figure 4);

d) when the type test validity of a previously type tested assembly is extended to a design modification (Figure 5).

6.2 Extension of validity of a test report to other functional units (situation a)

Figure 2 shows how one can extend the validity of a given type test report by the following steps:

– step 1: examine the report with respect to the description of the tested object (FU or combination of several FUs), and collect additional information (e.g. from referenced drawings);

– step 2: compare the relevant design parameters of the tested object with the extension criteria proposed in Clause 5 applicable to the considered type test (e.g. clearance between phases for the power frequency voltage withstand test) by using technical arguments, calculations or simulations;

– step 3: check the various FUs of the family or combination of FUs, to determine which of them share the same design parameters or have design parameters which could be considered as covered by the tested object (e.g. clearance between phases equal to or greater than those of the tested object). The check also considers contradicting design parameters, which can restrict the extension of validity of test results concerning other characteristics.

NOTE "Contradicting design parameters" means that their variation in one direction increases one performance but decreases another performance (characteristic) for the same object.

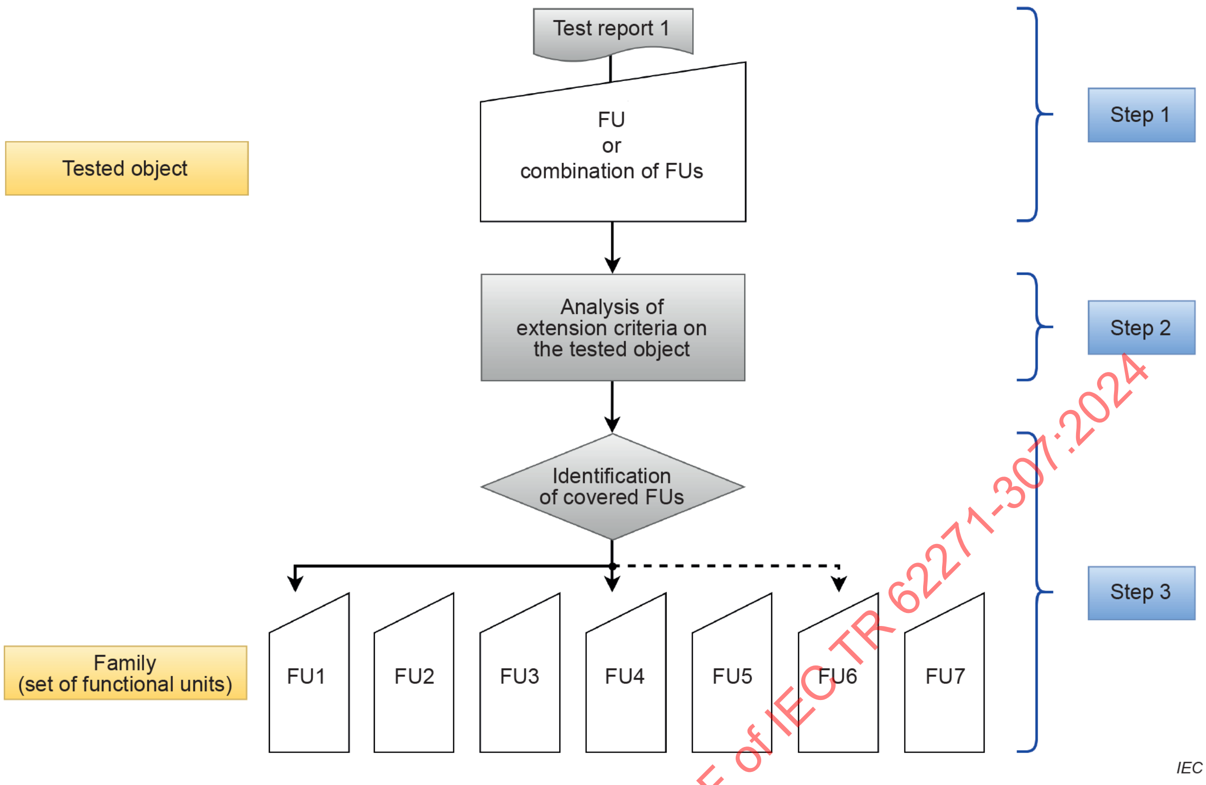

Figure 2 – Extension of validity of one test report – Situation a)

If a FU of the family or a combination of FUs can be checked positively with respect to the proposed criteria, no further tests are required, and the available test report is acceptable for this FU.

6.3 Validation of a family by selection of test objects (situation b)

6.3.1 General

Figure 3 shows how one can select the test objects in such a way that the total number of tests is minimized for validation of the whole family. The steps illustrated are intended to be carried out for each characteristic of the family of switchgear and controlgear:

– step 1: for a given characteristic (e.g. dielectric withstand), analyse the associated design parameters (e.g. clearance between phases) proposed in Table 2 to Table 7 and identify which members of the family form a homogeneous group (see definition in 3.8) by using technical arguments, calculations or simulations;

– step 2: within each homogeneous group, select a test object with associated characteristics to cover the whole group (i.e. the test results obtained on this test object will allow extension of validity to the whole group);

– step 3: perform the type tests.

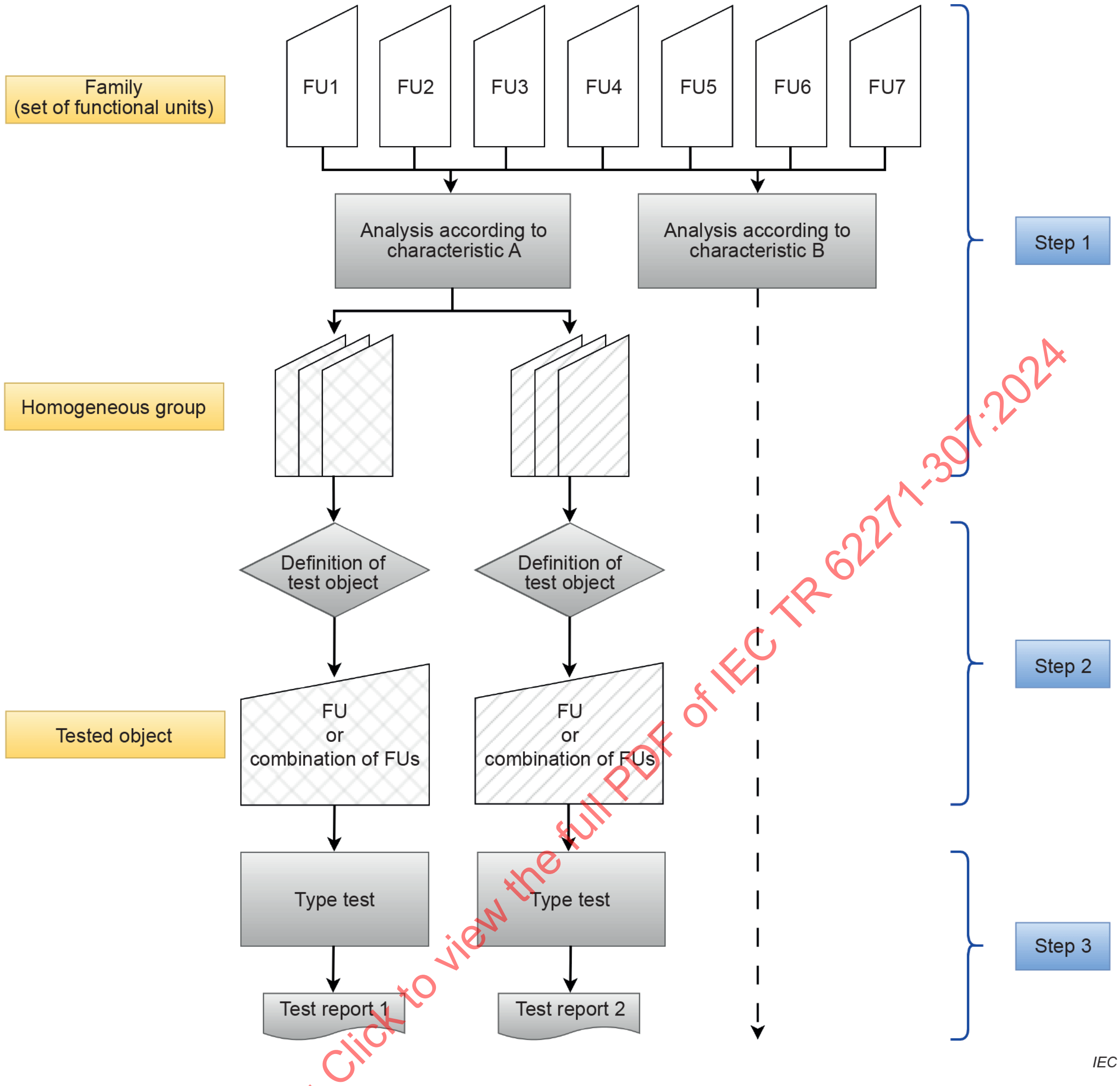

Figure 3 – Validation of a family by selection of appropriate test objects – Situation b)

6.3.2 Mapping of the family

Considering the type test to be performed and the associated acceptance criteria of design parameters proposed in the relevant clauses, step 1 in situation b) can be prepared by a mapping of the family of switchgear and controlgear. This analysis comprises:

– identifying the variation of design parameters within the family of switchgear and controlgear for each characteristic;

– identifying homogeneous groups fulfilling the acceptance criteria of design parameters for one or more type tests.

Such mapping differs with the type test under consideration, because the relevant set of parameters and criteria for possible extension of validity of the results are different so that the analysis is intended to be prepared for each kind of test.

As a family of switchgear and controlgear has many dimensions with respect to the design parameters listed for the considered type tests, the representation of the result of the analysis is complex. Several tables as given in this document can be established, or spreadsheets with columns for different type tests can be created. Preferably, explanations are included for traceability reasons and future use.

6.3.3 Specification of test objects

On the basis of the mapping, test object(s) can be chosen in such a way that the validity of the results of a type test can be extended to other functional units of the family. Most often, it will not be possible to specify only one test object (one functional unit in the family) which combines all the most severe conditions in order to validate the whole family. Usually, more than one test object will be necessary.

Some hints can be provided:

- homogeneous groups with shared technical characteristics are often covered by the lowest or the highest value of design parameters or by the highest value of a rating;
- extension of validity is easier to establish when considering numerical data i.e. design parameters (ratings, cross sections, clearances...);
- identification of homogeneous groups can require analysis by skilled engineers;
- all extension criteria listed in the tables for the considered type tests to be reviewed.

6.4 Validation of an assembly by existing test reports (situation c)

Figure 4 shows how one can check the validity of type test reports for a given assembly, based on a family of switchgear and controlgear:

- step 1: identify the different functional units (FUs) used in the assembly;
- step 2: for each FU and each characteristic, identify the homogeneous group to which it belongs (those FUs of the same family from which validity of test results could be extended) using the design parameters provided in Table 2 to Table 7 and technical arguments, calculations or simulations;
- step 3: check the available test reports and incorporate the test report, if appropriate, in the supporting documentation of the evaluation.

If an appropriate test report is not available, the extension of validity is not possible.

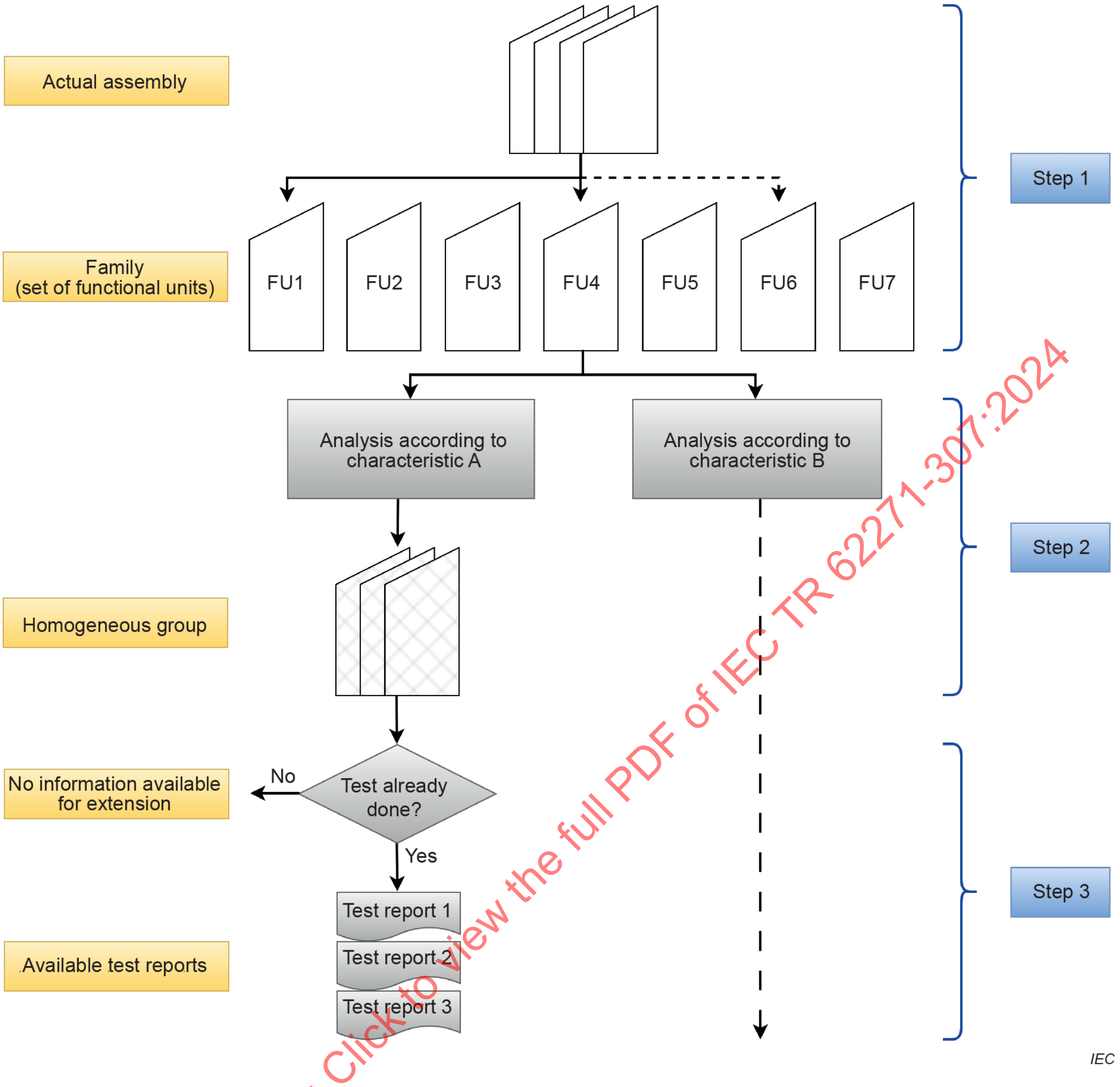

Figure 4 – Validation of actual assembly with existing test reports – Situation c)

6.5 Validation of a design modification (situation d)

Figure 5 shows how one can check the validity of type test reports for a given modified functional unit (FU), based on test reports from a homogeneous group belonging to the same family of switchgear and controlgear:

– step 1: for each characteristic, identify the homogeneous group to which it belongs (those FUs of the same family from which validity of test results could be extended) using the design parameters provided in Table 2 to Table 7 and technical arguments, calculations or simulations;

– step 2: check the available test reports and incorporate the test report, if appropriate, in the supporting documentation of the evaluation.

If an appropriate test report is not available, the extension of validity is not possible.

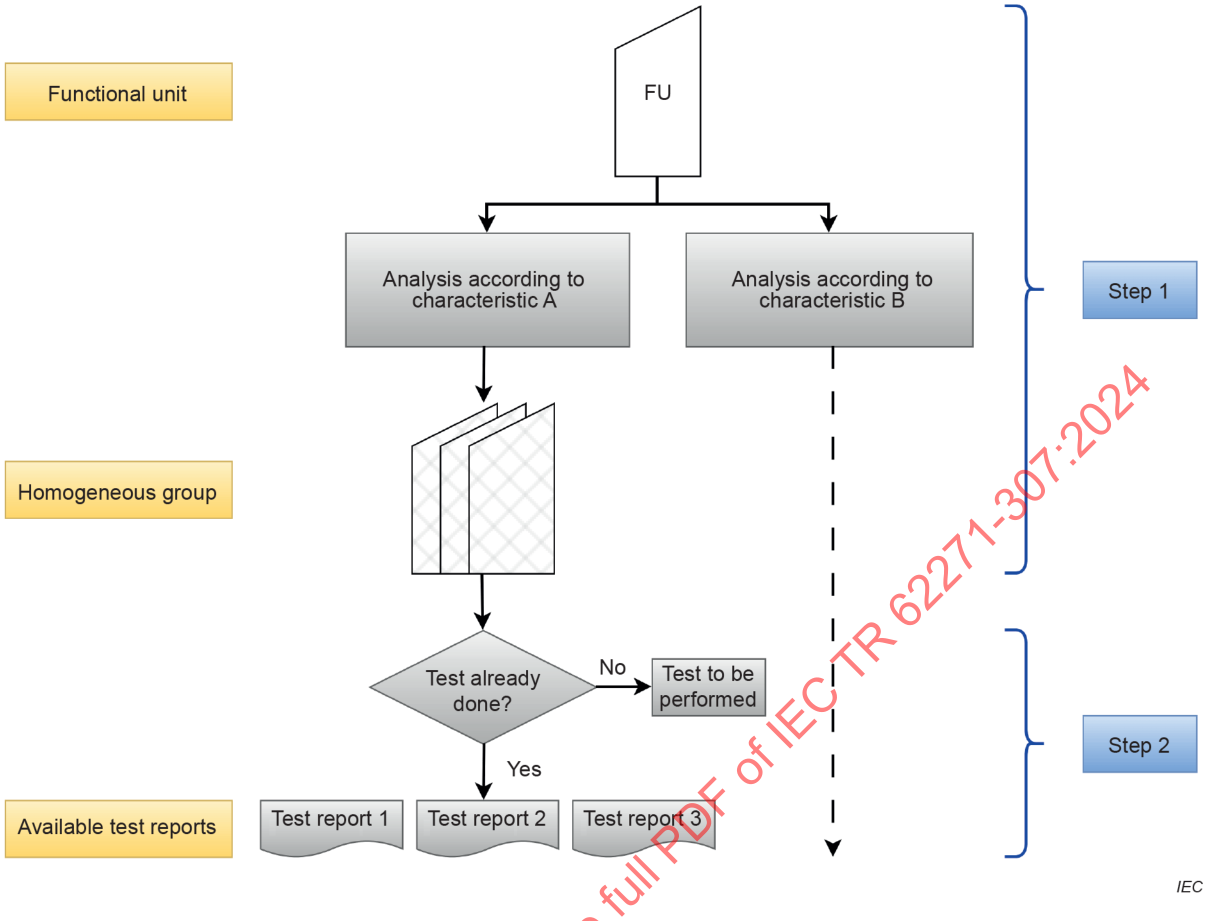

Figure 5 – Validation of a design modification – Situation d)

Annex A
(informative)

Rationale for the extension criteria

A.1 General

The definition of an acceptance criterion for each of the design parameters listed in Table 2 to Table 7 rests on proven technical and physical principles and manufacturer and user experience. The evaluation of the criteria is performed out of a generalized view which assumes that the manufacturer has designed the switchgear and controlgear according to the same technical and physical principles on which the criteria are based. In case of doubts concerning acceptance criteria further evidence is needed to support extension of validity, for example calculations. In the following, those technical and physical principles, which result in the selection of extension criteria, i.e. design parameters and corresponding acceptance criteria in Table 2 to Table 7, are provided.

A.2 Dielectric tests

A.2.1 General

Design parameters such as clearance between phases and clearance to earth and the corresponding acceptance criteria need to be taken into consideration when evaluating the extension of validity of dielectric withstand tests. The principles behind each of the extension criteria (items) listed in Table 2 are given below.

A.2.2 Clearances (items 1 and 2)

Phase to phase and phase to earth clearances are directly related to the dielectric withstand. Larger clearances increase the dielectric withstand capability compared to the type tested switchgear and controlgear provided that all other design parameters listed in Table 2 are unchanged or enhanced with respect to dielectric properties.

Phase to phase and phase to earth clearances could be smaller for switchgear and controlgear having a higher number of parallel conductors per phase to cope with higher rated current. Even if the conductors are arranged in the same manner (i.e. vertical, horizontal or trefoil alignment) dielectric withstand could be reduced compared to the type tested switchgear and controlgear. For a smaller number of parallel conductors, the opposite might be true and can be used for extension of validity of dielectric type tests. If the arrangement of conductors differs significantly, even with equal or larger clearances, the dielectric withstand compared to the type tested switchgear and controlgear cannot be demonstrated without further technical analysis.

The installation of additional earthing facilities or test points can reduce the clearance to earth, hence reducing the dielectric withstand compared to the type tested switchgear and controlgear.

A.2.3 Insulating supports and material (items 3 and 4)

An increased creepage distance for insulating supports with the same dielectric properties of the material increases the dielectric withstand compared to the type tested switchgear and controlgear. However, the dielectric withstand capability might be influenced by the field distribution along the insulating surface. The presence of field control electrodes or insulating barriers could affect the electrical field at the surface of the insulating support. Therefore, the electric field distribution basically needs to remain unchanged, for example by parts on floating potential or the introduction of additional components such as a voltage divider.

The insulating material requires to have equal or improved dielectric properties compared to the type tested switchgear and controlgear. Important dielectric properties are for example dielectric strength, permittivity and tracking index. If these properties cannot be determined from available specifications, a test of properties might be necessary as written in the condition to item 4.

The impact of insulating barriers and additional insulation on the withstand voltage is difficult to assess. Changes in the design of such insulating parts will normally invalidate the dielectric type test, unless it can be shown that the design change is insignificant.

A.2.4 Live parts (items 5 and 6)

Live parts with a lower surface roughness entail a more uniform electric field distribution, result in a lower electrical field strength, and hence increase the dielectric withstand.

Conductors with a larger radius, including bends and corners in the path, result in lower local electrical field strength, hence also increase the dielectric withstand. This extension criterion is also applicable to other conductive parts at high potential and even to earthed parts. The influence of earthed parts needs to be evaluated when they are opposite to live parts and can influence the dielectric withstand.

A.2.5 Open contact gap and isolating distance (items 7 and 8)

If the open contact gap of a switching device or the isolating distance is determined by the assembly design, then a larger gap will increase the dielectric withstand compared to the type tested switchgear and controlgear. This applies for example to an earthing switch or switch-disconnector with separate supports for fixed and moving contacts.

If the contact gap is incorporated in a switching component, the influence from the assembly on the dielectric withstand might be minor, however, it needs to be considered. The influence might come from the proximity of the earthed enclosure or partition, for example.

A.2.6 Minimum functional pressure for insulation (item 9)

The pressure or the corresponding density of a gas used for insulation has direct influence on the dielectric withstand capability. Therefore, tests are required at minimum functional pressure for insulation defined by the manufacturer. A higher pressure or density usually increases the dielectric withstand performance compared with the type tested switchgear and controlgear. Since different gases have different dielectric properties, this extension criterion can only be applied to the same gas after verifying that the dielectric withstand capability increases with increasing pressure in the range of functional pressures.

A.2.7 Minimum ambient temperature in service (item 10)

In case partial liquefaction of the insulation gas or gas mixture starts below the minimum ambient temperature in service, there is no impact on the dielectric withstand capability. However, in case the liquefaction starts above the minimum ambient temperature in service, usually the component with highest dielectric withstand capability having a low vapour pressure at service temperatures, this behaviour implies a reduction of the insulation level and therefore needs to be considered when comparing a functional unit filled with two different gases or gas mixtures.

A.2.8 Minimum dielectric properties of insulation gas or gas mixture (item 11)

The level of insulation provided by a gas or gas mixture depends not only on its inherent properties but on the geometries of parts under voltage and all surrounding components earthed or isolated. Also, the pressure or density has influence on such insulation properties. Therefore, there is a need to evaluate the minimum dielectric properties of the insulation gas or gas mixture for identical construction design at defined minimum functional pressure for insulation for each defined gas composition in order to make possible an extension of validity of performed type tests from the weakest to stronger insulation case.

A.3 Continuous current tests

A.3.1 General

The continuous current of switchgear and controlgear is dependent upon the parts that experience the highest temperature rise during current flow through the main circuits. These parts can comprise contacts of switching devices, bolted connections (or equivalent) of conductors, terminals, and accessible parts of the switchgear and controlgear such as enclosures.

The temperature rise of these parts can be influenced by many design parameters such as centre distance between conductors, material type of conductors, contact pressure, enclosure size and volume, area of ventilation openings and power dissipation of components and/or devices.

The general principles behind the extension criteria (items) influencing temperature rise of the switchgear and controlgear and the corresponding acceptance criteria listed in Table 3 are given in more detail below.

A.3.2 Centre distance between phase conductors (item 1)

In a three-phase circuit the alternating magnetic field generated by current in a conductor will induce eddy currents in the same and adjacent conductors which will alter the overall current distribution in all conductors. For example, the current density is higher in an area of the conductor furthest away from the adjacent conductor when current flow is in the same direction. This is known as the proximity effect and it can increase the power loss and produces higher temperatures within the switchgear and controlgear. The centre distance between phase conductors measured from the geometric centres of the conductors is therefore important when validating the temperature rise criteria. These distances can be impacted by the arrangement of conductors within the compartment.

Switchgear and controlgear having conductors arranged in the same manner, i.e. vertical, horizontal or trefoil alignments, with the same number of conductors per phase and larger centre distances between phases can be considered to produce lower power losses and hence contribute to lower temperature rise of the switchgear and controlgear. If the arrangement of conductors differs significantly from the already tested assembly, then larger centre distances cannot ensure lower power losses and temperature rise. In such cases further technical analysis can be required.

It is noted that IEC 62271-1:2017, 7.5.2, permits to test up to 1 250 A with a single-phase source with all poles connected in series, which indicates that the mutual influence of the other poles is not significant in this case.

A.3.3 Phase to earth distance (item 2)

Eddy currents can be induced in metallic, non-current carrying parts of the switchgear and controlgear. Because of the lower conductivity of steel and small thickness of walls, this effect is normally negligible for enclosures. However, alternating magnetic fields create heat losses in ferromagnetic steel enclosures perpendicular to the current path due to the reversal of magnetic domains in the material. This can lead to additional heating power losses which cause higher temperature rise. The relevant phase to earth distance is not a clearance, nor a centre distance, but a distance determined by the effects described above.

If these current heating effects cannot be excluded, the phase to earth distance needs to be evaluated. Switchgear and controlgear with greater than or equal phase to earth distance then can be considered to produce equal or lower heat losses. If the arrangement of conductors in proximity to the earthed parts of the switchgear and controlgear differs significantly then again lower temperature rise cannot be ensured.

A.3.4 Enclosure and compartment volume (item 3)

The temperature rise within a switchgear and controlgear compartment is directly influenced by the ability of the enclosure to dissipate heat via conduction and/or convection and radiation to the ambient environment. This effect is dependent upon the surface area of the switchgear and controlgear enclosure (and hence volume) and the type of material used. For the same power loss, switchgear and controlgear with larger surface area of the enclosure walls will dissipate more heat and hence have lower temperature rise of the internal parts. Similarly, material having lower thermal resistance will dissipate more heat. The use of non-ferromagnetic steel for the enclosure can avoid heat generation by eliminating the magnetizing current effect.

The convection behaviour of gas within the switchgear and controlgear compartment can, in principle, be affected by the volume and the surface area of the compartment. This effect is difficult to assess and can in some cases impact the heat dissipation. Further reference can be made to IEC TR 60890 [1] to gain understanding of the effects of enclosure/compartment dimensions on temperature rise.

A.3.5 Pressure (density) of insulating gas (item 4)

The pressure or the corresponding density of insulating gas in a high-voltage compartment has direct influence on the ability to dissipate heat away from current carrying conductors to the enclosure and further to the ambient environment. An increase in the minimum functional pressure or density increases the heat transfer capability of the gas resulting in a reduction of temperature rise of the internal parts of the switchgear and controlgear. Since different gases have different thermal properties, this extension criterion can only be applied to the same gas.

A.3.6 Conductors (items 5 and 6)

Current flow through the conductors of the main circuit produces a power loss (I^2R) which is dependent on the current magnitude, I, and conductor resistance, R. The I^2R power loss from the main circuit contributes the most significant portion of total power loss within the switchgear and controlgear. An increase in cross sectional area of a conductor, while maintaining a constant current magnitude, will lower the current density and therefore the power loss of the conductor assuming the same type of conductor material. This effect decreases the temperature rise of internal parts.

For a given arrangement of conductors within the switchgear and controlgear, heat removal from hot spots will be improved and the temperature of these hot spots lowered for a conductor system with lower electrical and thermal resistance per unit length of conductor.

A.3.7 Conductor joints and connections (items 7, 8 and 9)

Joints and connections contribute to power loss and hence to temperature rise due to the I^2R losses resulting from current flow through the joint or connection resistance. The resistance at joints and connections, also called contact resistance, depends upon the raw material and type of metallic coating, contact pressure (or force) and contact surface area. Assuming the same type of contact material (either conductor material for uncoated surfaces or coating material for coated surfaces), an increase in contact pressure and/or contact surface area will lower the resistance across the joint or connection resulting in lower power losses and a reduction in temperature rise at that location.

Although the resistivity of the coating material has limited influence on the overall resistance due to its small thickness, the permissible maximum temperature of the coating as defined in IEC 62271-1 has an impact. An extension can only be made from the material with lower permissible maximum temperature to that with a higher assigned value for permissible maximum temperature.

Further reference can be made to IEC TR 60943 [12] to gain understanding of the impact that contact resistances can have on temperature rise and to find information about contact resistances for connections and joints using equal or different materials and metallic coatings. Copper is deemed a "better" contact material than aluminium when oxygen is present, for example, due to the low conductivity of the aluminium oxide which will be formed if no other measures are taken.

A.3.8 Ventilation area of partitions and enclosure (item 10)

To enable effective dissipation of heat by air convection, some switchgear and controlgear designs include ventilation openings in compartments and/or the enclosure. For switchgear and controlgear having larger ventilation openings, both for incoming and outgoing air flow, the net heat dissipation will be greater and hence the temperature rise of internal parts reduced.

The position of ventilation openings is also important. Significant changes to the location of such openings within a compartment or enclosure can impede the flow of air through the switchgear and controlgear and could reduce the net dissipation of heat.

The modification of the degree of protection (IP-code) of a mesh or grid covering ventilation openings can also have an impact on the heat dissipation. A higher degree of protection could result in a reduction of the effective area of the ventilation opening reducing the air flow through the switchgear and controlgear.

Further reference can be made to IEC TR 60890 [1] to gain understanding of the effects of ventilation on temperature rise.

A.3.9 Power dissipation of components (item 11)

The incorporation of components such as switching devices, fuses and current transformers can contribute significantly to the temperature rise within the switchgear and controlgear. Such components have a finite resistance and will be subject to I^2R power losses caused by the current flow through them. Switchgear and controlgear components having lower I^2R power losses will produce lower overall temperature rise in particular at the critical parts of these components.

The power loss of primary and secondary windings of current transformers depends on the primary and secondary currents. Therefore, both windings need to be considered. The data sheet of current transformers can provide the resistance of the secondary winding at an elevated temperature.

A.3.10 Insulating barriers (Item 12)

The addition of insulating barriers between phase conductors or between conductors and enclosure walls will probably increase the dielectric withstand of the switchgear and controlgear, however, they can also impede air flow within the switchgear and controlgear and reduce heat transfer to the enclosure. This might have a negative impact on the heat dissipation and thus increase the temperature within the switchgear and controlgear. Therefore, the addition of such barriers will normally require repeating the continuous current type test.

The surface area of insulating barriers is important in that an increase in the surface area will tend to restrict air flow whereas a reduction in surface area would produce the opposite effect. The effect is less important for vertical barriers but can have a large impact for horizontal barriers.

A.3.11 Insulating coating of conductors and enclosures (items 13 and 14)

The use of solid insulation on conductors and/or enclosures will generally restrict the ability to dissipate heat into the surrounding medium due to its thermal resistance. On the other hand, it might help removing heat by radiation depending on the heat transfer capability of the insulating material and emission coefficient of the external surface.

Paint or special coatings on the conductors and the enclosure can lower the temperature rise by improving the heat transfer to the surrounding enclosure by thermal radiation. Thermal resistivity and emission coefficient of the coating are basically the same. The colour of the paint has no significant effect on the thermal radiation since the emission coefficient is mainly determined by the polymeric properties of the paint. Conversely, some coatings or coverings that can be intended to improve the dielectric withstand performance can reduce the heat transfer.

For a specified material, a reduction in the thickness of such material will normally improve the heat transfer capability and contribute to a reduction in temperature rise of the internal parts in the switchgear and controlgear such as the conductor connections. It needs to be noted, however, that such a reduction in solid insulation material thickness will also result in a reduction in the dielectric withstand of the coating.

A.3.12 Insulating material in contact with conductors (item 15)

When changing the insulation material of support insulators, for example, the temperature class of the material is the same or a larger value will ideally be achieved in order not to risk a degradation of the material at rated continuous current conditions.

A.3.13 Minimum thermal performance of gas or gas mixture (item 16)

The ability of a gas or gas mixture to carry the heat losses generated by the inner components to the walls of the gas-filled compartment containing those components depends on several physical characteristics of the gas or gas mixture itself, like density, viscosity, conductivity and specific heat capacity, but also it depends on the geometries of the inner components, their disposition and the geometry of the walls of the enclosure. That makes it very complex to directly compare different gases and gas mixtures without performing comparative tests on identical construction designs at defined minimum functional pressure for insulation. In general, for the same gas or gas mixture increasing the pressure improves its thermal performance to carry the generated heat, this is the reason to make this evaluation at same minimum functional pressure.

A.4 Mechanical tests

A.4.1 General

For mechanical tests the extension criteria focus on the comparison of mechanical parts with respect to strength, structure and resulting or applied forces. Particular attention needs to be given to the safety aspects, especially with respect to the interlocking systems.

Interlocks between different components of the equipment can be required for safety reasons concerning the access to operation interfaces and the insertion or withdrawal of removable parts.

Mechanical parts to be compared are:

– shutter systems,

– contacts of removable parts,

– interlocks and kinematic chains.

According to IEC 62271-200:2021, 7.102.2, or IEC 62271-201:2014, 6.102.2, interlocks are considered to be satisfactory, if:

– the switching devices cannot be operated;

– access to the interlocked compartments is prevented;

– the insertion and withdrawal of the removable parts are prevented;

– the switching devices, removable parts and the interlocks are still operative and the effort to operate them before and after the tests, does not differ from the maximum hand operating forces (manual operation) or peak energy consumption (motor operation) by more than 50 %. In case of the test with 750 N, damage is acceptable, provided that the interlock still prevents operation.

Besides the checking of the correct functioning of interlocks in a type test, the standard requires the proof of functionality and usability even after an endurance test.

The general principles behind each of the extension criteria (items) included in Table 4 are given in more detail below.

A.4.2 Shutter systems (item 1)

Two different shutter systems having the same technical principles of, for example, shutter actuation or interaction with the switching device, need to be compared considering the strength of the mechanical linkage and the whole mass of the shutters, as follows:

1) With focus on the mechanical linkage, extension is possible from a weaker system to a stronger one. The strength of a design can be determined by consideration of the materials used, dimension of parts, strength of interconnecting shafts, etc. One example is the length and thickness of a shaft in the mechanical linkage. Due to the complexity of shutter systems, an extension of validity can only be made to shutter systems using the same principal design;

2) In general, lower mass is easier to move and exerts lower stress on the mechanical components. Lower masses can be achieved by smaller dimensions of moving parts not involved in the mechanical linkage and, for example, change of the material.

A.4.3 Contacts of removable parts (item 2)

Concerning the contacts of removable parts in switchgear and controlgear, the focus is on the mechanical behaviour during connecting and disconnecting operations. The comparison comprises the number of contact points, the contact forces acting between movable and fixed contacts, and the contact surface roughness. Possible wear of contact coatings will be considered too, since the standard requires a continuous layer even after mechanical endurance.

All the following points need to be evaluated under the condition that the design of the contact system is identical or directly comparable with respect, for example, to the shape of contact fingers and the kind and hardness of the material:

1) Each contact causes friction during insertion: a higher number of contacts with identical force per contact leads to an increase of operating force of the movable device. Therefore, the number of contact points needs to be less than or equal to the tested system for an extension of validity. Care has to be applied, if the contact force changes with the number of contacts due to, for example, a common spring system. In this case further evidence for extension is required.
2) Friction during insertion of the removable part decreases with lower contact force per contact point. Besides this effect, a lower contact force also leads to less wear of the contact area and therefore allows extending the validity. It is noted that lower contact forces might impede the extension of validity with respect to the short-time and peak withstand current performance.
3) The friction between moveable and fixed contacts also depends on the roughness of the participating surfaces: higher roughness causes higher force for the operation of the removable part and additionally increases contact wear.

A.4.4 Interlocking systems (items 3 and 4)

Interlocking systems are linked to operator safety. The comparison requires an evaluation of functionality and strength of the mechanical linkage. Two types of interlocking systems are considered:

- an interlocking system directly operated on the kinematic chain of the switching device, which has to react to the manual operating force or any power-driven force. In this case, it is necessary to test the locked interlocking system to the limits prescribed by the standard during pushing and/or turning the access point or shaft for manual operation, or during actuation of non-electrically interlocked power operating devices;
- an interlocking system preventing access to the operating chain of the switching device, which are normally designed for being actuated by small forces exerted by the fingers of a hand. These access systems avoid the application of forces that could damage the components of the device.

An extension of validity of interlocking systems can only be attempted when the compared systems are based on the same technical principle and design elements. The strength of the locked mechanical linkage, i.e. in the condition, where the interlock condition is challenged, needs to be identical or better. This might be assessed under the same conditions as described under item 1.

Extension can also be allowed, if the applied torque or force is limited to a smaller value, for example by a strain-limiting device or a different handle and by a smaller operating force of the access preventing device.

A.5 Short-time withstand current and peak withstand current tests

A.5.1 General

Short-circuit currents generate electromagnetic forces between the phase conductors, which depend on the course of the current carrying path including bends and corners. These mutual forces can be calculated for simple conductor geometries by analytical equations; for complex geometries, however, finite-element simulation tools are needed. The smaller the centre distance between conductors, the higher are the mutual forces. The ability of the switchgear and controlgear design to cope with these forces is determined by the strength of all supports considering steady state and transient components of the current. In addition, all movable contacts and fixed connections are important. All these influences need to be considered in the evaluation of design parameters.

Additionally, a calculation of the thermal stress using the equation $I_k{}^2 t_k$ might be done when the assessment is made for a lower I_k and higher t_k than the ones tested respecting the principles provided in IEC 62271-1:2017, 7.6.3.

Table 5 can be applied not only to the main circuit, but also to the earthing circuit. In this case, mainly items 5 and 6 need to be considered. Since the earthing circuit is normally designed to withstand only a single short-circuit fault with maintenance afterwards, the requirements on the other items are reduced.

The general principles behind each of the extension criteria (items) included in Table 5 are given in more detail below.

A.5.2 Centre distance between phase conductors (item 1)

If the centre distance between phases is larger than in the type-tested switchgear and controlgear, the mutual forces between phases are smaller. Therefore, the design under evaluation is able to withstand the same short-circuit current applied in the type test assuming that all connections and contacts in the current path have the same design (see condition to item 5) and the path of the conductors do not produce higher electromagnetic forces than in the type tested design (see item 2).

A.5.3 Conductors (items 2, 5 and 6)

The electromagnetic forces due to bends and corners in the conductor path can exceed the mutual forces between phases. An extension of validity might be possible, when all inner angles of the conductors bends and corners have the same or larger values than in the original geometry. If the current path differs too much from the type tested design, an extension might be achieved by a complete modelling of the three-dimensional conductor arrangement and subsequent calculation of the electromagnetic forces by appropriate programs.

The mutual electromagnetic forces between two conductors are determined by their centre distances, not by the cross-section of the conductors. However, because of the heating effect of the current and possible current density effects, it has to be ensured that the cross-section of the conductors is the same as or larger than in the original switchgear and controlgear. The similarity of the connections, for example between busbar, needs to be evaluated with regard to local heating effects.

The material of the conductors first determines the heat loss in relation to the material resistivity, second the mechanical stability of the conductors and third the current carrying capability of connections. Because these connections can involve a complicated behaviour, a deviation from the original material is not permitted without type test.

In case of earthing circuits, the earth fault current can not only be conducted via conductors made specifically for this purpose, but also via the metallic enclosure. It is difficult to compare assemblies which mainly rely on this effect. Conductors include connections in the earthing circuit up to the earthing terminal.

A.5.4 Insulating conductor supports (items 3 and 4)

During short-circuit current the mechanical reaction of all insulating parts supporting the conductors might result in damage of the supports, which would make a type test invalid. Therefore, it is assumed that the supports are designed according to the same principles and have the same or better strength than the type tested design. For complicated support structures this might not be evident, in which case a mechanical stress calculation might be required.

For conductors supported by a row of insulators, the strength of the design is not only determined by the strength of the supports, but also by the arrangement of the supports. As minimum requirement, the distance between two supports are the same or smaller to ensure the same mechanical strength. This criterion needs to be evaluated for all supports of all conductors.

A.5.5 Insulating material in contact with conductors (item 7)

The short-circuit current will heat up the conductors during the short-time current. All supports or components in contact with the conductors will experience the same temperature as the conductors, where they are in contact with them. Different materials from that used in the type tested assembly can be used if they have the same or higher temperature class and provide the same or better mechanical strength (see item 3).

A.5.6 Enclosure, partitions or bushings (item 8)

The mechanical withstand of the supports of any conductor is also determined by the strength of its mounting base. Therefore, the enclosure can have an influence on the short-circuit current withstand capability. The wall thickness of the enclosure, for example, has to be the same or larger, and similar stiffening elements of the enclosure are used. This item also considers the strength of partitions and bushings, which is difficult to assess simply by geometry. If different partitions and bushings are used, they need to be verified in an arrangement of components simulating the new switchgear and controlgear design or type-tested within other functional units.

A.5.7 Contacts of removable part (item 9)

Any modifications in the design of movable contacts in the current path can impair the short-circuit current withstand capability. Since it is difficult to assess the impact of even small modifications, different contact geometries need to be type-tested in the new switchgear and controlgear or verified in a similar arrangement of the contacts.

A.6 Making and breaking tests

A.6.1 General

The making and breaking performance of the components is type tested according to the relevant standards. The scope of this document is limited to the impact of assembly parameters on making and breaking tests.

The making and breaking performance of a device in a switchgear and controlgear assembly can depend on electromagnetic forces in the vicinity of the making and breaking contacts, on the dielectric properties influenced by nearby potentials and the outflow of hot gases produced during making and breaking. In the following, these effects are checked for each design parameter given in Table 6. The mechanical chain of the operating mechanism might also have an impact on the performance of the switching device, for example an earthing switch. Such an influence can be considered under the relevant component standard.

The general principles behind each of the extension criteria (items) included in Table 6 are given in more detail below.

A.6.2 Clearance between phases and to earth (items 1 and 2)

If the clearance between phase conductors is larger than in the type-tested switchgear and controlgear, the dielectric withstand level is larger in the new design and hot gases expelled from interrupting parts, for example nozzles, have a smaller chance to bridge phases and ignite a short-circuit.

Electromagnetic forces acting between conductors might influence the interruption performance and would be reduced with an increased centre distance between phases. If the centre distance is changed, the switching device needs to be verified according to its own component standard with respect to making and breaking performance.

The distance between phases might have an impact on the making and breaking performance, if the strength of the kinematic chain between operation point and farthest pole is reduced by a larger phase distance increasing the length of the operation shaft.

If the clearance between conductors and earth is larger, then the dielectric withstand is increased. As a result, the possible impact of vented arc products or gases on the making and breaking performance is reduced.

A.6.3 Enclosure and compartment volume (item 3)

If the air, gas or liquid contained inside the compartment or the enclosure of the assembly is involved in the making and breaking process, venting of arc products and gases might have a negative impact on the performance of the switching device. For larger volumes, it can be assumed that this impact is less severe.

A.6.4 Insulating gas (item 4)

For higher pressure or density of the insulating gas the making and breaking performance is improved inside the pressure limits for correct mechanical operation of the switching device.

However, there might be an impact of the gas density on the travel characteristics of a switching device. For vacuum interrupters inside gas-insulated switchgear and controlgear, for example, the pressure of the insulating gas can influence the opening and closing speed of the driving mechanism through the differential pressure on the bellows. This is relevant for the making and breaking capacity as well as for the endurance of the switching device. If the opening and closing speed of the drive mechanism is within the tolerances prescribed by the manufacturer, the mechanical impact of the gas pressure can be neglected.

A.6.5 Conductors (items 5 and 6)

The heating effect of the current flowing in the connecting conductors normally has no impact on the making and breaking process. However, if such an impact cannot be excluded, it needs to be ensured that the cross-section of the conductors is equal or larger than in the type tested switchgear and controlgear.

The electro-dynamic forces due to the current flowing in the connection paths of the switching device might impair the breaking and making performance, for example, when during the breaking operation some switching devices use a local magnetic field to manage the arc behaviour. Under this condition the impact of a new arrangement of the current path needs to be considered, possibly simulated by calculation or verified in a similar arrangement of a different functional unit.

A.6.6 Insulating supports (items 7, 8 and 9)

If the making and breaking performance is influenced by the mechanical stability of moving or fixed contacts, the mechanical stability of the supports of these contacts can have an impact on the performance of the device. A typical example is an earthing switch in an air insulated high-voltage compartment. Though the mechanical strength of such insulating supports, which were already validated by a short-time withstand current and peak withstand current test, was confirmed, nevertheless there could be an impact during the making and breaking operation.

A.6.7 Dielectric withstand capability (item 10)

During the making and breaking operations, the insulating elements need to withstand the transitory overvoltage which can be generated and therefore, if the insulating elements like the insulating gas or gas mixture and/or the insulating supports differ from those of the type tested unit, it needs to be verified that the dielectric withstand capability of the unit to be validated is not inferior to that of the type tested one.

A.7 Internal arc fault tests

A.7.1 General

Internal arc classification (IAC) is demonstrated for metal-enclosed or solid-insulation enclosed switchgear and controlgear by the relevant type test by meeting the acceptance criteria specified by IEC 62271-200:2021, 7.105.5, or IEC 62271-201:2014, 6.105.5. These criteria consider several issues such as opening of doors and covers, enclosure fragmentation and burn through, ignition of indicators simulating person clothes, and the integrity of earthing connections. The fulfilment of all these acceptance criteria intends to ensure protection of persons in the event of an internal arc. It has to be remarked that these acceptance criteria are not mixed up with the acceptance criteria used in Table 7.

Pressure rise, hot gas and heating of material are effects of the internal arc and exert mechanical and thermal stress on the compartment. The severity of impact is related to the amount of energy generated by the arc, the volume in which the arc energy is deposited, and the efficiency of pressure relief devices for venting hot gases. On the other hand, a stronger structure of the compartment and its doors and covers can improve the capability to withstand this stress. Finally, the amount and direction of vented hot gases determine the probability of indicator ignition in combination with the installation conditions.

Based on the above considerations the extension criteria given in Table 7 have been determined. Their evaluation results in a more favourable condition to meet the acceptance criteria of IEC 62271-200 or IEC 62271-201. The rationale behind all extension criteria (items) listed in Table 7, which is applicable to design modifications of a single high-voltage compartment within a family of switchgear and controlgear, is provided below.

A.7.2 Clearance between phases and to earth (items 1 and 2)

The energy generated by the internal arc increases with the arc voltage, which in turn is proportional to the length of the arc. When the arc burns between the phases, a smaller clearance between the conductors leads to a shorter arc and therefore to less arc energy and to a reduced severity of the test.

The same rationale can be applied to the clearance between conductors and earth. However, when the arc burns against the enclosure walls, which is most often the case, the region where the arc is initiated and stays during the whole arc duration needs to be considered. In principle, smaller clearances cannot be permitted, since the probability to burn through the compartment walls is higher for a smaller clearance. This effect might be disregarded, when the burn through in this region has no impact on the acceptance criteria no. 3 and 4 of IEC 62271-200:2021 or IEC 62271-201:2014. An example could be the melting through a non-accessible enclosure side.

A.7.3 Compartment volume (item 3)

The larger the net volume of the high-voltage compartment, the lower is the specific arc energy per volume, and the lower is the thermal and mechanical stress on the compartment. The rate of pressure rise is reduced, which in turn reduces the overshoot of pressure after a pressure relief device opens. However, the mechanical withstand capability of the compartment, including doors and covers, needs also to be considered (see items 12 and 14). In the case of larger net compartment volume the amount of gas to be exhausted is higher, which influences the dimensioning of the pressure relief system. In particular cases, the performance of a test on the smallest and on the largest compartment covers all intermediate size compartments.

A.7.4 Pressure of insulating gas (item 4)

With smaller initial pressure or density which is determined by the filling pressure, the gas quantity in the compartment is smaller and results in a smaller overshoot of pressure after opening of the relief device though the rate of pressure rise is identical. See CIGRE TB 602 [7]. Therefore, the stress on the compartment is less severe. Though the obtained gas temperature will be higher in this case, the release of thermal energy through the pressure relief device is the same. The thermal energy is determined by the product of density and temperature, which also determine the pressure. Therefore, an impact outside the compartment is not expected.

A.7.5 Material in the region of arc initiation (items 5, 6, 7 and 8)

In general, the type tests are carried out with the arc initiated in a location and in a manner as specified in IEC 62271-200:2021, A.5.2 or IEC 62271-201:2014, AA.5.2. The behaviour of the internal arc is affected by the arc initiation conditions in an almost unpredictable way. Therefore, it is not possible to extend the results of a type test carried out on a particular compartment when the arrangement of components would require a different position of the arc initiation. With "region", the space and metal or insulating parts around the arc initiation point is meant, which determines the arc voltage and composition of the arc plasma.

The roots of the internal arc melt the surface of conductors and consume material until in the worst case the complete conductor is melted away. This effect is less probable when the cross-section of the conductor is larger. Also, the material of conductors is decisive from this point of view. It is known that air as well as SF_6 behaves differently when burning on different materials because of the release of exothermic energy from the reaction of the gas with the material. Thus, the materials of conductors require to be the same as in the type tested switchgear and controlgear.

The kind of material might also have an impact on the composition of the exhausted hot gases i.e. the probability of indicator ignition. The external material of insulating parts exposed to the arc can be either vaporized or burnt during the arcing test. The effect of the resulting gases on the pressure rise and exhaust of hot gases is difficult to predict. Therefore, extension of validity can only be considered for the same material. This also takes care of the fact that the material might have an impact on the mechanical strength of the insulating supports at the point of arc initiation.

A.7.6 Pressure relief opening devices (items 9, 10 and 11)

A lower pressure relief (exhaust) opening pressure and a larger area of the opening make the venting of the hot gases out of the compartment more efficient, decrease the overshoot of pressure and hence reduce the mechanical stress on the switchgear and controlgear enclosure, door and covers. Therefore, the probability to pass the acceptance criteria no. 1, 2 and 3 from IEC 62271-200:2021 or IEC 62271-201:2014 is higher. However, larger opening areas might change the outflow of hot gases considerably and might have an impact on the ignition of indicators placed around the switchgear and controlgear (acceptance criterion no. 4). Thus, the applicability of item 9 of Table 7 needs to be limited to switchgear and controlgear fitted with a gas exhaust duct, where indicators do not play a role for the hot gas flowing into the duct.

In gas insulated switchgear and controlgear circular gas-tight burst discs are often used, the opening pressure of which can be tested statically with good reliability and therefore the acceptance criterion of item 10 can be applied. In air insulated switchgear and controlgear (AIS), flaps are commonly used, where the opening pressure is determined by the strength of all elements intended to let open the relief flap, for example screws, when an overpressure is created by the arc fault. In this case, item 11 can be evaluated, for example, from the material and dimension of such screws. Of course, the elements retaining the flap from flying off need to have the same or higher strength.

A.7.7 Enclosure and compartments (items 12, 13, 14 and 15)

Improved strength of the compartments, enclosure doors and covers leads to a higher probability to meet the acceptance criteria according to IEC 62271-200 or IEC 62271-201. The evaluation of mechanical strength can be performed by evidence for simple geometries or by numerical calculations for complex geometries. Note 4 in Table 7 puts attention to the distance between all fixing points (bolts, hinges and latches). The material thickness of the enclosure walls influences the strength of the compartment, but also can affect burn through. For thicker walls, the probability of burn through will be reduced compared to thinner walls. It might have to be considered that if the stiffness of the enclosure is greatly increased then care will be taken in ensuring that the enclosure as a whole reacts in a similar way as in the test object.

The degree of protection (IP-code) of the enclosure is a measure of possible small openings in the enclosure. Hot gases might escape through holes and gaps and might ignite indicators placed outside the switchgear and controlgear. From that perspective, the enclosure needs to be "tighter" i.e. possess a smaller total area of holes, gaps, and openings, which might be coherent with an equal or higher IP-code. It is assumed that the peak pressure in the compartment is always determined by the area of the relief device. If any holes in the enclosure in accordance with the IP-code have an impact, the two compartments cannot be compared for extension of validity.

It is obvious that a higher IP-code needs to be considered in the exhaust cross-sectional area i.e. item 9.

A.8 Rationale for extension criteria with respect to arc fault ratings and installation conditions

A.8.1 General

Below, some explanations are provided for each of the extension criteria (items) listed in Table 8, which is applicable to the installation conditions of a switchgear and controlgear assembly.

A.8.2 Rated arc fault current and duration (items 1 and 2)

The lower the value of the test current and/or arc duration, the lower is the energy generated by the internal arc. Lower energy reduces the thermal stress and decreases the pressure rise and the overshoot of pressure in the compartment and hence reduces the mechanical stress on the compartment.

A.8.3 Rated voltage (item 3)

The rated voltage is generally not a basic test parameter for the internal arc test, though the rated voltage of the switchgear and controlgear implicates the minimum clearances between phases and to earth, which in turn determine arc length, arc voltage and the amount of fault arc energy. However, for the given compartment geometry and provided that the making current peak is not suppressed below 90 % of the prospective value, the arc energy does not depend on the rated voltage. This condition is ensured by the requirements for the actual test current specified in IEC 62271-200:2021, A.4.2 or IEC 62271-201:2014, AA.4.2 (see also note 1 of Table 8).

In principle, extension to higher rated voltage could be possible following this rationale. However, IEC 62271-200:2021, A.4.2, and IEC 62271-201:2014, AA.4.2, pose requirements on the evaluation of the 90 % prospective peak current and premature extinction of the arc which have to be respected.

A.8.4 Rated frequency (item 4)

The impact on the outcome of an internal arc test is negligible, when the frequency at the first three half-cycles of the test is in the range of 48 Hz to 62 Hz.

A.8.5 Arrangement of assembly (items 5, 6 and 7)

Provided a minimum distance to the ceiling is ensured as specified in IEC 62271-200:2021, Clause A.1, or IEC 62271-201:2014, Clause AA.1, the higher the distance between the switchgear and controlgear assembly and the ceiling (equivalent for the lateral and rear walls), the lower is the gas temperature and density of the hot gases reflected from the ceiling towards the indicators, and the lower is the probability of indicator ignition. If an exhaust duct is installed on top of the switchgear and controlgear assembly, the ceiling height is not relevant. However, the laboratory requires a minimum distance to the ceiling of 100 mm during the test to be able to document permanent deformations of the exhaust duct.

A.8.6 Indoor or outdoor installation (item 8)

In order to simulate outdoor conditions in case of accessibility from all sides, neither ceiling nor walls of an installation room are required. Hot gases ejected from the switchgear and controlgear freely flow into the environment and cannot be reflected by surrounding walls, which makes the test inside an installation room more severe for same accessibility. See also A.8.7 and A.8.8.

A.8.7 Type of accessibility (item 9)

In the test set-up required for accessibility type B, lighter weight indicators (with less energy needed to ignite) are placed closer to the switchgear and controlgear than in the test required for accessibility type A. As far as the acceptance criterion no. 4 (ignition of indicators) of IEC 62271-200:2021 or IEC 62271-201:2014 is concerned, the test set-up for accessibility type B covers type A.

A.8.8 Accessible sides (item 10)

For accessibility type A and B, the set-up for a type test carried out according to classification FLR comprises the set-ups for classification F, FR and FL and therefore covers them as long as the distance between switchgear and controlgear and rear wall complies with the requirements given in IEC 62271-200:2021, A.1.1, or IEC 62271-201:2014, Clause AA.1, under the heading: accessible rear side. Theoretically, FLR also covers the classifications LR, L and R, which however make little sense, since the main target of the classification is to protect persons in front of the switchgear and controlgear (F).