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TECHNICAL REPORT

colour inside

High-voltage switchgear and controlgear – Part 312: Guidance for the transferability of type tests of high-voltage/ low-voltage prefabricated substations

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 312: Guidance for the transferability of type tests of high-voltage/low-voltage prefabricated substations

FOREWORD

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IEC TR 62271-312, which is a Technical Report, has been prepared by subcommittee 17C: Assemblies, of IEC technical committee 17: High-voltage switchgear and controlgear.

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

Draft TR	Report on voting
17C/737/DTR	17C/753B/RVDTR

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 document 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 document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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- withdrawn,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

IMPORTANT – The 'colour inside' logo on the cover page of this publication 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 312: Guidance for the transferability of type tests of high-voltage/low-voltage prefabricated substations

1 Scope

This document refers to high-voltage / low-voltage prefabricated substations (hereinafter prefabricated substations) as specified in IEC 62271-202:2014.

This document, among other options as agreed between manufacturer and user, can be used for the transferability of type tests performed on one or more prefabricated substations with a defined set of ratings and arrangement of components to another prefabricated substation with a different set of ratings or different arrangement of components. It supports the selection of appropriate representative test objects for that purpose in order to optimize the type testing procedure for a consistent conformity assessment.

This document utilises a combination of sound technical and physical principles, manufacturer and user experience and mutually agreed upon methods of calculation to establish pragmatic guidance for the transferability of type test results, 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 60050-441:1984, *International Electrotechnical Vocabulary (IEV) – Part 441: Switchgear, controlgear and fuses*
IEC 60050-441:1984/AMD1:2000

IEC 60076-1:2011, *Power transformers – Part 1: General*

IEC 60076-2, *Power transformers – Part 2: Temperature rise for liquid-immersed transformers*

IEC 60076-7, *Power transformers – Part 7: Loading guide for mineral-oil-immersed power transformers*

IEC 60076-11, *Power transformers – Part 11: Dry-type transformers*

IEC 60076-12, *Power transformers – Part 12: Loading guide for dry-type power transformers*

IEC 60282-1:2020, *High-voltage fuses – Part 1: Current-limiting fuses*

IEC 61439-1:2020, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

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

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 62271-202:2014, *High-voltage switchgear and controlgear – Part 202: High-voltage/low-voltage prefabricated substation*

IEC TR 62271-208:2009, *High-voltage switchgear and controlgear – Part 208: Methods to quantify the steady state, power-frequency electromagnetic fields generated by HV switchgear assemblies and HV/LV prefabricated substations*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-441, IEC 62271-202 and the following apply.

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

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

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

3.1
prefabricated substation
prefabricated and type-tested assembly comprising an enclosure containing in general power transformers, high-voltage and low-voltage switchgear and controlgear, high-voltage and low-voltage interconnections, auxiliary equipment and circuits

Note 1 to entry: The term type-tested assembly includes prefabricated substations verified based on the transferability of type test results in accordance with this document.

[SOURCE: IEC 62271-202:2014, 3.101, modified – New Note 1 to entry.]

3.2
prefabricated substation under consideration
prefabricated substation being verified based on the transferability of type test results in accordance with this document

3.3
component
essential part of the prefabricated substation, which serves one or several specific functions

Note 1 to entry: Examples of components include power transformer, high-voltage switchgear and controlgear, low-voltage switchgear and controlgear, etc.

[SOURCE: IEC 62271-202:2014, 3.105, modified – Addition of "power" in Note 1 to entry.]

3.4
enclosure
part of a prefabricated substation providing protection against external influences to the components and a specified degree of protection for operators and the general public with respect to approach to, or contact with, live parts and against contact with moving parts

[SOURCE: IEC 62271-202:2014, 3.103, modified – Replacing “substation” by “components" in the definition.]

3.5
class of enclosure
difference of temperature rise between the power transformer in the enclosure and the same power transformer outside the enclosure at normal operating conditions

[SOURCE: IEC 62271-202:2014, 3.112, modified – In the definition, "power" was added, "normal service conditions as defined in 2.1" was replaced by "normal operating condition", and the note was deleted.]

3.6
compartment
part of a prefabricated substation enclosed except for openings necessary for interconnection, control or ventilation

Note 1 to entry: A compartment can be designated by the component contained therein, for example, power transformer, high-voltage switchgear and controlgear, low-voltage switchgear and controlgear respectively.

[SOURCE: IEC 62271-202:2014, 3.104, modified – In Note 1 to entry, addition of "power".]

3.7
prefabricated substation layout
three-dimensional spatial arrangement of main components, covers, doors, ventilation openings and compartments, if any

Note 1 to entry: Relative clearances and distances from main components to one another and to the enclosure can vary.

3.8
high-voltage switchgear compartment
compartment inside the prefabricated substation where the high-voltage switchgear and controlgear or high-voltage electrical protection of the circuit is installed

3.9
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]

3.10
family of high-voltage 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)

[SOURCE: IEC TR 62271-307:2015, 2.102, modified – Addition of "high-voltage" in the term.]

3.11
main circuit
all conductive parts of a prefabricated substation included in a circuit which is intended to transmit electrical energy

[SOURCE: IEC 62271-202:2014, 3.107]

3.12
high-voltage interconnection
electrical connection between the terminals of the high-voltage switchgear and controlgear and the high-voltage terminals of the power transformer

[SOURCE: IEC 62271-202:2014, 3.105.1, modified – Replacing "high-voltage/low-voltage power transformer" by "power transformer" in the definition.]

3.13
low-voltage interconnection
electrical connection between the low-voltage terminals of the power transformer and the incoming terminals of the low-voltage switchgear and controlgear

[SOURCE: IEC 62271-202:2014, 3.105.2, modified – Replacing "high-voltage/low-voltage power transformer" by “power transformer” in the definition.]

3.14
test object
item submitted to a test, including any accessories, unless otherwise specified

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

3.15
transferability criteria
principle for evaluating based on the design parameters, which can be applied to validate the performance of an untested prefabricated substation based on the positive results of a test performed on another prefabricated substation for a specific characteristic

4 Use of transferability criteria

4.1 General

Because of the variety of types of prefabricated substations, size of enclosures, layout and different types of components, it is neither practical nor affordable to perform type tests with all the possible variations and combinations. Therefore, the performance of a particular prefabricated substation can be evaluated with reference to type test reports of other prefabricated substation(s). This document gives support for the transferability of type test results concerning the following characteristics according to 6.1 of IEC 62271-202:2014:

– temperature rise;
– dielectric;
– electromagnetic field;
– mechanical;
– short-circuit; and
– internal arc.

Subclauses 5.2 to 5.7 provide, for each kind of characteristic, a non-exhaustive list of design parameters, which should be analysed for the transferability of type test results.

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

For each characteristic, the design parameters of the prefabricated substation under consideration, listed in the respective column of Table 2 to Table 7, should be compared with the design parameters of the already type-tested prefabricated substation(s) by applying the transferability criteria provided in the same tables. The affirmation of every transferability criteria for a determined characteristic supports the type test results transferability from the original prefabricated substation(s) to the prefabricated substation under consideration. The transferability of the type test results of a particular characteristic does not imply immediate acceptance of other characteristic(s), as each characteristic should be independently assessed. For example, the affirmation of item 7 in Table 2 for transferability assessment of temperature rise type test results reads: power transformer total losses of the prefabricated substation under consideration should be equal or smaller than those of the type-tested prefabricated substation.

If any of the transferability criteria cannot be affirmed, further evidence e.g. by technical arguments, calculation or simulation, or specific tests may be used and it can be subjected to agreement between the manufacturer and the user. Calculations can only be applied in a comparative sense as indicated in 4.3.

4.2 Design parameters for transferability criteria

Some ratings of a prefabricated substation are not linked to the parameters of specific main components. For example, a layout change can significantly affect the performance of a prefabricated substation characteristic.

The criteria for the transferability of type test results available for a prefabricated substation depend on a number of design parameters such as the examples listed in Table 1. Every prefabricated substation is characterized by its own set of design parameters.

The transferability of type test results of a component with regard to its particular product standard is outside the scope of this document.

Table 1 – Examples of design parameters

Design parameter
Thermal conductivity of enclosure material (steel, reinforced concrete, polyester)
Insulation type of the power transformer (oil- or dry-type)
Effective cross-section of ventilation openings (inlet and outlet)
Degree of protection (IP code) of the enclosure
Distance from components incorporating the main circuits of a prefabricated substation to the enclosure
Mechanical strength of the enclosure roof material
Material of high voltage interconnections conductors
Design, position and cross-section area of gas flow cooling device(s)
NOTE This table includes examples only; it is not intended to be complete.

4.3 Use of calculations

4.3.1 General

For the purpose of this document, calculations and simulations may only be applied in a comparative sense. Calculation results available for a type-tested prefabricated substation can be used for validation and be compared with calculation results obtained for the prefabricated substation under consideration. The comparison is always based on the design parameters and the acceptance criteria provided in Table 2 to Table 7.

In many cases the performance of a given prefabricated substation, 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 low-voltage interconnection layout can 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 prefabricated substation can be sufficient using an analytical or empirical formula, and sometimes a complete three-dimensional simulation model should be required using a complex numerical tool provided that 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 as examples.

4.3.2 Temperature rise calculations

The assessment procedure is applied to the prefabricated substation under consideration taking into account the total losses generated inside the prefabricated substation, the layout, and the area and mounting conditions of the enclosure walls and the effective area of the ventilation openings. The air temperature inside the enclosure in various locations 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. Furthermore, more complex CFD tools (computational fluid dynamics) or other techniques such as nodal tools may be applied requiring a complete three-dimensional model of the prefabricated substation and main components.

IEC 61439-1 gives conditions for the verification of temperature rise by calculation and IEC TR 60890 [1][1] provides calculation procedures for low voltage assemblies, which can also be applied to a prefabricated substation while having due regard for the particular limitations of this calculation method.

4.3.3 Electric field calculations

Since IEC 62271-202:2014 only requires dielectric type tests on interconnections between the main components (i.e. interconnection between the high-voltage switchgear and controlgear and the power transformer and interconnection between the power transformer and the low-voltage switchgear and controlgear), the dielectric withstand performance of two prefabricated substations may be assessed by an electric field simulation of both designs comparing the resulting electric field strengths.

When the installation conditions can affect their dielectric withstand, finite element (FE) or finite volume (FV) software tools exist, which allows the simulation of complex three-dimensional geometries. It should be noted that this document does not provide information for the extrapolation but only for the interpolation of design parameters, e.g. extending validity to higher values of electric field strengths is not covered.

4.3.4 Electromagnetic field calculations

In case the reference prefabricated substation has been evaluated following the calculation methodology described in IEC TR 62271-208, the same procedure should be applied to the prefabricated substation under consideration in a comparative sense.

4.3.5 Mechanical stress calculations

The mathematical methods of calculation make provision for the full assessment in relation to the mechanical withstand capability of the enclosure. Furthermore, national structural codes and other local regulations may also make provision for the assessment in relation to the mechanical withstand capability of the enclosure.

4.3.6 Short-circuit current calculations

This subclause may only be applied to the interconnection between the components, (i.e. interconnection between the high-voltage switchgear and controlgear and the power transformer and interconnection between the power transformer and the low-voltage switchgear and controlgear) and the earthing circuit of the prefabricated substation.

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1 Numbers in square brackets refer to the Bibliography.