

INTERNATIONAL STANDARD

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

**Appareillage à haute tension –
Partie 202: Postes préfabriqués haute tension/basse tension**



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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –**Part 202: High-voltage/low-voltage prefabricated substation**

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International Standard IEC 62271-202 has been prepared by subcommittee 17C: High-voltage switchgear and controlgear assemblies, of IEC technical committee 17: Switchgear and controlgear.

This second edition cancels and replaces the first edition published in 2006. This edition constitutes a technical revision.

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

- a) regarding temperature-rise test an alternative method for liquid filled transformers is (re)introduced and the temperature-rise test method for dry-type transformers is specified more precisely;
- b) testing procedure for short time and peak withstand current tests are specified more precisely;
- c) assessment of electromagnetic fields is considered including a type test (optional) according IEC/TR 62271-208:2009;

- d) influence of the product on the environment is considered (Clause 12);
- e) internal arc test requirements have been adapted to IEC 62271-200:2011 and requirements for the assessment of pressure relief volumes below the floor / ground has been assigned;
- f) the method for defining the load factor in an enclosure for liquid filled transformers is extended with different temperature rises for the transformer outside the enclosure (Annex DD);
- g) for the calculation of the load factor of dry-type transformers in an enclosure the insulation systems according to IEC 60076-1:2011, Tables B.1 and B.2 are worked out in detail.

The text of this standard is based on the following documents:

FDIS	Report on voting
17C/595/FDIS	17C/598/RVD

Full information on the voting for the approval of this standard 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.

This standard should be read in conjunction with IEC 62271-1:2007 and its Amendment 1:2011, to which it refers and which is applicable, unless otherwise specified. In order to simplify the indication of corresponding requirements, the same numbering of clauses and subclauses is used as in IEC 62271-1. Amendments to these clauses and subclauses are given under the same numbering, whilst additional subclauses are numbered from 101.

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

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- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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The contents of the corrigendum of April 2015 have been included in this copy.

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INTRODUCTION

Prefabricated substations are defined as a type-tested assembly comprising an enclosure containing in general transformers, low-voltage and high-voltage switchgear, connections and auxiliary equipment to supply low-voltage energy from a high-voltage system or vice versa. These substations are in locations accessible to the public and should ensure protection to persons according to the specified service conditions.

This means that, in addition to the specified characteristics, ratings and relevant test procedures, particular attention has been paid to the specification concerning the protection of persons, both operators and general public. Use of type-tested components and suitable design and construction of the enclosure ensure this protection. The correct design and performance of the prefabricated substation are verified by means of relevant type tests described in this standard, including internal arc tests.

HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 202: High-voltage/low-voltage prefabricated substation

1 General

1.1 Scope

This part of IEC 62271 specifies the service conditions, rated characteristics, general structural requirements and test methods of high voltage/low voltage or low voltage/high voltage prefabricated substations, which are cable-connected, to be operated from inside (walk-in type) or outside (non-walk-in type) for alternating current of rated voltages above 1 kV and up to and including 52 kV on the high voltage side, and for one or more transformers for service frequencies up to and including 60 Hz for outdoor installation at locations with public accessibility and where protection of personnel is provided.

Prefabricated substations can be situated at ground level or partially or completely below ground level.

In general a prefabricated substation comprises an enclosure containing the following electrical components:

- power transformers;
- high voltage and low voltage switchgear and controlgear;
- high voltage and low voltage interconnections;
- auxiliary equipment and circuits.

However, relevant provisions of this standard are applicable to designs where not all these electrical components exist (for example, an installation consisting of power transformer and low voltage switchgear).

Non-prefabricated substations should comply with the applicable requirements of IEC 61936-1:2010.

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 60050-461 (all parts), *International Electrotechnical Vocabulary* (available at www.electropedia.org)

IEC 60068-2-75, *Environmental testing – Part 2-75: Tests – Test Eh: Hammer tests*

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

IEC 60076-2:2011, *Power transformers – Part 2: Temperature rise for liquid-immersed transformers*

IEC 60076-3:2013, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*

IEC 60076-5:2006, *Power transformers – Part 5: Ability to withstand short circuit*

IEC 60076-7:2005, *Power transformers – Part 7: Loading guide for oil-immersed power transformers*

IEC 60076-10:2001, *Power transformers – Part 10: Determination of sound levels*

IEC 60076-11:2004, *Power transformers – Part 11: Dry-type transformers*

IEC 60076-12:2008, *Power transformers – Part 12: Loading guide for dry-type power transformers*

IEC 60076-13:2006, *Power transformers – Part 13: Self-protected liquid-filled transformers*

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

Amendment 1:1999

Amendment 2:2013

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60721-1:1990, *Classification of environmental conditions – Part 1: Environmental parameters and their severities*

Amendment 1:1992

Amendment 2:1995

IEC 60721-2-2:2012, *Classification of environmental conditions – Part 2-2: Environmental conditions appearing in nature – Precipitation and wind*

IEC 60721-2-4:1987, *Classification of environmental conditions – Part 2: Environmental conditions appearing in nature – Solar radiation and temperature*

Amendment 1:1988

IEC/TS 60815-1:2008, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions – Part 1: Definitions, information and general principles*

IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 61180-1:1992, *High-voltage test techniques for low-voltage equipment – Part 1: Definitions, test and procedure requirements*

IEC 61439-1:2011, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

IEC 61439-2:2011, *Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies*

IEC 62262:2002, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

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

Amendment 1:2011

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 62271-201:2006, *High-voltage switchgear and controlgear – Part 201: AC insulation enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

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*

IEC/TR 62271-300:2006, *High-voltage switchgear and controlgear – Part 300: Seismic qualification of alternating current circuit-breakers*

ISO/IEC Guide 51:1999, *Safety aspects – Guidelines for their inclusion in standards*

ISO 1052:1982, *Steels for general engineering purposes*

ISO 1182:2010, *Reaction to fire tests for products – Non-combustibility tests*

ISO 1716:2010, *Reaction to fire tests for products – Determination of the gross heat of combustion (calorific value)*

ISO 6508-1:2005, *Metallic materials – Rockwell hardness test – Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)*

2 Normal and special service conditions

Clause 2 of IEC 62271-1:2007 is applicable, except as follows.

2.1 Normal service conditions

Unless otherwise specified in this standard, the prefabricated substation is designed to be used under normal service conditions for outdoor switchgear and controlgear according to IEC 62271-1:2007.

Inside the enclosure it is assumed that normal indoor conditions prevail according to IEC 62271-1:2007. However, the ambient temperature inside the enclosure of the prefabricated substation will be different from the ambient temperature as defined in 3.111.

If the ambient temperature inside the substation is higher than the limits fixed for the components in their respective product standards, de-rating may be necessary.

2.1.1 Indoor switchgear and controlgear

Subclause 2.1.1 of IEC 62271-1:2007 is applicable.

Additional subclauses:

2.1.1.101 Low-voltage switchgear and controlgear

Subclause 7.1 of IEC 61439-1:2011 is applicable.

2.1.1.102 Transformer

IEC 60076-1:2011 is applicable.

A transformer loaded with rated normal current inside an enclosure has a temperature rise, which is higher than in open-field conditions and the temperature limits as defined in IEC 60076-2:2011 or IEC 60076-11:2004 can be exceeded.

The service conditions of the transformer will be determined according to the local outside service conditions and the class of the enclosure (see 4.101.2).

This will enable the transformer manufacturer or user to calculate its possible derating (see Annex DD).

2.1.2 Outdoor switchgear and controlgear

Subclause 2.1.2 of IEC 62271-1:2007 is not applicable.

2.2 Special service conditions

Subclause 2.2 of IEC 62271-1:2007 is applicable, except as follows.

When a prefabricated substation is used under conditions different from the normal service conditions given in 2.1, the following applies.

2.2.1 Altitude

Subclause 2.2.1 of IEC 62271-1:2007 is applicable, except as follows.

Precaution should be taken for the following equipment.

Additional subclauses:

2.2.1.101 High-voltage switchgear and controlgear

For installation at an altitude higher than 1 000 m, refer to IEC 62271-1:2007.

2.2.1.102 Low-voltage switchgear and controlgear

For installation at an altitude higher than 2 000 m, refer to 7.2 of IEC 61439-1:2011.

2.2.1.103 Transformer

For installation at an altitude higher than 1 000 m, refer to IEC 60076-2:2011 or IEC 60076-11:2004.

2.2.2 Pollution

Subclause 2.2.2 of IEC 62271-1:2007 is applicable, except as follows.

In the case where there is exposed primary insulation inside the enclosure, the degree of pollution should be selected having consideration that airborne salt or industrial pollution introduced via the enclosure ventilation will not be washed off by rain. The degree of pollution inside the enclosure in such circumstances may be more onerous than existing outside the enclosure.

For substations that are intended to be installed in environments with the site pollution severity classes c, d and e according to IEC/TS 60815-1:2008, the exposed insulation, if any, should be designed in order to withstand these pollution levels. Alternatively, measures should be taken in order to prevent the build-up of pollution on the exposed surfaces of the insulation.

For installation in polluted ambient air, the degree of pollution should be specified according to the relevant standards for the following equipment.

Additional subclauses:

2.2.2.101 High-voltage switchgear and controlgear

Refer to 2.2.2 of IEC 62271-1:2007.

NOTE Metal-enclosed switchgear and controlgear, under the scope of IEC/TS 62271-304 and intended to be used in service conditions more severe with respect to condensation and pollution than the normal service conditions specified in this standard, can be classified with a "Design Class" 1 or 2 according to IEC/TS 62271-304 to demonstrate its ability to withstand such severe conditions.

2.2.2.102 Low-voltage switchgear and controlgear

Refer to IEC 60664-1:2007 and 7.1.3 of IEC 61439-1:2011.

2.2.2.103 Transformer

IEC 60076 series, in general, do not address pollution as a special service condition. However IEC 60067-11:2004 describes unusual service conditions for dry type transformers that could give guidance in case of polluted environment.

2.2.3 Temperature and humidity

Subclause 2.2.3 of IEC 62271-1:2007 is applicable, except as follows.

For a prefabricated substation situated where the ambient temperature can be significantly outside the normal service condition range for the enclosure stated in 2.1, the preferred ranges of temperature to be specified should be:

–50 °C and +40 °C for very cold climates.

–5 °C and +50 °C for very hot climates.

If the service conditions at the intended installation site do not fall within the limits of "normal services conditions, taking into account the class of the enclosure (see 4.101.2), then the limits of the temperature rise for the transformer shall be modified accordingly (See Annex DD).

2.2.4 Vibrations, shock or tilting

Subclause 2.2.4 of IEC 62271-1:2007 is applicable.

2.2.5 Wind speed

Subclause 2.2.5 of IEC 62271-1:2007 is applicable.

2.2.6 Other parameters

Subclause 2.2.6 of IEC 62271-1:2007 is applicable.

3 Terms and definitions

Clause 3 of IEC 62271-1:2007 is not applicable.

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

3.101

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

3.102

transport unit

part of a prefabricated substation suitable for shipment without being dismantled

3.103

enclosure

part of a prefabricated substation providing protection against external influences to the substation 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

3.104

compartment

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

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

3.105

component

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

Note 1 to entry: For example, transformer, high-voltage switchgear and controlgear, low-voltage switchgear and controlgear, etc.

3.105.1

high voltage interconnection

electrical connection between the terminals to the high voltage switchgear and controlgear and the high voltage terminal of the high voltage/low voltage power transformer

3.105.2

low voltage interconnection

electrical connection between the low voltage terminals of the high voltage/low voltage power transformer and the incoming terminals of the low voltage switchgear and controlgear

3.106

partition

part of a prefabricated substation separating one compartment from other compartments

3.107

main circuit

all conductive parts of a prefabricated substation included in a circuit intended to transmit electrical energy

3.108

auxiliary circuit

all conductive parts of a prefabricated substation included in a circuit (other than the main circuit) intended to control, measure, signal, regulate, illuminate, etc.

3.109

rated value

quantity value assigned, generally by the manufacturer, for a specified operating condition of a prefabricated substation

[SOURCE: IEC 60050-151:2001, 151-16-08, modified]

3.110

degree of protection

extent of protection provided by an enclosure against access to hazardous parts, against ingress of solid foreign objects and/or against ingress of water and verified by standardized test methods

3.111

ambient air temperature

temperature, determined under prescribed conditions, of the air surrounding the enclosure of the prefabricated substation

3.112

class of enclosure

difference of temperature rise between the transformer in the enclosure and the same transformer outside the enclosure at normal service conditions as defined in 2.1

Note 1 à l'article: The transformer rated values (power and losses) correspond to the maximum rated values of the prefabricated substation.

3.113

transformer load factor

per unit value of constant current that can be taken from the transformer at constant rated voltage

3.114

internal arc classified prefabricated substation

prefabricated substations for which prescribed criteria for protection of persons are met in the event of an internal arc as demonstrated by type tests

3.114.1

type of accessibility

characteristic related to the level of protection given to people accessing a defined area inside or around the prefabricated substation

3.114.2

arc fault current

three-phase and – where applicable – the single phase-to-earth r.m.s. value of the short-circuit current for which the prefabricated substation is designed to protect persons in the event of an internal arc

3.114.3

arc fault duration

duration of the short-circuit current for which the prefabricated substation is designed to protect persons in the event of an internal arc

3.115

degree of protection against mechanical impacts

extent (level) of protection of the equipment provided by an enclosure against harmful mechanical impacts and verified by standardized test methods

4 Ratings

Clause 4 of IEC 62271-1:2007 is applicable, except as follows.

The ratings of a prefabricated substation are the following:

- a) rated high voltage;
- b) rated low voltage;
- c) rated insulation levels;
- d) rated frequency (f_r);
- e) rated normal currents for main circuits (I_r);
- f) rated short-time withstand currents (I_k, I_{ke}, I_{cw}) for main and earthing circuits;
- g) rated peak withstand currents (I_p, I_{pe}, I_{pk}), for main and earthing circuits;
- h) rated duration of short circuit (t_k, t_{ke}) for main and earthing circuits;
- i) rated supply voltage of closing and opening devices and auxiliary and control circuits;
- j) rated supply frequency of closing and opening devices and auxiliary and control circuits;
- k) rated maximum power of the prefabricated substation;
- l) temperature rises and rated power of each transformer;
- m) transformer losses at rated operating voltage and rated current;
- n) rated class of enclosure;
- o) ratings of the internal arc classification (IAC), if assigned by the manufacturer.

4.1 Rated voltage (U_r)

Subclause 4.1 of IEC 62271-1:2007 is not applicable for the prefabricated substation assembly.

Rated voltage of a prefabricated substation is defined by the rated voltages of its high voltage switchgear and controlgear, high voltage/low voltage power transformer and low voltage switchgear and controlgear.

Refer to IEC 62271-1:2007 for high-voltage switchgear and controlgear.

Refer to IEC 60947-1 and 5.2 of IEC 61439-1:2011 for low-voltage switchgear and controlgear.

Subclause 5.4.1 of IEC 60076-1:2011 is applicable for the transformer.

NOTE These values are determined by the characteristics of the high voltage/low voltage power transformer. High voltage and low voltage switchgear and controlgear can have rated voltages higher than the high voltage/low voltage power transformer rated voltages.

4.2 Rated insulation level

Subclause 4.2 of IEC 62271-1:2007 is not applicable for the prefabricated substation assembly.

Rated insulation level of a prefabricated substation is defined by the rated insulation levels of its high voltage switchgear and controlgear and low voltage switchgear and controlgear.

For high-voltage switchgear and controlgear, refer to IEC 62271-1:2007 and for low-voltage switchgear and controlgear refer to 5.2 of IEC 61439-1:2011 and IEC 60947-1:2007.

The minimum rated lightning impulse voltage withstands of the low-voltage switchgear and controlgear shall be at least the value given for overvoltage category IV in Table A.1 of IEC 60664-1:2007. Depending on the network in different countries, it may be necessary to choose a higher insulation level.

4.3 Rated frequency (f_r)

Subclause 4.3 of IEC 62271-1:2007 is not applicable for the prefabricated substation assembly.

For high-voltage switchgear and controlgear, refer to IEC 62271-1:2007, and for low-voltage switchgear and controlgear, refer to IEC 60947-1:2007 and 5.5 of IEC 61439-1:2011.

4.4 Rated normal current and temperature rise

4.4.1 Rated normal current (I_r)

Subclause 4.4.1 of IEC 62271-1:2007 is not applicable for the prefabricated substation assembly.

For high-voltage switchgear and controlgear, refer to IEC 62271-1:2007 and for low-voltage switchgear and controlgear, refer to 5.3 of IEC 61439-1:2011.

4.4.2 Temperature rise

Subclause 4.4.2 of IEC 62271-1:2007 is not applicable for the prefabricated substation assembly.

For any outer accessible part of the enclosure of the substation the maximum permissible temperature shall not exceed 70 °C at a maximum ambient temperature of 40°C excluding solar radiation effects.

For high-voltage switchgear and controlgear, refer to IEC 62271-1:2007.

For low-voltage switchgear and controlgear, refer to 9.2 of IEC 61439-1:2011.

For transformer function, refer to IEC 60076-2:2011 and IEC 60076-11:2004.

Components in a prefabricated substation which are subject to individual specifications not covered by the scope of IEC 62271-1:2007, IEC 61439-1:2011, IEC 60076-2:2011 and IEC 60076-11:2004 shall not exceed the maximum permissible temperatures and temperature-rise limits stated in the relevant standard for each component.

The maximum permissible temperature rise for high voltage and low voltage interconnections are those specified in IEC 62271-1:2007 and 9.2 of IEC 61439-1:2011 as applicable for contacts, connections and metal parts in contact with insulation. For the transformer, the load factor will be taken into account to comply with Clause 2 of this standard. Refer to Annex DD, and also to IEC 60076-7 and to IEC 60076-12:2008.

4.4.3 Particular points of Table 3

Subclause 4.4.3 of IEC 62271-1:2007 is applicable.

4.5 Rated short-time withstand current (I_k)

Subclause 4.5 of IEC 62271-1:2007 is not applicable for the prefabricated substation assembly.

For the rated short-time withstand currents I_k and I_{ke} of high voltage switchgear and controlgear, high voltage interconnection and earthing circuit, 4.5 of IEC 62271-1:2007 is applicable with the following additions:

Additional subclauses:

4.5.101 Rated short-time withstand current of high voltage switchgear and controlgear and high voltage interconnection (I_k)

Rated short-time withstand current I_k shall be assigned to high voltage switchgear and also to high voltage interconnection.

NOTE In principle, the rated short-time withstand current of a main circuit cannot exceed the corresponding rated values of the weakest of its series connected components. However, for each circuit or high-voltage compartment, advantage can be taken of apparatus limiting the short-circuit current, such as current-limiting fuses, reactors, etc.

4.5.102 Rated short-time phase to earth withstand current (I_{ke})

A rated short-time withstand phase to earth current shall be assigned to the earthing circuit (I_{ke}). This value may differ from that of the main circuit.

NOTE The short-circuit current ratings applicable to the earthing circuit depend upon the type of system neutral earthing for which it is intended. See Table 103.

4.5.103 Rated short-time withstand currents of low voltage switchgear and controlgear and low voltage interconnection (I_{cw})

Refer to 5.3.4 of IEC 61439-1:2011.

4.6 Rated peak withstand current (I_p)

Subclause 4.6 of IEC 62271-1:2007 is not applicable for the prefabricated substation assembly.

For the rated peak withstand currents I_p and I_{pe} of high voltage switchgear and controlgear, high voltage interconnection and earthing circuit, 4.6 of IEC 62271-1:2007 is applicable with the following additions:

Additional subclauses:

4.6.101 Rated peak withstand current (I_p)

NOTE In principle, the rated peak withstand current of a main circuit cannot exceed the corresponding rated values of the weakest of its series connected components. However, for each circuit or high-voltage compartment, advantage can be taken of apparatus limiting the short-circuit current, such as current-limiting fuses, reactors, etc.

4.6.102 Rated peak phase to earth withstand current (I_{pe})

A rated peak withstand phase to earth current shall be assigned to the earthing circuit (I_{pe}). This value may differ from that of the main circuit.

4.6.103 Rated peak withstand currents of low voltage switchgear and controlgear and low voltage interconnection (I_{pk})

Refer to 5.3.3 of IEC 61439-1:2011.

4.7 Rated durations of short circuit (t_k)

Subclause 4.7 of IEC 62271-1:2007 is not applicable for the prefabricated substation assembly.

For the rated durations of short circuit t_k and t_{ke} for high voltage switchgear and controlgear, high voltage interconnection and earthing circuit 4.7 of IEC 62271-1:2007 is applicable with the following additions:

Additional subclauses:

4.7.101 Rated duration of short circuit (t_k)

A rated duration of short circuit shall be assigned to high voltage switchgear and to high voltage interconnection.

NOTE In principle, the rated duration of short circuit for a main circuit cannot exceed the corresponding rated value of the weakest of its series connected components. However, for each circuit or high-voltage compartment, advantage can be taken of apparatus limiting the duration of the short-circuit current, such as current-limiting fuses.

4.7.102 Rated duration of phase to earth short circuit (t_{ke})

A rated duration of phase to earth short circuit shall also be assigned to the earthing circuit (t_{ke}). This value may differ from that of the main circuit.

4.7.103 Rated duration of short circuits for low voltage switchgear and controlgear and low voltage interconnection

Refer to 5.3.4 of IEC 61439-1:2011 for low voltage switchgear and controlgear and assign a rated duration of short-circuit to the low voltage interconnection

4.7.104 Rated duration of short circuits for transformers

Refer to IEC 60076-5:2006 and IEC 60076-11:2004.

4.8 Rated supply voltage of closing and opening devices and auxiliary and control circuits (U_a)

Subclause 4.8 of IEC 62271-1:2007 is not applicable for the prefabricated substation assembly.

For high-voltage switchgear and controlgear, refer to IEC 62271-1:2007; for low-voltage switchgear and controlgear, refer to IEC 61439-1:2011.

4.9 Rated supply frequency of closing and opening devices and of auxiliary circuits

Subclause 4.9 of IEC 62271-1:2007 is not applicable for the prefabricated substation assembly.

For high-voltage switchgear and controlgear, refer to IEC 62271-1:2007; for low-voltage switchgear and controlgear, refer to IEC 61439-1:2011.

4.10 Rated pressure of compressed gas supply for controlled pressure systems

Subclause 4.10 of IEC 62271-1:2007 is not applicable to the prefabricated substation assembly.

For high-voltage switchgear and controlgear, 4.10 of IEC 62271-1:2007 is applicable.

4.11 Rated filling levels for insulation and/or operation

Subclause 4.11 of IEC 62271-1:2007 is not applicable to the prefabricated substation assembly.

For high-voltage switchgear and controlgear, 4.11 of IEC 62271-1:2007 is applicable.

Additional subclauses:

4.101 Rated maximum power and class of enclosure

4.101.1 Rated maximum power of the prefabricated substation

The rated maximum power of the prefabricated substation is given by the maximum rated power and the total losses of the transformer(s) (as defined in IEC 60076-1:2011 or IEC 60076-11:2004) for which the substation has been designed.

4.101.2 Rated class of enclosure

The rated class of the enclosure is the class of the enclosure corresponding to the rated maximum power of the prefabricated substation.

The rated class of the enclosure, the transformer temperature rise and the service conditions are used to determine the load factor of the transformer according to Annex DD.

There are six rated classes of enclosure: classes 5, 10, 15, 20, 25 and 30 corresponding to a maximum value of difference of the temperature rise of the transformer of 5 K, 10 K, 15 K, 20 K, 25 K and 30 K, respectively (see Figures 101 and 102).

NOTE The manufacturer can assign to an enclosure several classes corresponding to different values of power and losses of the transformer. These additional classes are confirmed by test according to 6.5 (see also 8.103).

4.102 Ratings of the internal arc classification

4.102.1 General

If an IAC classification is assigned by the manufacturer, several ratings shall be specified. These ratings are subdivided into type of accessibility, arc fault currents and arc fault durations.

4.102.2 Types of accessibility (A, B, AB)

Three types of protection in case of an internal arc are considered:

Accessibility type A: for substations providing protection to the operators during normal operations inside or in front of the high voltage side of the substation.

NOTE 1 To verify the protection to the operators a distinction is made between two types of substations, depending on their operating mode.

- a) Substation operated from inside: Authorized personnel inside the substation with the door open.
- b) Substation operated from outside: Authorized personnel on the high voltage operating side of the substation with the door open.

Accessibility type B: for substations providing protection to the general public in the vicinity of the substation on all its sides at any time.

NOTE 2 To qualify for this classification, unrestricted accessibility is considered to all sides of the substation with all doors closed, irrespective of the operational mode of the substation (from the inside or from the outside).

Accessibility type AB: for substations providing protection to both operators and the general public.

To qualify for this classification, these substations shall comply with the requirements for type A and type B with the same value of the test current in kA and duration in second(s).

4.102.3 Rated arc fault currents (I_A , I_{Ae})

The standard value of rated arc fault currents should be selected from the IEC 60059:1999 standard current ratings.

Two ratings of the arc fault currents are recognised:

- a) three-phase arc fault current (I_A);
- b) single phase-to earth arc fault current (I_{Ae}), when applicable.

When only a three-phase rating is specified, the single phase rating is by default 87 % of the three-phase rating, and need not be specified.

NOTE 1 The manufacturer specifies the compartments of the high-voltage switchgear and controlgear to which the single phase-to earth arc fault current rating applies. Such value is assigned to switchgear and controlgear where its construction will prevent the arc from becoming multiphase, as demonstrated during the internal arc test.

NOTE 2 Rationale for this 87 % is the arc fault test with 2-phase ignition; refer to 8.104.6.

In the case where all high-voltage compartments are only designed for single phase-to-earth arc faults, I_A rating shall not be assigned.

NOTE 3 Information about the relationship between type of neutral earthing and the single phase-to-earth arc fault current is provided in 8.104.6, and Table 103.

4.102.4 Rated arc fault duration (t_A , t_{Ae})

Standard recommended values for the three-phase arc fault duration (t_A) are 0,1 s, 0,5 s and 1 s.

If applicable, the test duration (t_{Ae}) of the single phase-to-earth arc fault shall be stated by the manufacturer.

NOTE It is in general not possible to calculate the permissible arc duration for a current which differs from that used in the test.

5 Design and construction

Clause 5 of IEC 62271-1:2007 is not applicable to the prefabricated substation assembly.

Prefabricated substations shall be designed so that normal service, inspection and maintenance can be carried out safely. Additionally, the substation shall be designed and constructed in such a manner that the risk of unauthorized access is minimized. Attention shall be paid to hinges, vent covers, locking mechanisms, etc.

The design of the substation shall take into account the possible interactions (e.g. electrical, mechanical and thermal) in the performance of different components.

All the components shall comply with their relevant IEC standards.

In particular,

- transformers according to IEC 60076-1:2011, IEC 60076-11:2004 or IEC 60076-13:2006;
- high-voltage switchgear and controlgear according to IEC 62271-200:2011 or IEC 62271-201:2006;
- low-voltage switchgear and controlgear according to IEC 60947-1 and IEC 61439-2:2011.

5.1 Requirements for liquids in switchgear and controlgear

For high-voltage switchgear and controlgear 5.1 of IEC 62271-1:2007 is not applicable to substation assembly.

5.2 Requirements for gases in switchgear and controlgear

For high-voltage switchgear and controlgear 5.2 of IEC 62271-1:2007 is not applicable to substation assembly.

NOTE For the handling of SF₆ refer to IEC/TR 62271-4 (see Bibliography).

5.3 Earthing of switchgear and controlgear

Subclause 5.3 of IEC 62271-1:2007 is not applicable and it is replaced as follows:

A main earthing conductor system shall be provided to connect to the earth all metallic parts of the prefabricated substation not belonging to the main and/or secondary/auxiliary circuits of the equipment. It consists in a main earthing conductor on which each component is connected through a single circuit.

If the framework of the enclosure, or the reinforcement of the concrete, is made of metallic bolted or welded material, it may serve as the main earthing conductor system.

Annex EE shows some typical examples of earthing systems.

The main earthing conductor system shall be capable of carrying the rated short time and peak phase to earth withstand currents from each element of the prefabricated substation to the external earthing connection, under the neutral earthing condition of the system.

NOTE 1 In general, the above requirement is fulfilled if an earthing conductor of adequate cross-section is provided extending the whole length of the prefabricated substation. As guidance, the current density in the earthing conductor, if of copper, does under the specified earth-fault conditions not exceed 200 A/mm² for a rated duration of short circuit of 1 s, and 125 A/mm² for a rated duration of short circuit of 3 s.

NOTE 2 A method of calculating cross-sectional areas of conductors is given in IEC 60724; refer to Bibliography.

The earthing circuit is normally designed to withstand one occurrence of a single short-circuit fault, and maintenance could be needed after such an event.

If a dedicated earthing conductor is applied as earthing circuit of the switchgear and controlgear, its cross-section shall be not less than 30 mm².

The continuity of the earth system shall be ensured and appropriate measures preventing corrosion, loosening bolts etc. shall be taken, taking into account the thermal and mechanical stresses caused by the current it may have to carry.

NOTE 3 The users can establish procedures to check the integrity of all parts of the earthing system (internal and external) either periodically or after a short-circuit current has flown into the earthing system.

Components to be connected to the earthing circuit shall include:

- the enclosure of the prefabricated substation if it is metallic;
- the enclosure, if metallic, of the high-voltage switchgear and controlgear from the terminal provided for that purpose;
- the metal shields and the earthing conductors of the high-voltage cables;
- the transformer tank or metal frame of dry-type transformers;
- the frame and/or enclosure, if metallic, of the low-voltage switchgear and controlgear;
- the earthing connection of automatic controls and remote-control devices.

If the enclosure of the prefabricated substation is metallic, covers, doors and other accessible metallic parts of this enclosure shall be designed to carry 30 A (d.c.) from themselves to the prefabricated substation main earthing point, with a voltage drop of maximum 3 V. Adequate earthing measures around the prefabricated substation shall be provided to prevent dangerous touch and step voltages.

If the enclosure of the prefabricated substation is not metallic, it is not necessary to connect covers, doors and other accessible metallic parts of this enclosure to the earthing circuit unless there is a risk of live parts coming into contact with them.

5.4 Auxiliary and control equipment

Subclause 5.4 of IEC 62271-1:2007 is not applicable.

For the low-voltage installation inside the prefabricated substation (for example, illumination, auxiliary supply, etc.), refer to IEC 60364-4-41:2005 or IEC 61439-1:2011, as appropriate.

5.5 Dependent power operation

Subclause 5.5 of IEC 62271-1:2007 is not applicable to substation assembly.

5.6 Stored energy operation

Subclause 5.6 of IEC 62271-1:2007 is not applicable to substation assembly.

5.7 Independent manual or power operation (independent unlatched operation)

Subclause 5.7 of IEC 62271-1:2007 is not applicable to substation assembly.

5.8 Operation of releases

Subclause 5.8 of IEC 62271-1:2007 is not applicable to substation assembly.

5.9 Low- and high-pressure interlocking and monitoring devices

Subclause 5.9 of IEC 62271-1:2007 is not applicable to substation assembly.

5.10 Nameplates

Instead of subclause 5.10 of IEC 62271-1:2007 the following applies.

Each prefabricated substation shall be provided with a durable and clearly legible nameplate, which shall contain at least the following information:

- manufacturer's name or trade mark;
- type designation;
- internal arc designation, where applicable;
- serial number;
- instruction book reference;
- number of this standard;
- year of manufacture.

The ratings of the high voltage switchgear and controlgear, power transformers and low voltage switchgear and controlgear shall be provided with separated nameplates, as in their respective product standard.

5.11 Interlocking devices

Subclause 5.11 of IEC 62271-1:2007 is not applicable and it is replaced as follows:

Interlocking can be necessary to ensure the correct sequence of operation of equipment, to minimise the risk to personnel and damage to the equipment. Interlocking can be achieved by electrical or mechanical methods. In the event of the loss of power supply electrical interlocking schemes shall be designed to fail safely.

5.12 Position indication

Subclause 5.12 of IEC 62271-1:2007 is not applicable to substation assembly.

5.13 Degree of protection provided by enclosures

Subclause 5.13 of IEC 62271-1:2007 is applicable, with the following additions.

The minimum degree of protection of the enclosure of the prefabricated substation shall be IP23D in accordance with IEC 60529:1989, Amendment 1:1999, Amendment 2:2013. A higher degree of protection may be specified in accordance with IEC 60529:1989, Amendment 1:1999, Amendment 2:2013.

For compartmented substations, the degrees of protection may be defined for each part of the enclosure corresponding to each compartment.

NOTE The degree of protection of the prefabricated substation can be reduced when substation/compartment doors are open (for example, for operation, inspection, etc.). Other precautions can be necessary for the protection of persons against approach to hazardous parts, fulfilling the safety measures of 8.1 of IEC 61936-1:2010.

5.14 Creepage distances for outdoor insulators

Subclause 5.14 of IEC 62271-1:2007 is not applicable.

5.15 Gas and vacuum tightness

Subclause 5.14 of IEC 62271-1:2007 is not applicable to substation assembly.

5.16 Liquid tightness

Subclause 5.15 of IEC 62271-1:2007 is not applicable to substation assembly.

5.17 Fire hazard (flammability)

Subclause 5.17 of IEC 62271-1:2007 is not applicable and it is replaced as follows:

For the enclosure of the prefabricated substation refers to 5.104.2.

5.18 Electromagnetic compatibility (EMC)

Subclause 5.18 of IEC 62271-1:2007 for high-voltage switchgear and controlgear and 9.4 of IEC 61439-1:2011 for low-voltage switchgear and controlgear are applicable.

Emission and immunity characteristics of a prefabricated substation are given by those of its active components.

Additional subclauses:

5.101 Protection of the prefabricated substation against mechanical stress

The enclosure of a prefabricated substation shall have sufficient mechanical strength and shall withstand the following loads and impacts:

a) roof load:

- minimum 2 500 N/m² (erection loads or other loads);

If the prefabricated substation is installed in places where higher stress can be expected (for example, underground substation placed in vehicle traffic areas, snow loads, etc.), this shall be taken into account and, where applicable, follow national or local regulations in force, or specification of the user.

- snow loads according to the local climatic conditions;
- b) wind loads on the enclosure:
 - wind loads according to 2.1.2 of IEC 62271-1:2007;
- c) external mechanical impacts on covers, doors and ventilation openings:
 - external mechanical impacts with an energy of 20 J corresponding to a degree of protection IK10.

Accidental mechanical impacts above this value (for example, traffic collisions) are not covered by this standard and should be prevented, if necessary, by other means provided external to and around the prefabricated substation.

5.102 Protection of the environment due to internal defects

In the case of internal defects leading to hazardous liquids escaping from the equipment (example: oil of a transformer, oil of switchgear), provision shall be taken to retain hazardous liquids preventing the soil to be polluted.

If one or several retention tanks are part of the enclosure, their capacity shall be at least:

- for each individual tank: the total hazardous liquid volume of the corresponding hazardous liquid containing part (for example, transformer, switchgear, etc.);
- for a common tank: the total hazardous liquid volume of the biggest hazardous liquid containing part (for example, transformer, switchgear, etc.).

5.103 Internal arc fault

A prefabricated substation that satisfies the requirements of this standard is designed, in principle, to prevent the occurrence of internal arc faults.

To achieve this objective the manufacturer of the prefabricated substation shall assure the correct manufacture, verifying it by carrying out routine tests according to Clause 7. In turn, the user shall make a proper selection, according to the characteristics of the network, operating procedures and service conditions (refer to Clause 8).

There should be little probability that an internal arc occurs during the entire service life, if the substation is installed, operated and maintained following the instructions provided by the manufacturer; however, this cannot be completely disregarded.

Failure within the enclosure of a prefabricated substation due either to a defect or an exceptional service condition or mal-operation may initiate an internal arc, which constitutes a hazard, if persons are present. Failures can occur in any part of the substation. However, as no internal arc testing requirements for low voltage switchgear and transformers are described in their respective relevant standards, only arc faults occurring within the enclosure of the enclosed high voltage switchgear and controlgear and in the high voltage interconnections are taken into consideration in this standard (see 6.102).

NOTE IEC/TR 61641:2008 gives guidance for an internal arc test in enclosed low voltage switchgear and controlgear.

For substation arrangements without high voltage switchgear, see 6.102.2.

To consider this hazard, distinction shall be made between operators and general public. The operator can be inside the substation (if operated from inside) or in front of it (if operated from outside). However, the general public may be around the substation at any time. The general public will never be inside the substation or in close proximity to the operating side when operations are being performed with the doors open (if operated from outside). These areas are considered to be of restricted access only for operators.

Evidence of the effectiveness of the design at providing protection to general public and/or to operators in case of an internal arc fault may be required. This evidence shall be obtained by testing the substation according to 6.102 and Annex AA. Substations that have been successfully tested qualify as class IAC-A or IAC-B or IAC-AB.

In the event of an internal arc fault, some gases with toxic characteristics may be present. However, it is not relevant to the safety of the operator because in such situation evacuation of the switching room is mandatory. Later on, ventilation of the room is necessary before re-entering.

5.104 Enclosure

5.104.1 General

The enclosure shall meet the following conditions:

- the degree of protection shall comply with 5.13;
- parts of the enclosure made of non-conductive materials shall meet special dielectric requirements. Tests to verify compliance are described in 6.2.101.2.2;
- measures shall be taken in order to avoid deformation, which could be caused by transport or handling when carried out according to the manufacturer's instructions;
- means shall be provided to guarantee safe access to operations concerning transformer tap-changer or for inspection, for example, by opening a door or, if necessary, by removing a cover;
- cooling of the prefabricated substation by natural ventilation;

NOTE This standard covers only designs using natural ventilation. Prefabricated substations employing other means of cooling (for example, forced cooling) are subject to an agreement between manufacturer and user. In any case, the forced cooling can be carried out by pushing fresh air at the bottom of the enclosure or exhausting the hot air at the top. An attention is paid to avoid any short cut between the air inlet and the air outlet that can reduce the efficiency of the ventilation system.

- it is acceptable that part of the enclosure of a component becomes part of the substation enclosure. In such a case, this part shall comply with the applicable requirements of both this standard and the relevant product standard of the component.

5.104.2 Fire behaviour

5.104.2.1 General

The materials used in the construction of the enclosure of the prefabricated substation shall have the following minimum level of behaviour against fire occurring inside or outside of the prefabricated substation.

The materials shall be either non-flammable or, if synthetic materials are used, they shall be in accordance with 5.104.2.3.

NOTE 1 For fire behaviour, only reaction to fire is considered. Fire resistance may be considered, according to local regulations, subject to agreement between manufacturer and user.

NOTE 2 For aesthetic reasons, additional cladding materials which cannot comply with non-flammability tests could be used. These materials do not form any part of the structure of the enclosure of the substation.

5.104.2.2 Traditional materials

The materials listed below are suitable for prefabricated substations and considered as non-flammable:

- concrete;
- metal (steel, aluminium, etc.);

- plaster;
- glass fibre or rockwool.

5.104.2.3 Synthetic materials

The use of enclosures made of synthetic materials is subject to agreement between the manufacturer and the user

If agreed synthetic materials shall be tested according to ISO 1182:2010 and ISO 1716:2010 complying as a minimum with the values given in Table 101.

Table 101 – Synthetic material characteristics

Performance characteristics	Requested values	Standard
PCS gross heat of combustion [in MJ/kg]	$\leq 3,0$ MJ/kg	ISO 1716:2010
Temperature rise (T) [in °C]	≤ 50 °C	ISO 1182:2010
Loss of mass (Δm) [in %]	≤ 50 %	ISO 1182:2010
Flaming time (t_f) [in s]	20 s	ISO 1182:2010

5.104.2.4 Other materials

The manufacturer shall prove the non-flammability of the materials used which shall be at least equivalent to 5.104.2.3.

5.104.3 Corrosion

5.104.3.1 General

The enclosure can be made of different materials (concrete, metal, synthetic materials, etc.). The materials of the enclosure should resist deterioration under the environmental conditions (see Clause 2) during its expected lifetime, provided that the maintenance recommendation given by the manufacturer is followed.

An additional coating or surface treatment can be used.

To assess the performance of such treatments appropriate relevant international standards may be used.

The IEC 60068 series gives information on environmental testing procedures and severity of tests.

Characteristics of materials coatings and painting should be stated by the manufacturer. Additional information is given in Annex FF.

If the enclosure is part of the main earthing conductor system, precautions shall be taken to prevent corrosion of the elements and contact surfaces in the earthing current path, in order to maintain the current-carrying capacity during its expected service lifetime.

5.104.3.2 Concrete

Concrete shall be protected against the effects of water penetration, carbonation, frost, chloride diffusion and chemical attacks.

Painting or roughcast painting may be used as appropriate. The adherence, ageing (damp heat) and abrasion resistance should be considered.

5.104.3.3 Metals

Protection against corrosion shall be ensured by the use of suitable materials or by the application of suitable protective coatings to the exposed surfaces. Additional information is given in FF.1.1 and FF.1.2. The manufacturer shall carefully consider the corrosion characteristic of the material.

5.104.3.4 Synthetic and composite materials

Ageing (dry heat and damp heat) and ultraviolet radiation should be considered. Additionally, these materials may be protected by appropriate painting or coating.

5.104.4 Covers and doors

Covers and doors are part of the enclosure. When they are closed, they shall provide the degree of protection specified for the enclosure. When ventilation openings are incorporated in covers or doors, reference is made to 5.104.5.

Two categories of covers or doors are recognized with regard to access to the compartments of the prefabricated substation:

- a) those which need to be opened for normal operation (removable covers, doors). These shall not require tools for their opening or removal. They shall be provided with locking facilities unless the safety of persons is assured by a suitable interlocking device;
- b) all other covers, doors or roof. They shall be provided with locking facilities or it shall not be possible to open or remove them before doors used for normal operation have been opened. They shall require tools for their opening or removal.

The doors shall open outwards at an angle of at least 90° and be equipped with a device able to maintain them in an open position. In case where doors are horizontally hinged at the top the minimum opening angle should be 90°. Below ground-level prefabricated substations require an access hatch, providing adequate safety for personnel and the passer-by. It shall be possible for a single person to operate this hatch.

It shall be possible to secure the access hatch to prevent closure whilst operators are within the substation or working on the equipment from outside the substation.

5.104.5 Ventilation openings

Ventilation openings shall be so arranged or shielded that the same degree of protection (IP code) and the same degree of protection against mechanical impacts (IK code) as specified for the enclosure, or for the ventilated compartment including partitions, are maintained.

Such openings may make use of wire mesh or similar, provided that the IK level is maintained.

5.104.6 Partitions

The degree of protection of partitions, if any, shall be specified according to IEC 62271-1:2007 Table 7.

The degree of protection against mechanical impacts of partitions, if any, shall be specified according to IEC 62262:2002.

5.105 Other provisions

5.105.1 Provisions for dielectric tests on cables

Enough space and proper means of access shall be provided to the high-voltage connection compartments and/or cable test points of the high voltage switchgear and controlgear in order to perform safely dielectric tests on the cables.

5.105.2 Accessories

Adequate space should be provided for keeping accessories, for example, earthing devices, operating handles, etc.

5.105.3 Operation aisle

The width of an operation aisle inside a prefabricated substation shall be adequate for performing any operation or maintenance. The width of such an aisle shall be 800 mm or greater. Doors of switchgear and controlgear inside the prefabricated substation shall either close in the direction of the exit or rotate such that they shall not reduce the width of the aisle. Doors in any open fixed position or mechanical drives protruding from the switchgear and controlgear shall not reduce the width of the aisle to less than 500 mm.

5.105.4 Labels

Labels for warning, manufacturers' instructions, etc., and those according to local standards and regulations shall be durable and clearly legible.

5.106 Sound emission

The transformer(s) are the main source of sound. On the other hand there is no requirement in high voltage and low voltage switchgear and controlgear relevant standards on this matter and the direct contribution of the high voltage and low voltage components to the sound level of the substation is considered, in principle, negligible. However, if required, the determination of substation sound level is to be made according to IEC 60076-10:2001, on the complete substation to take into account any possible interaction between the high voltage and low voltage switchgear and the enclosure with the transformer (see Annex BB).

5.107 Electromagnetic fields

Prefabricated substations in service generate electromagnetic fields that may need assessment to:

- assist with planning, installation, operating instruction and service;
- take measures to meet requirements or regulations on electromagnetic fields.

If an evaluation of electromagnetic fields generated by a prefabricated substation is required the methodology described in IEC/TR 62271-208:2009 should be followed.

6 Type tests

6.1 General

Subclause 6.1 of IEC 62271-1:2007 is applicable with the following addition.

In principle, the type tests shall be made on a representative configuration of the components of a complete prefabricated substation. Components contained in a prefabricated substation shall be tested according to the relevant standards (refer to 1.2).

Because of the variety of types, ratings and possible combinations of components, it is not practical to make type tests with all the possible configurations of a prefabricated substation. The performance of any particular configuration may be substantiated by test data of comparable configurations.

Care shall be taken that none of the tested parameters of the substation are negatively affected.

The type tests and verifications comprise the following:

Mandatory type tests: Subclause

- a) tests to verify the insulation
level of the prefabricated substation 6.2
- b) tests to prove the temperature rise of the components contained in.....
a prefabricated substation 6.5
- c) tests to prove the capability of the main and earthing circuits to be subjected
to the rated peak and the rated short-time withstand currents.....6.6
- d) tests to verify the degree of protection.....6.7
- e) tests or calculations to verify the withstand of the enclosure of the prefabricated substation
against mechanical stress 6.101
- f) tests to verify the auxiliary and control circuits 6.10

Mandatory type tests, where applicable:

- g) Tests to assess the effects of arcing due to an internal arc fault (for prefabricated
substations class IAC-A IAC-B or IAC-AB).....6.102
- h) EMC compatibility tests 6.9

Optional type tests (subject to agreement between manufacturer and user):

- i) tests to verify the sound level of a prefabricated substation Annex BB
- j) Measurement or calculation of electromagnetic fields generated..... by a
prefabricated substation.....6.103

Type tests may impair the suitability of the tested parts for subsequent use in service. Therefore, specimens used for type test shall not be used in service without agreement between manufacturer and user.

6.1.1 Grouping of tests

Subclause 6.1.1 of IEC 62271-1:2007 is applicable with the following modifications.

The mandatory type tests (not including items f) and g) shall be carried out on a maximum of four test specimens.

6.1.2 Information for identification of specimens

Subclause 6.1.2 of IEC 62271-1:2007 is applicable.

6.1.3 Information to be included in type-test reports

Subclause 6.1.3 of IEC 62271-1:2007 is applicable with the following addition:

For the report regarding internal arc tests, refer to 6.102.6.

6.2 Dielectric tests

Since the high voltage switchgear, transformer(s) and low voltage switchgear contained in a prefabricated substation have been type-tested according to the relevant standards, this subclause applies only to the interconnection between the components when the installation conditions can affect their dielectric withstand. Therefore, the equipment to be subjected to dielectric tests is as follows:

- the interconnection between the high-voltage switchgear and the transformer;
- the interconnection between the transformer and the low-voltage switchgear.

6.2.1 Ambient air conditions during tests

Subclause 6.2.1 of IEC 62271-1:2007 is applicable.

6.2.2 Wet test procedure

Subclause 6.2.1 of IEC 62271-1:2007 is not applicable.

6.2.3 Conditions of switchgear and controlgear during dielectric tests

Subclause 6.2.3 of IEC 62271-1:2007 is not applicable. Refer instead to 6.2.101.

6.2.4 Criteria to pass the test

Subclause 6.2.4 of IEC 62271-1:2007 is applicable for the high voltage interconnection, with the following modification:

- the second paragraph of item a) that refers to wet test is not applicable.

6.2.5 Application of the test voltage and test conditions

Subclause 6.2.5 of IEC 62271-1:2007 is not applicable. Refer instead to 6.2.101.2.

6.2.6 Tests of switchgear and controlgear of $U_r \leq 245$ kV

Subclause 6.2.6 of IEC 62271-1:2007 is applicable for the high voltage interconnection with the following modifications.

The tests shall be performed with the applicable test voltages given in Table 1a or 1b of 4.2 of IEC 62271-1:2007. For test voltages to earth and between phases, columns (2) and (4) shall be used.

6.2.7 Tests of switchgear and controlgear of $U_r > 245$ kV

Subclause 6.2.7 of IEC 62271-1:2007 is not applicable.

6.2.8 Artificial pollution tests for outdoor insulators

Subclause 6.2.8 of IEC 62271-1:2007 is not applicable.

6.2.9 Partial discharge tests

Subclause 6.2.9 of IEC 62271-1:2007 is not applicable.

Some of the components used within the prefabricated substation can require by their relevant standards a partial discharge test.

6.2.10 Dielectric tests on auxiliary and control circuits.

Subclause 6.2.10 of IEC 62271-1:2007 is applicable.

6.2.11 Voltage test as condition check

Subclause 6.2.11 of IEC 62271-1:2007 is not applicable.

Additional subclauses:

6.2.101 Tests on the high-voltage interconnection

6.2.101.1 General conditions

The dielectric tests are not required when the high-voltage interconnection is made of high-voltage cables connected by type-tested earth-shielded connectors or by other types of terminations which have been type-tested on both the high-voltage switchgear and the transformer sides in the installation conditions of the prefabricated substation.

In all other cases, the interconnection shall be subjected to dielectric tests according to 6.2.101.2 to 6.2.101.4.

The tests may be carried out with the transformer replaced by a replica reproducing the field configuration of the transformer bushings.

For the tests, the high-voltage connection is connected to the test supply through the high-voltage switchgear. Only the switching devices that are in series in the supply circuit are closed. All other switching devices are open.

Voltage-limiting devices shall be disconnected during dielectric tests.

Secondary terminals of current transformers shall be short-circuited and connected to earth. Voltage transformers shall be disconnected.

6.2.101.2 Application of test voltage

6.2.101.2.1 On the high-voltage interconnections

The test voltages shall be applied connecting each phase conductor of the main circuit in turn to the high-voltage terminal of the test supply. All other conductors of the main circuit and the auxiliary circuits shall be connected to the earthing conductor of the frame, and to the earth terminal of the test supply.

Where non-earth-shielded high-voltage connections are used, the non-conductive material shall likewise withstand the test voltages specified in 6.2.101.4. The methods specified in IEC 60243-1 should be applied to the tests to meet the relevant requirements.

6.2.101.2.2 In the case of an enclosure of non-conductive material

The insulation between non-earth-shielded live parts of the interconnections between the high-voltage switchgear and controlgear and the transformer and the accessible surface of the enclosure shall withstand the test voltages specified in 6.2.101.3 and 6.2.101.4.

In order to check compliance, accessible surfaces of the enclosure made from insulation materials shall be covered on the accessible side with a circular or square metal foil having an area as large as possible, but not exceeding 100 cm², which shall be connected to earth.

The foil shall be placed in the most unfavourable situation for the test. In case of doubt about the most unfavourable situation, the test shall be repeated with different situations.

The insulation between the non-earth-shielded live parts of the interconnections between the high-voltage switchgear and controlgear and the transformer and the inner surface of insulating parts of the enclosure facing these shall withstand during 1 min at least 150 % of the rated voltage of the prefabricated substation.

In order to check compliance with this requirement, accessible surfaces of the enclosure made from non-conductive materials between the non-earth-shielded connections of the high-voltage switchgear to transformer and the inner surface of the non-conductive materials of the enclosure shall be subjected to a power-frequency test of 150 % of the rated voltage for 1 min after covering the inner surface of the non-conductive material facing the non-earth-shielded connection by a metal foil connected to earth.

The methods specified in IEC 60243-1 should be applied to the tests to meet the relevant requirements.

6.2.101.3 Lightning impulse-voltage tests

The high-voltage interconnection shall be subjected to lightning impulse-voltage tests according to 6.2.6.2 of IEC 62271-1:2007 with the following addition.

To obtain the correct wave shape during the test it can be necessary to disconnect the power transformer or use a mock up instead.

During the lightning impulse-voltage tests, the grounded terminal of the impulse generator shall be connected to the earthing conductor of the enclosure of the prefabricated substation.

6.2.101.4 Power-frequency voltage withstand tests

The high-voltage interconnection shall be subjected to 1 min power-frequency voltage withstand tests in dry conditions in accordance with 6.2.6.1 of IEC 62271-1:2007 with the following addition.

During the power-frequency voltage test, one terminal of the test transformer shall be connected to earth and to the earthing conductor of the prefabricated substation.

To avoid the saturation of the power transformer during the test it can be necessary to disconnect the power transformer or use a mock up instead.

6.2.102 Tests on low-voltage interconnection

6.2.102.1 General conditions

When the low-voltage interconnection is partially or totally covered by a non-metallic enclosure, the enclosure shall be covered by a circular or square metal foil having an area as large as possible, but not exceeding 100 cm² connected to the earth. The foil shall be applied to all surfaces that can be touched by an operator.

For the tests, the low-voltage interconnection is connected to the test supply through the low-voltage switchgear. Only the switching devices that are in series in the supply circuit are closed. All other switching devices are open.

6.2.102.2 Lightning impulse-voltage tests

The low-voltage interconnection shall be subjected to lightning impulse-voltage tests. The test voltage is specified in Table F.1 of IEC 60664-1:2007, where the rated impulse-voltage test is chosen in accordance with 4.2 of this standard.

Overvoltage suppressing means shall be disconnected or tests shall be made according to IEC 61180-1:1992.

The 1,2/50 μ s impulse voltage shall be applied three times for each polarity at intervals of 1 s minimum.

The test voltage shall be applied connecting each phase conductor of the main circuit in turn to the high-voltage terminal of the test supply. All other conductors of the main circuit and the auxiliary circuits shall be connected to the earthing conductor or the frame and to the earth terminal of the test supply.

There shall be no disruptive discharge during the tests.

To obtain the correct wave shape during the test it can be necessary to disconnect the power transformer or use a mock up instead.

6.2.102.3 Verification of creepage distances

The shortest creepage distances between phases, between circuit conductors at different voltages and live and exposed conductive parts shall be measured. The measured creepage distance with respect to material group and pollution degree shall comply with the requirements in Table F.2 of IEC 60664-1:2007.

6.3 Radio interference voltage (r.i.v.) test

Subclause 6.3 of IEC 62271-1:2007 is not applicable.

6.4 Measurement of the resistance of circuits

Subclause 6.4 of IEC 62271-1:2007 is not applicable to the complete prefabricated substation.

6.5 Temperature-rise tests

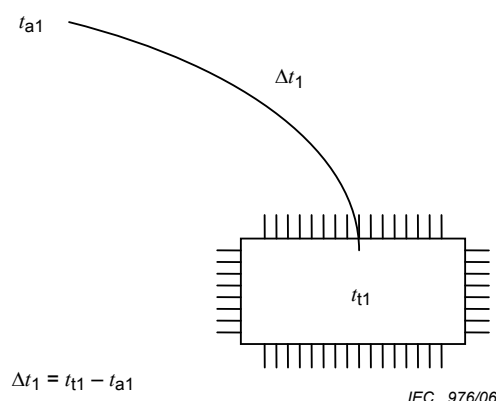
Subclause 6.5 of IEC 62271-1:2007 is not applicable.

Replacement:

6.5.101 General

The purpose of this test is to check that the design of prefabricated substation enclosure operates correctly and does not impair the life expectancy of the substation components. Their life expectancy will not be influenced if the acceptable limits of deterioration of insulation through thermal effects are not exceeded. Depending on the results of the temperature-rise test de-rating of the components may be necessary.

In particular, the test shall demonstrate that the temperature rises of the transformer inside the enclosure do not exceed those measured on the same transformer outside the enclosure by more than the value which defines the class of enclosure, for example, 5 K, 10 K, 15 K, 20 K, 25 K or 30 K. Refer to Figures 101 and 102.

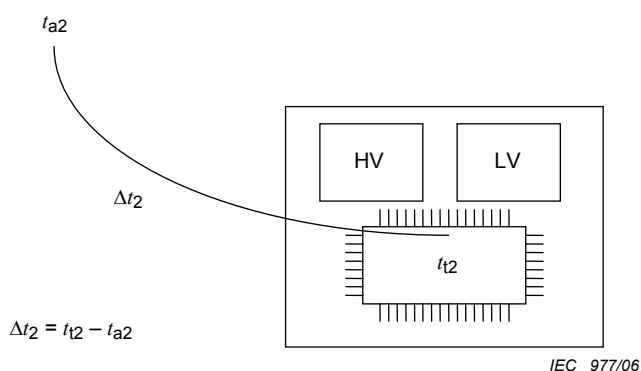
**Key**

t_{a1} ambient air temperature of the test room

t_{t1} transformer temperatures measured according to IEC 60076-2:2011 and IEC 60076-11:2004

Δt_1 temperature rise of the transformer outside an enclosure

Figure 101 – Measurement of transformer temperature rise in ambient air: Δt_1

**Key**

t_{a2} ambient air temperature of the test room

t_{t2} transformer temperatures measured according to IEC 60076-2:2011 and IEC 60076-11:2004

Δt_2 temperature rise of the transformer inside an enclosure

Figure 102 – Measurement of transformer temperature rise in an enclosure: Δt_2

6.5.102 Test conditions

The enclosure shall be complete with its components positioned as designed for service. The doors shall be closed and cable access points sealed to represent service conditions. The power and losses of the transformer should be those corresponding to the rated maximum power of the prefabricated substation, as defined in 4.101.1.

Transformer, high voltage and low voltage interconnections, and low-voltage equipment temperature-rise tests will be performed simultaneously.

The temperature-rise test of the high voltage switchgear is not required.

NOTE 1 It is a common practice that the high voltage switchgear operates at much lower current (load) than its rated one. Taking this into account, the additional increase of temperature caused by operating inside the

substation enclosure in most cases has no relevant influence on the required current capability of the high voltage switchgear.

The test will be executed in a room whose dimension, insulation or air condition will keep the ambient air temperature of the room within the ambient limits specified in 6.5.104.1.

The environment shall be substantially free from air currents, except those generated by heat from the equipment under test. In practice, this condition is reached when the air velocity does not exceed 0,5 m/s.

NOTE 2 In the case of an underground prefabricated substation, the test can be performed above ground. Experience has proven that the difference in temperature rise is not significant compared to underground.

6.5.103 Test methods

6.5.103.1 General

Two situations can be considered, depending of the type of transformers installed in the substation:

- liquid-filled transformers;
- dry-type transformers.

6.5.103.2 Liquid filled transformers

6.5.103.2.1 General

If the substation is equipped with liquid filled transformers two test methods can be used to carry out the temperature-rise tests.

The preferred one requires the use of independent sources of current to supply the high voltage and the low voltage sides of the substation.

An alternative method can be used if the laboratory can provide only one source of current or the design of the substation makes the connection arrangements of the two sources of current impossible.

6.5.103.2.2 Preferred method

6.5.103.2.2.1 General

This method requires different connections of supply for the high voltage and the low voltage sides respectively.

6.5.103.2.2.2 Connection of supplies

In the following the connexion of supplies are explained.

a) High-voltage side.

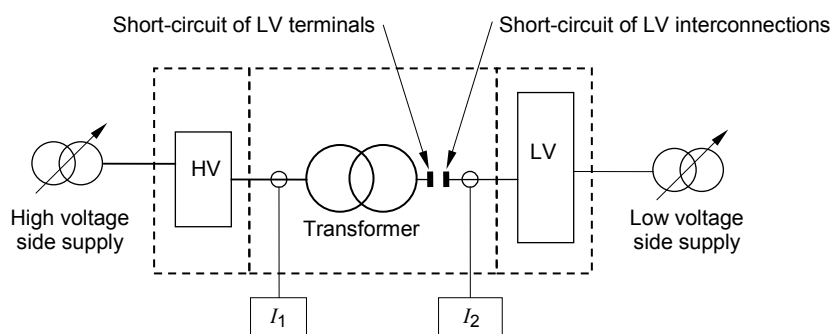
The transformer and high voltage switchgear with its tee-off (fuses with correct rating or circuit-breaker) shall be connected and the low-voltage outgoing terminals of the transformer shall be short-circuited. The supply shall be connected to the incoming high-voltage switchgear terminals. Refer to Figure 103.

b) Low-voltage side.

The temperature-rise test on the low-voltage side shall be carried out in accordance with 10.10 of IEC 61439-1:2011 and the following specific requirements.

The low-voltage switchgear shall be isolated from the transformer, at a convenient point as close as practicable to the transformer terminals. At this point adjacent to the transformer terminals, a short-circuit shall be applied to the connections between the

transformer and the low-voltage switchgear. Test current shall be applied to the low-voltage switchgear via the outgoing feeders.



IEC 0939/14

Key

I_1 sufficient current to generate the total rated losses of liquid filled transformers or high voltage rated current for dry type transformers

I_2 low voltage rated current of the transformer

Figure 103 – Diagram of the preferred temperature-rise test method

6.5.103.2.2.3 Application of test currents

a) High-voltage side.

The transformer circuit is supplied with sufficient current to generate the total rated losses of the transformer, at its reference temperature, using the method defined in IEC 60076-2:2011.

This test will require a small percentage of current above the rated current flowing through the complete circuit so as to compensate for the transformer no-load losses.

NOTE During test, the resistance will vary according to the temperature of the transformer. Thus, the test supply current is varied accordingly to maintain the generated losses constant and equal to the total transformer losses throughout the test.

b) Low-voltage side.

The low-voltage circuit is supplied with the rated low-voltage current of the tested transformer.

The distribution of this supply current at the low voltage outgoing feeders shall be chosen to be the worst case in respect of heat generation.

In case outgoing feeders are equipped with fuses, these fuses shall be present during test and shall represent the service conditions.

6.5.103.2.3 Alternative method

6.5.103.2.3.1 General

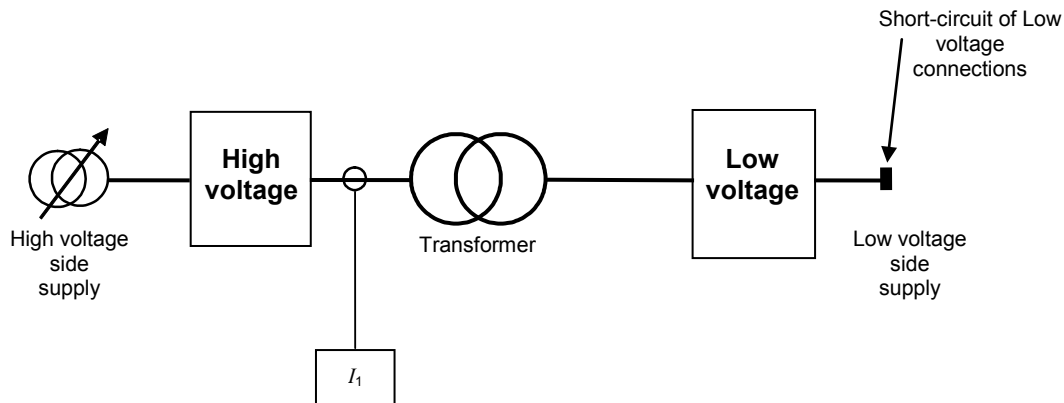
This method requires one single supply of current.

6.5.103.2.3.2 Connection of supplies

The high voltage switchgear and controlgear, the high voltage/low voltage power transformer and the low voltage switchgear and controlgear shall be connected. The outgoing terminals of the low voltage switchgear and controlgear shall be short-circuited. The supply shall be connected to the incoming terminals of the high voltage switchgear and controlgear (see Figure 104).

6.5.103.2.3.3 Application of test currents

The substation is supplied with sufficient current to generate the total rated losses of liquid filled transformers, at its reference temperature, using the method defined in the relevant product standard.



IEC 0940/14

Key

I_1 sufficient current to generate the total rated losses of liquid filled transformer high voltage or rated current for dry type transformers

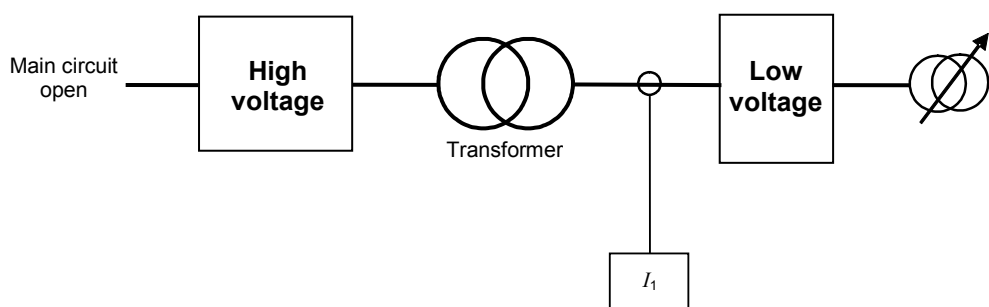
Figure 104 – Diagram of the alternative temperature-rise test method

6.5.103.3 Dry-type transformers

For a temperature-rise test on a prefabricated substation equipped with a dry-type transformers the method for the temperature-rise test should follow the simulated load method as described in IEC 60076-11:2004 consisting of two consecutive steps.

Step 1:

The rated operating voltage (three-phase) at rated frequency is applied to the low-voltage winding of the transformer via one of the outgoing feeders of the low voltage switchgear. The high-voltage winding is connected to the high voltage switchgear. High voltage main circuit is open (see Figure 105). After thermal equilibrium has been reached of the windings and magnetic core individual winding temperature-rises of the transformer shall then be measured.



IEC 0941/14

Key I_1 no load current of the transformer**Figure 105 – Diagram for open-circuit test****Step 2:**

The connection of supplies is made according to 6.5.103.2.2.2 (Figure 103) or 6.5.103.2.3.3 (Figure 104).

The high voltage side of the prefabricated substation is supplied with the high voltage rated current of the high voltage/low voltage power transformer. The low voltage side of the substation is supplied with the low voltage rated current of the high voltage/low voltage power transformer.

When the steady-state condition of the windings and magnetic core is obtained, the temperature rises of the individual windings are measured together with the temperature rises of the low voltage switchgear and the interconnections.

After completion of the two steps above the temperature rise is calculated by the formula given in 23.2.1 of IEC 60076-11:2004.

6.5.104 Measurements**6.5.104.1 Measurement ambient air temperature**

The ambient air temperature is the average temperature of the air surrounding the prefabricated substation (for an enclosed substation, it is the air outside the enclosure). It shall be measured during the last quarter of the test period by means of at least four thermometers, thermocouples or other temperature-detecting devices equally distributed around the prefabricated substation at about the average height of its current-carrying parts and at a distance of about 1 m from the prefabricated substation. In case of underground substations, these devices shall be placed at the middle-height of the ventilation openings. The thermometers or thermocouples shall be protected against air currents and undue influence of heat. In order to avoid indication errors because of rapid temperature changes, the thermometers or thermocouples may be put into small bottles containing about half a litre of oil.

During the last quarter of the test period, the change of ambient air temperature shall not exceed 1 K in 1 h. If this is not possible because of unfavourable temperature conditions in the test room, the temperature of an identical prefabricated substation under the same conditions, but without current, can be taken as a substitute for the ambient air temperature. This additional prefabricated substation shall not be subjected to an undue amount of heat.

The ambient air temperature during tests shall be more than +10 °C but less than +40 °C. No correction of the temperature-rise values shall be made for ambient air temperatures within this range.

6.5.104.2 Transformer

The top oil temperature rise for liquid-filled transformers shall be measured as given in IEC 60076-2:2011. The average winding temperature rises for dry-type transformers shall be measured as given in IEC 60076-11:2004. (See 6.5.103.3).

6.5.104.3 Low voltage switchgear

The low-voltage switchgear and controlgear temperature rises shall be measured as given in 10.10 of IEC 61439-1:2011.

It is not necessary to repeat the temperature-rise test, when other configurations, different from the tested one, are used, unless the losses in the low voltage side are higher than in the tested configuration, or there are indications that the new low voltage switchgear itself may not perform within the specified temperature limits.

The temperature and temperature rise of the low voltage interconnections and their terminals shall be measured.

The air temperature in the location where electronic equipment may be installed shall be measured.

6.5.104.4 High voltage switchgear

The temperature and temperature rise of the high voltage interconnections and their terminals shall be measured.

The air temperature in the location where electronic devices may be installed shall be measured.

6.5.105 Acceptance criteria

The prefabricated substation shall be deemed to have passed the temperature-rise test if:

- a) the transformer temperature rises do not exceed the corresponding temperature rises measured on the same transformer without an enclosure by more than the temperature class of the prefabricated substation (see Figures 101 and 102);

Acceptance criteria:

$$\Delta t = \Delta t_2 - \Delta t_1$$

Class 5 : $\Delta t \leq 5 \text{ K}$

Class 20: $\Delta t \leq 20 \text{ K}$

Class 10: $\Delta t \leq 10 \text{ K}$

Class 25: $\Delta t \leq 25 \text{ K}$

Class 15: $\Delta t \leq 15 \text{ K}$

Class 30: $\Delta t \leq 30 \text{ K}$

NOTE The temperature rise test can be used to determine the class of enclosure as long as criteria b, c and d are fulfilled

- b) the temperature rises and temperatures of the terminals of the high-voltage interconnections do not exceed the requirements of 6.5.6 of IEC 62271-1:2007;
- c) the temperature rises and temperatures of low-voltage interconnections and low-voltage switchgear do not exceed the requirements of 9.2 of IEC 61439-1:2011;
- d) the temperature rises and temperatures of the substation enclosure do not exceed the requirements of IEC 62271-1:2007 for accessible parts expected to be touched in normal operation (see Table 3 of IEC 62271-1:2007).

6.6 Short-time withstand current and peak withstand current tests

Since the high voltage switchgear, transformer(s) and low voltage switchgear contained in a prefabricated substation have been type-tested according to the relevant standards, this clause applies only to the high voltage and low voltage interconnections.

Type tested high voltage and low voltage interconnections do not need to be tested unless the installation conditions can affect the short circuit withstand performance.

Non type tested high voltage interconnections shall be tested following the procedure described in 6.6 of IEC 62271-1:2007 with the addition of the following paragraphs.

The test currents will be applied in such a manner that the complete high voltage connection to the transformer is tested. All parts supporting the interconnection shall be maintained in place, as in service condition, during the test. The test can be performed feeding the interconnection through the high voltage switchgear.

In particular, when the high voltage interconnection is protected by current-limiting devices situated in the high voltage switchgear, provisions of 6.6 a) of IEC 62271-200:2011 are applicable.

Non type-tested low voltage interconnections shall be tested following the procedure described in IEC 61439-1:2011 for low voltage switchgear. The test currents will be applied in such a manner that the complete connection to the transformer is tested. All parts supporting the interconnection shall be maintained in place, as in service condition, during the test.

The earthing conductor system of the prefabricated substation shall be tested according to 6.6 of IEC 62271-1:2007. It is not required to repeat the type tests on the main earthing circuits of individually type-tested components.

After the test, some deformation of the main earthing conductor and of the connections to the components is permissible, but the continuity of the circuit shall be preserved.

Generally, no test of the connections of metallic covers and doors to the main earthing conductor is required, if adequate design is demonstrated. However, in case of doubt, they shall be tested at 30 A (d.c.). The voltage drop shall be lower than 3 V.

6.7 Verification of the protection

Subclause 6.7 of IEC 62271-1:2007 is applicable.

6.8 Tightness tests

Subclause 6.8 of IEC 62271-1:2007 is not applicable to the substation assembly.

6.9 Electromagnetic compatibility tests (EMC)

For high voltage switchgear and controlgear, 6.9 of IEC 62271-1:2007 is applicable, with the exception of the radio interference voltage test.

For low voltage switchgear and controlgear, 10.12 of IEC 61439-1:2011 is applicable.

A test on a complete substation is not necessary provided that the high voltage switchgear and low voltage switchgear have been tested according to the relevant standards.

6.10 Additional tests on auxiliary and control circuits

6.10.1 General

Subclause 6.10.1 of IEC 62271-1:2007 is applicable.

6.10.2 Functional tests

Subclause 6.10.2 of IEC 62271-1:2007 is not applicable:

A functional test of all low-voltage circuits shall be made to verify the proper functioning of auxiliary and control circuits in conjunction with the other parts of the prefabricated substation.

The tests shall be performed with the upper and lower value limits of the supply voltage defined in 4.8.

For low-voltage circuits, sub-assemblies and components, functional tests can be omitted if they have been fully performed during a test applied to similar prefabricated substation.

6.10.3 Electrical continuity of earthed metallic parts test

Subclause 6.10.3 of IEC 62271-1:2007 is applicable.

6.10.4 Verification of the operational characteristics of auxiliary contacts

Subclause 6.10.4 of IEC 62271-1:2007 is applicable.

6.10.5 Environmental tests

Subclause 6.10.5 of IEC 62271-1:2007 is applicable with the following limitations:

- tests do not apply for indoor switchgear and controlgear operated under normal service conditions as defined by Clause 2 of IEC 62271-1:2007;
- when the tests as stated in 6.10.5 of IEC 62271-1:2007 have been performed on the separate components of a representative auxiliary and control circuit, no further environmental tests are needed;
- when tests are performed, 6.10.5 of IEC 62271-1:2007 is applicable on a typical layout of the auxiliary and control circuits.

6.10.6 Dielectric test

Subclause 6.10.6 of IEC 62271-1:2007 is applicable.

6.11 X-radiation test procedures for vacuum interrupters

Subclause 6.11 of IEC 62271-1:2007 is not applicable to the prefabricated substation.

Additional subclauses:

6.101 Calculations and mechanical tests

6.101.1 Wind pressure

The mechanical effects of the wind pressure on the prefabricated substation may be verified by calculation. Refer to 5.101

6.101.2 Roof loads

The mechanical effects of loads on the roof of the prefabricated substation may be verified by calculation. Refer to 5.101

6.101.3 Mechanical impacts

Mechanical impact tests shall be performed on external places of the enclosure that are likely to be weak, for example, doors, covers and ventilation openings. Refer to Annex CC for the test procedure. Refer to 5.101

6.102 Internal arc test

6.102.1 General

These tests are applicable to prefabricated substations, intended to be qualified as class IAC-A or IAC-B or IAC-AB with respect to protection of persons in the event of an internal arc at high voltage side.

These tests cover the cases of faults resulting in an arc occurring inside the prefabricated substation in the high voltage switchgear and the high voltage interconnections with all doors closed (IAC-B) or with the door(s) used to give access to the high voltage switchgear open (IAC-A) (see 4.102).

This classification is intended to offer a tested level of protection in the event of internal arcs to personnel operating the substation in normal operating conditions and with its high voltage switchgear and controlgear in normal service position, as defined in the relevant standard (Class IAC-A) and to persons in the vicinity of the substation with its doors closed (Class IAC-B).

NOTE This standard covers only internal arcs occurring in the high voltage side of the substation, including high voltage interconnections (for example, between high voltage switchgear and power transformers).

Internal arcs within the transformers or the low voltage switchgear are not taken into account (see 5.103 for explanation of this exclusion).

Internal arcs inside the substation can occur in a number of locations and can cause various physical phenomena. For example, the energy resulting from an arc developed in the open air within the substation or in any insulating fluid within the enclosure of the high voltage switchgear will cause an internal overpressure and local overheating which will result in mechanical and thermal stressing of the enclosure of the substation. Moreover, the materials involved may produce hot decomposition products, either gaseous or vaporous, which may be discharged within the substation and later to the outside of it.

The internal arcing class IAC makes allowance for internal overpressure acting on covers, doors, floor(s), etc. It also takes into consideration the thermal effects of the arc or its roots on the enclosure and of ejected hot gases and glowing particles, but not damage to internal partition and shutters not being accessible in normal operating conditions.

The internal arc tests described below are intended to verify the effectiveness of the design in protecting persons in case of an internal arc. It does not cover all the effects that may constitute a hazard, such as the presence of gases with potential toxic characteristics that can be present after the fault.

The hazard of the propagation of fire after an internal arc to combustible materials or equipment placed in the proximity of the substation is not covered by this test.

6.102.2 Test conditions

To be qualified as class IAC-A or IAC-B, a substation shall be subjected to a test series on the high voltage switchgear and, if applicable, on the high voltage interconnection. To be

qualified as class IAC-AB, the substation shall be subjected to the test series for IAC-A and IAC-B.

For required tests, see Figures AA.4, AA.5, AA.6 and AA.7, showing the principles for the selection of tests and the corresponding number and type of tests to be performed.

Any device (e.g. protection relay with arc light detection or device transferring the current to a metallic short circuit) that may automatically trip the circuit before the end of the prospective duration of the test shall be made inoperative during the test. If these devices are integral part of the substation which prevents to make them inoperative without modification of the construction, the substation may be tested with the device operative; but the substation shall be qualified according to the actual duration of the arc. The test current shall be maintained for the rated short-circuit duration of the main circuit.

In the case of prefabricated substations without high voltage switchgear and having incoming high voltage cables directly connected to the bushings of the transformer, testing shall be carried out as follows:

- a three-phase test in the case of connections non insulated or fitted with site-made solid insulation;
- a single or two-phase test in the case of plug in insulated connections. For phase to ground test the current value to be stated by the manufacturer. For two-phase test current will be 87% of the rated short time withstand current.

In the case where open-air fuse-bases devices are used instead of high voltage switchgear, a three-phase test shall be performed at the feeding side of the fuse-bases.

6.102.3 Arrangement of the equipment

The following points shall be observed:

- tests shall be carried out on a prefabricated substation or representative part of it not previously subjected to arcing, or, if subjected, being in a condition which does not affect the result of the test;
- the substation shall be fully equipped. Mock-ups of internal components are permitted provided they have the same volume and external material as the original components;
- the substation shall be connected to earth at the point provided.

6.102.4 Test procedure

The method to verify the internal arc classification is defined in AA.6.

6.102.5 Criteria to pass the test

6.102.5.1 Prefabricated substation Class IAC-A

A substation is qualified as class IAC-A provided that:

- the five criteria as in 6.106.5 of IEC 62271-200:2011 have been met after every internal arc test on the high voltage switchgear, listed in Figure AA.4;

NOTE 1 Where the design of the substation includes a space below the floor to receive the exhausting gases, the behaviour of the floor is assessed from the point of view of the safety of the operator standing on it.

- where applicable (see Figure AA.6), the following criteria have been met after test on the high voltage interconnections.

Criterion no.1 Barriers, obstacles or enclosures of the high voltage interconnection, if any, are not moved or deformed further than the position of the indicators.

Criterion no.2 No material projections of an individual mass above 60 g.

NOTE 2 The value of 60 g is taken to follow IEC 62271-200:2011. In case of modification of IEC 62271-200:2011 in this respect, this standard adopts the new value.

Criterion no.3 Arcing does not cause holes in the accessible side of the envelope or protective screen, if any, of the high voltage interconnection.

Criterion no.4 Indicators do not ignite due to the effect of flames or hot gases.

If indicators have been ignited, the assessment criterion may be regarded as having been met, if proof is established of the fact that the ignition was caused by glowing particles rather than hot gases. Pictures taken by high-speed cameras, video or any other suitable means can be used by the test laboratory to establish evidence.

Indicators ignited as a result of paint or stickers burning are also excluded.

Criterion no.5 If the high voltage interconnection is protected by an enclosure connected to earth, this enclosure remains connected to its earthing point.

6.102.5.2 Prefabricated substation Class IAC-B

A substation is qualified as class IAC-B provided the following criteria have been met after the test listed in Figures AA.5 for the high voltage switchgear and AA.7, where applicable, for the high voltage interconnections.

Criterion No.1 Correctly secured doors and covers of the substation do not open. Deformations are accepted, provided that no part comes as far as the position of the indicators in every side. The substation needs not to comply with its IP code after the test.

Criterion No.2 No fragmentation of the enclosure occurs within the time specified for the test.

No material projections of an individual mass of 60 g or more occur.

NOTE The value of 60 g is taken to follow IEC 62271-200:2011. In case of modification of IEC 62271-200:2011 in this respect, this standard adopts the new value.

Criterion No.3 Arcing does not cause holes in the declared accessible faces of the enclosure from the floor level up to a height of 2 m.

Criterion No.4 Indicators do not ignite due to the effect of hot gases or burning liquids.

Should they start to burn during the test, the assessment criterion may be regarded as having been met, if proof is established of the fact that glowing particles rather than hot gases caused the ignition. Pictures taken by high-speed cameras, video or any other suitable means can be used by the test laboratory to establish evidence.

Indicators ignited as a result of paint or stickers burning are also excluded.

Criterion No.5 The enclosure remains connected to its earthing point. Visual inspection is generally sufficient to assess compliance. In case of doubt, the continuity of the earthing connection shall be checked.

6.102.5.3 Prefabricated substation Class IAC-AB

Substations which meet the requirements according to 6.102.5.1 and 6.102.5.2 are qualified as class IAC-AB.

6.102.6 Test report

The following information shall be given in the test report.

- rating and description of the substation with a drawing showing the main dimensions, details relevant to the mechanical strength, the arrangement of the pressure-relief flaps and the method of fixing the metal-enclosed switchgear and controlgear to the floor and/or to the walls;
- arrangement of the test connections;
- point and method of initiation of the internal arc;
- drawings of test arrangement (test specimen and mounting frame of indicators);
- applied voltage and frequency;
- for the prospective or test current:
 - a) r.m.s. value of the a.c. component during the first three half-cycles;
 - b) highest peak value;
 - c) average value of the a.c. component over the actual duration of the test;
 - d) test duration;
- oscillogram(s) showing currents and voltages;
- assessment of the test results, including a record of the observations in accordance with 6.102.4;
- photographs of the specimen under test, before and after test;
- other relevant remarks;
- arrangement of pressure relief ducts and space below the floor if used to exhaust gases.

6.102.7 Transferability of tests results

The validity of the results of a test carried out in a particular prefabricated substation design or representative part of it can be extended to another one (refer to 6.1) equipped with the same type of high voltage switchgear and controlgear (refer to 6.106.7 of IEC 62271-200:2011), provided that the original test was more onerous and the latter design can be considered as similar to the one tested in all the following respects:

- arc current and arcing time;
- directions of gas flow from the internal arc;
- dimensions and layout of the prefabricated substation;
- structure and strength of the enclosure, floor and partitions, if any;
- ventilation grids;
- performance of the pressure release device, if any.

6.103 Measurement or calculation of electromagnetic fields

General guidance regarding the measurement or calculation of electromagnetic fields in high voltage/low voltage prefabricated substations are given in IEC/TR 62271-208:2009.

7 Routine tests

Clause 7 of IEC 62271-1:2007 is not applicable to the prefabricated substation.

The routine tests shall be made on each complete prefabricated substation or on each transport unit and, whenever practicable, at the manufacturer's factory to ensure that the product is in accordance with the equipment on which the type test has been carried out.

Each component shall be previously routine tested in accordance with their component standard, and for the assembly the following routine tests and verifications apply: