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INTERNATIONAL STANDARD

NORME INTERNATIONALE

High-voltage switchgear and controlgear – Part 211: Direct connection between power transformers and gas-insulated metal-enclosed switchgear for rated voltages above 52 kV

Appareillage à haute tension – Partie 211: Raccordements directs entre transformateurs de puissance et appareillage sous enveloppe métallique à isolation gazeuse de tensions assignées supérieures à 52 kV

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

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

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 211: Direct connection between power transformers and gas-insulated metal-enclosed switchgear for rated voltages above 52 kV

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International Standard IEC 62271-211 has been prepared by subcommittee 17C: High-voltage switchgear and controlgear assemblies, of IEC technical committee 17: Switchgear and controlgear.

This first edition cancels and replaces the first edition of IEC/TR 61639:1996 and constitutes a technical revision.

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

a) transfer from technical report to international standard;
b) the minimum voltage rating was changed from 72,5 kV to above 52 kV;
c) update of normative references;
d) definition of insulated junction including limit of supply;

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e) definition of dielectric test of gas-insulated metal-enclosed switchgear for transformer connection in a three phase enclosure;

f) addition of interface tolerances at transformer side;

g) addition of transformer tolerances in service;

h) addition of exceptional loads for bushings and flanges;

i) consideration of oil- and gas-insulated transformers;

j) inclusion of three-phase enclosed direct connections.

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

FDIS	Report on voting
17C/596/FDIS	17C/600/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.

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

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

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

The contents of the corrigendum 1 of August 2015 and corrigendum 2 of August 2017 have been included in this copy.

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HIGH-VOLTAGE SWITCHGEAR AND CONTROLGEAR –

Part 211: Direct connection between power transformers and gas-insulated metal-enclosed switchgear for rated voltages above 52 kV

1 General

1.1 Scope

This part of IEC 62271 is applicable to single and three phase direct connections between gas-insulated metal-enclosed switchgear (GIS) for rated voltages above 52 kV and transformer arrangements to establish electrical and mechanical interchange ability and to determine the limits of supply of for the transformer connection.

Direct connections are immersed on one end in the transformer oil or insulating gas and on the other end in the insulating gas of the switchgear.

Transformer arrangements are single-phase transformers with single-phase enclosed arrangement, three-phase transformers with three single-phase enclosed arrangements or three-phase transformers with a three-phase enclosed arrangement with three transformer bushings.

The connection satisfies the requirements of IEC 62271-203 for gas-insulated metal-enclosed switchgear, IEC 60076 for power transformer and IEC 60137 for completely immersed bushings.

For the purpose of this international standard the term "switchgear" is used for "gas-insulated metal-enclosed switchgear".

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 60076 (all parts), *Power transformers*

IEC 60137:2008, *Insulated bushings for alternating voltages above 1 000 V*

IEC 61936-1, *Power installations exceeding 1 kV a.c. – Part 1: Common rules*

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

IEC 62271-203:2011, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV*

IEC 62271-207, *High-voltage switchgear and controlgear – Part 207: Seismic qualification for gas-insulated switchgear assemblies for rated voltages above 52 kV*

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2 Normal and special service conditions

2.1 Normal service conditions

Subclauses 2.1 of IEC 62271-1:2007 and IEC 62271-203:2011 are applicable.

2.2 Special service conditions

Subclauses 2.2 of IEC 62271-1:2007 and IEC 62271-203:2011 are applicable.

3 Terms and definitions

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

3.1
bushing
device that enables a conductor to pass through a transformer tank, and insulates the conductor from it

Note 1 to entry: The means of attachment (flange or fixing device) to the tank forms part of the bushing.

[SOURCE: IEC 60050-471:2007, 471-02-01, modified – update of the definition]

3.2
completely immersed bushing
a bushing both ends of which are intended to be immersed in an insulating medium other than ambient air (e.g. oil or gas)

[SOURCE: IEC 60050-471:2007, 471-02-04]

3.3
gas-insulated switchgear enclosure
part of gas-insulated metal-enclosed switchgear retaining the insulating gas under the prescribed conditions necessary to maintain safely the highest insulation level, protecting the equipment against external influences and providing a high degree of protection to personnel

[SOURCE: 3.103 of IEC 62271-203:2011]

3.4
main circuit end terminal
part of the main circuit of a gas-insulated metal enclosed switchgear forming part of the connection interface

[SOURCE: 3.2 of IEC 62271-209:2007]

3.5
transformer connection enclosure
part of the gas-insulated metal-enclosed switchgear which houses one end of a completely immersed bushing fitted on a power transformer and a main circuit end terminal

3.6
maximum operating gas pressure
maximum pressure of the gaseous insulating medium in which one end of the bushing is immersed, when in operation, the switchgear-power transformer connection assembly carrying its rated normal current at the maximum ambient air temperature

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3.7
design pressure of the enclosure
relative pressure used to determine the design of the enclosure

Note 1 to entry: It is at least equal to the maximum operating gas pressure in the enclosure at the highest temperature that the gas used for insulation can reach under specified maximum service conditions

[SOURCE: 3.113 of IEC 62271-203:2011, modified – update of the note to entry]

3.8
rated filling pressure p_{re} of gas for insulation
pressure (in Pa), for insulation, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa, which may be expressed in relative or absolute terms, to which the assembly is filled before being put into service

[SOURCE: 3.6.5.1 of IEC 62271-1:2007, modified – update of the term and the definition]

3.9
minimum functional pressure p_{me} for insulation
pressure (in Pa), for insulation, referred to the standard atmospheric air conditions of +20 °C and 101,3 kPa, which may be expressed in relative or absolute terms at which and above which the characteristics of the switchgear-power-transformer connection are maintained and at which replenishment becomes necessary

[SOURCE: 3.6.5.5 of IEC 62271-1:2007, modified – update of the term and the definition]

3.10
insulated junction
all parts which are needed to insulate the transformer from the switchgear including but not limited to the insulating flange

3.11
proctor density
moisture-density relationship of a soil for a given compactive effort depending on the amount of water the soil contains during soil compaction of controlled magnitude

4 Rating

4.1 Rated voltage (U_r)

The rated voltage shall be the rated voltage of the switchgear, selected from the following standard values:

72,5 kV – 100 kV – 123 kV – 145 kV – 170 kV – 245 kV – 300 kV – 362 kV – 420 kV – 550 kV

NOTE Values 800 kV and higher are not considered because there is little experience at this time.

4.2 Rated insulation level

The rated insulation level for the GIS part in the transformer connection enclosure shall be selected from the values given in the product standard IEC 62271-203. The rated insulation level for the transformer bushing shall be selected from the values given in the product standard IEC 60137.

NOTE Transformers can be tested at other insulation level values, according to the relevant standard.

The rated insulation level for a direct connection has to fulfil at least the requirements of IEC 62271-203.

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4.3 Rated frequency (f_r)

Subclause 4.3 of IEC 62271-1:2007 applies.

4.4 Rated continuous current (I_r) and temperature rise

The dimensions of the connection interfaces shown in Figure 2 allow a maximum value of 3 150 A for the rated continuous current. The connection interface is shown in Figure 1 as parts 3 and 4.

The contact surfaces of the connection interface shall be silver-coated, copper-coated or bare copper.

For the rated continuous current, the connection between switchgear and power transformer shall be designed that the temperature of the transformer connection enclosure and the temperature of the connection interface do not exceed the values given in 4.4.2 of IEC 62271-203:2011.

4.5 Rated short-time withstand current (I_k) and rated thermal short-time current (I_{th})

For the rated short-time withstand current of the GIS part of the transformer connection 4.5 of IEC 62271-1:2007 is applicable and for the rated thermal short-time current of the bushing 4.3 of IEC 60137:2008.

It is recommended to apply the same short-time currents for GIS and bushing.

4.6 Rated peak withstand current (I_p) and rated dynamic current (I_d)

For the rated peak withstand current of the GIS part of the transformer connection 4.6 of IEC 62271-1:2007 is applicable and for the rated dynamic current of the bushing 4.4 of IEC 60137:2008.

It is recommended to apply the same value for the rated peak withstand current for the GIS and the rated dynamic current for the bushing.

4.7 Rated duration of short-circuit (t_k) and rated duration (t_{th})

For the rated duration of the short-circuit current of the GIS part of the transformer connection 4.7 of IEC 62271-1:2007 is applicable and for the rated duration of the bushing 4.3 of IEC 60137:2008.

It is recommended to apply the same value for the rated duration of short circuit for the GIS and the rated duration for the bushing.

4.8 Rated filling pressure p_{re} of gas for insulation

The rated filling pressure p_{re} (or density) of gas for insulating is assigned by the switchgear manufacturer.

If SF_6 is used as the insulating gas, the minimum functional pressure for insulation p_{me}, used to determine the design of the transformer bushing insulation, shall be not more than 0,35 MPa (absolute) at 20 °C.

For higher rated lightning impulse withstand voltage (BIL) the minimum functional pressure may be increased.

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If a gas different from SF_6 or a gas mixture is used, the minimum functional pressure shall be chosen to provide the same dielectric strength. The minimum functional pressure shall be below the maximum operating pressure and design pressure of the enclosure.

5 Design and construction

5.1 Limits of supply

A typical direct connection is shown in Figure 1.

The limits of supply of the switchgear manufacturer and transformer manufacturer shall be according to Figure 1.

To minimize circulating currents between the switchgear and the transformer, bonding connections according to IEC 61936-1 shall be provided by the switchgear manufacturer between the different single phase switchgear enclosures; capable of carrying continuously the rated current of the transformer in normal operation. If circulating currents higher than 250 A are expected via the single-phase transformer connection enclosure, an insulated junction between the GIS and the transformer is necessary, see Figure 1 Part 9.This applies to the direct connection of three-phase and single-phase power transformers according IEC 60076 series.

NOTE 1 The tank of a transformer is not designed to carry any considerable, undefined continuous circulating currents. Practical experiences have shown that a load current of up to 1 250 A can be carried without additional precautions in the enclosure of the interface between the GIS and the transformer. This is due to the fact that approximately 80 % of the load current is carried by the bonding connection of the switchgear, to be installed preferably at the end of the switchgear enclosure at the transformer. Thus, approximately 20 % of the load current, therefore up to 250 A, could generate continuous circulating currents in the transformer enclosure. The confirmation of the current value in the bonding connection and through the transformer enclosure can be made by calculation.

NOTE 2 The user clarifies with the transformer manufacturer to confirm the maximum acceptable current via the transformer encapsulation to avoid the insulated junction, if possible.

An insulated junction may be also needed to achieve isolation between the transformer tank and the neighbouring earthed switchgear enclosures, and to achieve correct operation of the user's protection schemes for GIS and transformer faults.

The insulation level across the insulated junction shall be designed to withstand a power-frequency test voltage of 5 kV, r.m.s., for 1 min.

To limit the very-fast-front transient ground potential rises which may occur when a switching device operates, non-linear resistors may be connected in parallel with the insulated junction. The number and the characteristics of the non-linear resistors shall be determined by the switchgear manufacturer. [1][1]

According to this standard two different locations (shown in Figure 1) are acceptable for the insulated junction

a) location "A" between the flange of the transformer connection enclosure, part 6 in Figure 1, and the flange of the bushing, part 10 in Figure 1, or

b) location "B" between the transformer connection enclosure, part 6 in Figure 1, and the next switchgear housing, part 14 in Figure 1.

If the insulated junction is needed, the standard dimensions in accordance with Clause 8 shall be kept.

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

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Independent of the existence of an insulated junction, bonding connections between the single-phase enclosures of the switchgear need be provided by the switchgear manufacturer in accordance with IEC 61936-1 and IEC 62271-203.

Bonding connections always need to be provided between single-phase enclosed direct connection arrangements of single-phase, two-phase or three-phase transformers.

Bonding connections need not be provided for a three-phase transformer with a three-phase enclosed direct connection arrangement.

In the case of not having an insulated junction, bonding connections shall be designed not exceeding the permitted value of circulating current via the transformer tank as specified in this clause.

Without an insulated junction the bonding connection shall be made at the end of the transformer connection enclosure towards the bushing, i.e. location marked “A” in Figure 1.

With an insulated junction, in case of location marked “A” in Figure 1 the bonding connection shall be made at the end of the transformer connection enclosure towards the bushing.

In case of location marked “B” in Figure 1 the bonding connection shall be made at the end of the switchgear housing towards the bushing.

The transformer, including the bushing, shall be able to withstand very fast transient voltages which are generated by the switchgear.

If an insulated junction is applied, its design shall be also able to withstand the same value of the very fast transient voltages generated by the switchgear.

NOTE 3 Alternatively to the insulating junction an insulating spacer can be used.

5.2 Pressure withstand requirements

The maximum operating gas pressure used to determine the mechanical strength of the bushing shall be at least 0,85 MPa (absolute) at 20 °C.

The transformer connection enclosure and all pressurized connected parts shall satisfy the requirements provided in 5.103 of IEC 62271-203:2011 for the design pressure determined by the switchgear manufacturer as specified in 5.103.2 of IEC 62271-203:2011.

The design pressure of the transformer connection enclosure may be lower than the maximum operating gas pressure which is used to determine the mechanical strength of the bushing.

5.3 Gas and vacuum tightness

Subclause 5.15 of IEC 62271-203:2011 is applicable with the following addition:

For conditions up to the maximum occurring gas operating pressure, the bushing shall prevent insulating media, gas, diffusing into the transformer.

The bushing shall prevent entering insulating media, gas or oil, into the GIS.

The bushing shall be capable of withstanding the vacuum conditions when the transformer connection enclosure is evacuated, as part of the gas filling process and shall be capable of withstanding the vacuum conditions when the transformer is evacuated as part of its gas or oil filling process.

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In the case of a gas-insulated transformer the gas compartment of the transformer shall be completely separated and managed independently from the switchgear.

5.4 Mechanical forces applied on the connection interface

Normal loads applicable to bushings at the connection interface (part 3 and 4 in Figure 1) are given in IEC 60137:2008, Table 1, level I (see operating loads); the minimum normal load however shall not be less than 2 kN, acting either transversely or axially to the connection interface.

Table 1 of IEC 60137:2008 gives values for bushing installed up to 30° from the vertical.

If higher normal loads are to be expected at the connection interface, then the higher loads shall be selected from IEC 60137:2008, Table 1, Level II (heavy load).

For exceptional such as short current or seismic loads use cantilever test load level II of Table 1 in IEC 60137:2008.

For seismic requirements, it is necessary to carry out seismic calculation in order to identify the location of mechanical reinforcements, see IEC 62271-207.

It is the responsibility of the switchgear manufacturer to ensure that this specified force is not exceeded or agrees with the bushing manufacturer that the bushing shall withstand the higher forces.

The selection of the appropriate bushing is under the responsibility of the transformer manufacturer taking into account the maximum occurring short circuit forces between phase and ground, respectively also between phases in the case of a three-phase enclosure at both ends of the bushing.

In the case of different withstand currents of the GIS respectively the transformer, the higher withstand currents apply.

5.5 Mechanical forces applied on the bushing flange

In addition to the maximum operating gas pressure specified in 5.2, the flange of the bushing attached to the transformer connection enclosure is subjected, in service, to the following normal loads:

– part of the weight of the switchgear not supported by the switchgear's own supporting structures;
– part of the wind load, if applicable, not supported by the switchgear's own supporting structures;
– expansion or contraction stresses due to the temperature variations of the transformer tank.

The precise evaluation of these thermal stresses of the transformer tank shall be based on the thermal expansion factor of the material of the transformer tank, taking into account the lowest occurring ambient temperature (i.e. transformer out of service) and the occurring average maximum temperature the transformer tank will have in operation (i.e. normally 90 °C at a reference temperature of 20 °C). The thermal expansion factor of the material of the transformer shall be considered for mild steel with 12E-6 / K. Concerning the expansion-contraction of the transformer one cycle per day can be assumed.

NOTE 1 Variations of height or position due to draining the transformer oil and evacuating the transformer tank are not considered, assuming that the switchgear and the transformer are not connected together when these operations are performed.

Other expansion-contraction cycles need to be provided to the GIS manufacturer by the user.

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