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BSI Standards Publication

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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National foreword

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The UK participation in its preparation was entrusted to Technical Committee PEL/17, High voltage switchgear, controlgear and assemblies.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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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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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.

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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,
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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*

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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]

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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.

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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.

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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.

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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.

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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.

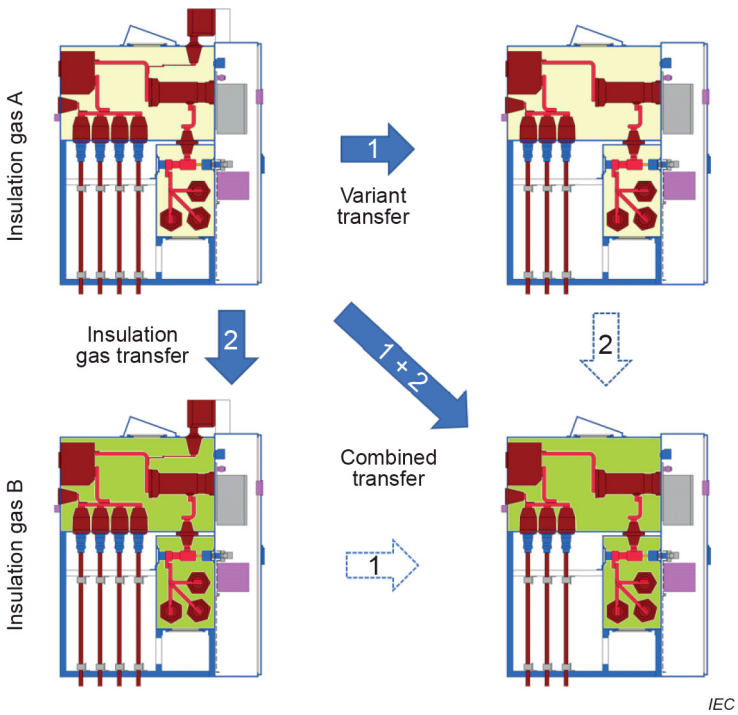

Figure 1 – Example for extension of validity of test report for dielectric testing with regard to different construction design variants and insulation gases of the same family of switchgear and controlgear

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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

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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.

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