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TECHNICAL REPORT

RAPPORT TECHNIQUE

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

Appareillage à haute tension –
Partie 307: Lignes directrices pour l'extension de validité des essais de type d'appareillages en courant alternatif sous enveloppe métallique et d'isolation solide pour tensions assignées supérieures à 1 kV et jusqu'à 52 kV inclus

IEC TR 62271-307:2015-09(en-fr)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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

This Technical Report is to be read in conjunction with IEC 62271-200 published in 2011 and IEC 62271-201 published in 2014.

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

Enquiry draft	Report on voting
17C/625/DTR	17C/632/RVC

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

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

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.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
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- replaced by a revised edition, or
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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 General

1.1 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 Technical Report may 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 assembly of the same family with a different set of ratings or different arrangements of components. 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.

This Technical Report 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.

1.2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-441:1984, *International Electrotechnical Vocabulary. Switchgear, controlgear and fuses*
IEC 60050-441:1984/AMD1:2000

IEC 62271-1:2007, *High-voltage switchgear and controlgear – Part 1: Common specifications*
IEC 62271-1:2007/AMD1:2011

IEC 62271-200:2011, *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*

2 Terms and definitions

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

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

2.101
switchgear and controlgear
general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures

[SOURCE: IEC 60050-441:1984, 441-11-01]

2.102
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)

2.103
functional unit (of an assembly)
a part of an assembly of switchgear and controlgear comprising all the components of the main circuits and auxiliary circuits that contribute to the fulfilment of a single function

Note 1 to entry: Functional units may 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 60050-441:1984, 441-13-04]

2.104
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.]

2.105
component
essential part of the high voltage or earthing circuits of metal and solid-insulation enclosed switchgear and controlgear which serves a specific function

Note 1 to entry: Examples of components include: circuit-breaker, disconnector, switch, fuse, instrument transformer, bushing, bus-bar.

[SOURCE: IEC 62271-200:2011, 3.113, modified – rephrasing of the definition and addition of a note to entry.]

2.106
main circuit
all the high voltage conductive parts of metal and solid-insulation enclosed switchgear and controlgear included in a circuit which is intended to carry the rated normal current

[SOURCE: IEC 60050-441:1984, 441-13-02, modified – rephrasing of the definition.]

2.107
test object
item submitted to a test, including any accessories, unless otherwise specified

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

2.108
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 a test performed on another assembly for a specific characteristic

2.109
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

2.110
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]

2.111
clearance between phases
the clearance between any conductive parts of adjacent phases

[SOURCE: IEC 60050-441:1984, 441-17-32; modified – modification of the term.]

2.112
clearance to earth
the clearance between any conductive parts and any parts which are earthed or intended to be earthed

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

2.113
centre distance between phases
distance between the centres of adjacent phase conductors

3 Use of extension criteria

3.1 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 may be evaluated by reference to type test reports of other assemblies of the same family of switchgear and controlgear. Subclauses 4.1 to 4.6 provide for each kind of type test (or characteristic) a non-exhaustive list of design parameters, which should be analysed for extension of validity.

The analysis should be based on sound technical and physical principles and may be supported by calculations, if applicable.

Each design parameter of the assembly to be assessed listed in the respective column of the tables in 4.1 to 4.6 should 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 or equal the clearance between phases of the tested assembly.

If any of the extension criteria cannot be affirmed, further evidence is required e.g. by technical arguments, calculation /simulation or specific tests. Calculations can only be applied in a comparative sense as indicated in 3.3.

3.2 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 should meet the manufacturer's specified tolerances for component parameters. The extension of validity of type tests according to a component standard is outside the scope of this Technical Report.

NOTE Some switching devices, such as earthing switches, may not be available as a separate component and need to 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 class of all insulation parts in contact with conductors	Component / assembly
Length of unsupported section of bus-bar	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 may depend on component parameters. Assembly parameters are considered within the scope of this Technical Report.

3.3 Use of calculations

3.3.1 General

For the purpose of this Technical Report, calculations and simulations may 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 Tables 2 to 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 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 Technical Report. Some of these calculation methods are briefly mentioned below with their particular characteristics.

3.3.2 Temperature rise calculations

The Technical Report IEC TR 60890 [1][1] provides calculation procedures for low voltage assemblies, which could also be applied to high voltage switchgear 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 may 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 CFD tools (computational fluid dynamics) may be applied requiring a complete 3-dimensional model of the switchgear.

3.3.3 Electric field calculations

The dielectric withstand performance of two assemblies may 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 [2] 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)“.

It may be remarked that this Technical Report does not provide information for extrapolation but only for interpolation of characteristics, e.g. extending validity to higher values of electric field strengths is not covered.

3.3.4 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 not recommended to use simulations for the extension of validity of mechanical type tests. Nevertheless, the strength of single parts or mechanical supports may be assessed by such calculations.

3.3.5 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 a guideline on short-circuit withstand of low voltage assemblies [3, 4, 5]. 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 bus-bars and forces on the supports may be assessed through stress analysis programs, when applying the calculated electro-magnetic forces. Additionally, a calculation of the thermal stress using $I_k^2 t_k$ might be done when the assessment is made for a lower I_k and higher t_k than the ones tested.

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[1] Numbers in square brackets refer to the Bibliography.

3.3.6 Internal arc pressure rise calculations

The comparison of the pressure withstand performance of two assemblies may be substantiated by pressure rise calculations for the compartments under investigation [6]. The calculations are able to provide the pressure rise in the compartments under consideration of 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 formula, otherwise using finite element mechanical stress analysis.

The flow of hot gases expelled from the compartment may be simulated by CFD programs, however, it is, at the time of the publication of this Technical Report, 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.

3.4 Information needed for extension of type test validity

For the extension of type test validity, similar information on the assembly under evaluation should be collected as is required for type test objects according to IEC 62271-1:2007, 6.1.3. In addition, the tables given in Clause 4 should 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 should be provided as far as they concern the comparison of the two assemblies.

It is recommended that the manufacturer provides relevant information on design parameters of the tested object as listed in the tables of Clause 4 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 may 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 should be given.

Documents providing traceability of the analysis performed should be established. Such documents should be 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 Application of extension criteria

4.1 Dielectric tests

The criteria listed in Table 2 should 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 may have been included in type tested objects according to IEC 62271-1:2007, 6.2.3, and therefore extension of the type test validity may only be performed on functional units or assemblies having the same arrangement and design of such insulation.

The test object shall 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 62271-200:2011, 6.2.6.1 and 6.2.6.2). 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 performance

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 [7])
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) should be considered. NOTE 2
7	Open contact gap	≥	If influenced by the switchgear assembly
8	Isolating distance	≥	If influenced by the switchgear assembly
9	Minimum functional pressure for insulation	≥	Same fluid; for fluid insulated switchgear

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.

4.2 Temperature rise tests

The extension criteria for temperature rise performance at rated normal 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 temperature rise test should be performed under the most severe conditions as required by the standard (e.g. IEC 62271-200:2011, 6.5), it is assumed that the impact of surrounding functional units on the temperature rise performance is equal or lower than the impact during the type test.

Where a functional unit may include different members of a family of components such as instrument transformers or fuses, these components should 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 6.5.2 of IEC 62271-200:2011.

Current transformers have to be tested and verified according to their own component standards. Where current transformers are fitted in a functional unit they may be considered acceptable if they have a power dissipation of the primary and secondary windings at the rated normal 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 higher primary resistance can only be applied in the switchgear and controlgear at lower normal current,