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TECHNICAL REPORT

RAPPORT TECHNIQUE

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

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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

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IEC 62271-208, which is a technical report, has been prepared by subcommittee 17C: High-voltage switchgear and controlgear assemblies, of IEC technical committee 17: Switchgear and controlgear.

In this technical report the word "shall" is used as a conditional "shall", in the event that this technical report is applied.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
17C/450/DTR	17C/462/RVC

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

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

A list of all the parts in the IEC 62271 series, 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 maintenance result 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

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INTRODUCTION

Manufacturers of electricity supply equipment may be asked to provide information about the electromagnetic field characteristics to enable the user to

- assess the electromagnetic field conditions to assist with planning, installation, operating instructions and service,
- take measures to meet requirements or regulations on electromagnetic fields,
- compare different products as far as their level of electromagnetic fields is concerned.

The purpose of this technical report is to describe a methodology for the evaluation (measurement or calculation) of generated electromagnetic fields.

The electromagnetic field characteristic of the equipment comprises the values of the electric and the magnetic fields around its accessible surfaces.

The electromagnetic field characteristic defined in this technical report refers to a single product as defined in the scope. In real installations, several field sources can superimpose, so the resulting electromagnetic fields on site may differ significantly from the single product characteristics.

This technical report does not define a mandatory test for the products mentioned in the scope.

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Neither the establishment of limits for the electromagnetic fields generated by equipment, nor the establishment of assessment methods for the human exposure to electromagnetic fields is within the content or intent of this technical report.

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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

1 Scope

This part of IEC 62271 gives practical guidance for the evaluation and documentation of the external electromagnetic fields which are generated by HV switchgear assemblies and HV/LV prefabricated substations. Basic requirements to measure or calculate the electric and magnetic fields are summarised for switchgear assemblies covered by IEC 62271-200 and IEC 62271-201, and for prefabricated substations covered by IEC 62271-202.

NOTE 1 The methods described in this technical report refer to three-phase equipment. However, the methodology may be used correspondingly for any single- or multi-phase equipment covered by this technical report.

This technical report applies to equipment rated for voltages up to and including 52 kV and power-frequencies from 15 Hz to 60 Hz. The electromagnetic fields which are generated by harmonics or transients are not considered in this technical report. However, the methods described are equally applicable to the harmonic fields of the power-frequency.

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Detailed generic information on requirements and measurements of low-frequency electromagnetic fields is given in IEC 61786.

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This technical report covers evaluation under factory or laboratory conditions before installation. The electric and the magnetic fields can be evaluated either by measurements or by calculations.

NOTE 2 Where practicable, the methods described in this technical report may also be used for installations on site.

It is not within the scope of this technical report to specify limit values of electromagnetic fields or methods for the assessment of human exposure.

2 Normative references

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

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards - Immunity for industrial environments*

IEC 61786, *Measurement of low-frequency magnetic and electric fields with regard to exposure of human beings – Special requirements for instruments and guidance for measurements*

IEC 62271-200, *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, *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 62271-202, *High-voltage switchgear and controlgear – Part 202: High-voltage/low-voltage prefabricated substation*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
EMF
abbreviation for the term “electromagnetic field(s)”

3.2
electric field characteristic
values (r.m.s.) and spatial distribution of the electric field strength at rated voltage and frequency around all accessible surfaces of the equipment. The electric field characteristic is the resultant of the r.m.s. values of the three orthogonal vector components

3.3
magnetic field characteristic
values (r.m.s.) and spatial distribution of the magnetic flux density at rated normal current and frequency around all accessible surfaces of the equipment. The magnetic field characteristic is the resultant of the r.m.s. values of the three orthogonal vector components

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NOTE The terms “resultant electric field” and “resultant magnetic field” are defined in IEC 61786.

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3.4
accessible surfaces
those parts of the walls and roof of prefabricated substations or HV switchgear assemblies that can be touched with all covers and doors in closed position in normal service conditions

3.5
reference surface
RS
virtual envelope containing the equipment for evaluation purposes

3.6
measurement surface
MS
defined outside the reference surface at 20 cm distance

NOTE This surface is used for measuring the hot spots and the variation of the EMF.

3.7
hot spot
centre of an area of a local maximum of the electric or the magnetic field

3.8
EMF characteristic
spatial distribution of the resultant (modulus) of the r.m.s. electric field strength (E) and the magnetic flux density (B). The spatial distribution is derived from a measurement or calculation grid

3.9
measurement volume
MV
virtual space in which the electromagnetic background field must not exceed an appropriate level to permit the uninfluenced measurement of the electric and magnetic fields generated by the equipment

4 Evaluation requirements

4.1 General

The EMF characteristic of HV switchgear assemblies or HV/LV prefabricated substations is the measured or calculated electric field strength and magnetic flux density around all accessible surfaces under the conditions for evaluation described below. These conditions represent the service, where the loading of the switchgear assemblies and, in a substation, of the transformer is at defined values.

As the electric and magnetic fields are dependent on the physical arrangement of incoming and outgoing cables and their loadings, these parameters have to be recorded. The presence of other field sources and shielding or other metallic structures shall be recorded.

The EMF characteristic shall be evaluated for the conditions that would result in the highest levels of electric and magnetic fields in normal, undisturbed service. These conditions include the highest currents and largest loops realistically possible through the assembly working at maximum capacity. EMF caused by switching operations, including interruption of fault currents, or other transient phenomena is deemed to be incidental and shall not be considered.

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The highest current on the HV side is the rated normal current given on the nameplate of the switchgear assembly, and on the LV side the rated normal current of the transformer with the highest rating. In a calculation both currents have to be simulated. During a measurement it is preferable to have both currents present.

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Electric field strength and magnetic flux density shall be recorded as the resultant of the r.m.s. values of the three orthogonal components.

The evaluation shall be carried out at the rated frequency of the equipment.

However, in the frequency range up to and including 60 Hz the actual value of frequency does not significantly affect the levels of generated E fields for any given values of voltage. Therefore evaluation at any frequency up to and including 60 Hz is considered valid.

Similarly, the difference in attenuation of B fields by metallic enclosures at 50 Hz and 60 Hz can be ignored for the purpose of this technical report. Therefore evaluation at 50 Hz is considered applicable also for 60 Hz and vice versa.

In the power-frequency range covered by this technical report the electric and magnetic fields may be treated separately. When selecting the conditions to obtain the highest level of electric and magnetic fields as realistically as possible in undisturbed service, the following subclauses shall be considered.

4.2 Methods of evaluation

The manufacturer may evaluate the EMF characteristic by measurement or by calculation.

4.3 Evaluation of electric fields

4.3.1 HV switchgear assemblies

The equipment shall be evaluated at the rated voltage of the HV switchgear assembly.

Only if the evaluation cannot be carried out at rated voltage, the results shall be extrapolated to the rated value. Since the electric field strength is a linear function of the voltage, the field strengths for different high voltages may be extrapolated linearly.

4.3.2 HV/LV prefabricated substations

The equipment shall be evaluated at the rated high voltage of the HV/LV transformer(s).

Only if the evaluation cannot be carried out at rated voltage, the results shall be extrapolated to the rated value. Since the electric field strength is a linear function of the voltage, the field strengths for different high voltages may be extrapolated linearly.

4.4 Evaluation of magnetic fields

4.4.1 HV switchgear assemblies

The HV switchgear assembly is loaded with its highest permissible current determined by the rated normal current given on the nameplate. The HV circuit must be selected to form the widest possible current loop between the incoming and outgoing functional units (panels) of the switchgear assembly to obtain the maximum magnetic field by using the smallest number of circuits, taking into account their rated normal current. An example is shown in Figure 1.

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If the evaluation cannot be carried out at the rated normal current the results shall be extrapolated to the rated value. Any saturation effect will be less pronounced at lower currents, therefore extrapolation from lower to higher values of current is allowed since it can only result in an overestimate of the B field.

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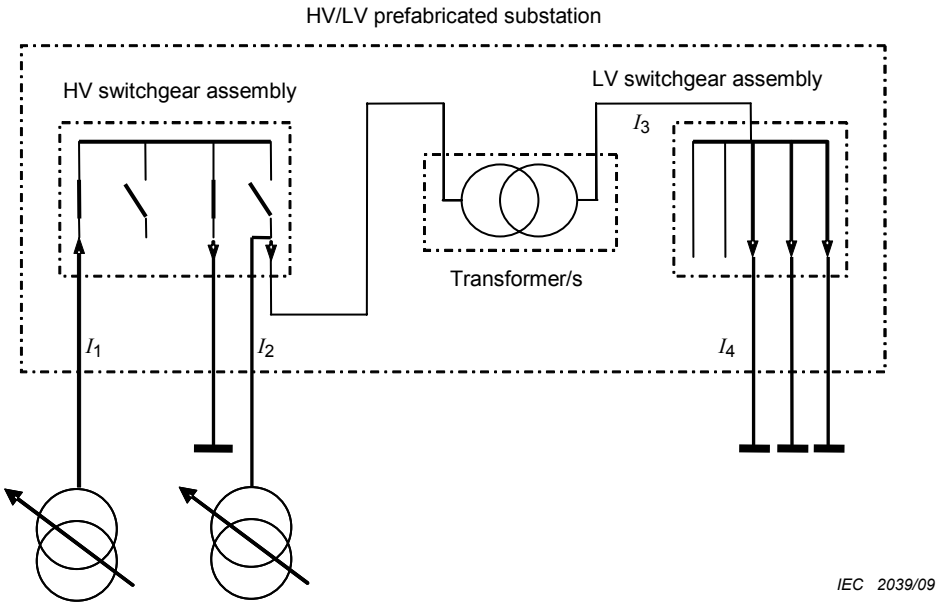

Key

I_1 = HV switchgear highest loop current
I_2 = HV/LV loop (HV side) current
I_3 = HV/LV loop (LV side) highest current
I_4 = HV/LV (LV outgoing) highest current

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Figure 1 – Example of test circuits configuration to obtain the maximum external magnetic field of a switchgear assembly and/or a prefabricated substation

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4.4.2 HV/LV prefabricated substations

For the HV switchgear assembly, 4.4.1 applies.

The LV switchgear assembly and the transformer shall be loaded with the highest normal current derived from the maximum rated power of the prefabricated substation for a given LV level. The circuit shall be configured to form the highest concentration of currents to obtain the maximum magnetic field. This can be achieved by using the smallest number of circuits, choosing those located closest to the enclosure of the prefabricated substation and taking into account their rated normal current. An example is shown in Figure 1.

If the design of the HV/LV prefabricated substation admits transformers of different rated power, the manufacturer shall at least provide an evaluation for the transformer with the highest rated power for a given LV level.

NOTE The rated power of the transformer should correspond to the cooling by natural ventilation. EMF evaluation with other means of cooling (for example forced cooling) should be subject to agreement between manufacturer and user.

If the evaluation cannot be carried out at the rated power for a given LV level, the results shall be extrapolated to the rated value. Any saturation effect will be less pronounced at lower currents, therefore extrapolation from lower to higher values of current is allowed since it can only result in an overestimate of the B field.

The extrapolation of magnetic field values is not permitted if the currents on the HV and LV sides of the prefabricated substation vary independently.

5 Measurements

5.1 General

At power-frequency the electric and magnetic field are independent from each other. Hence, magnetic flux density and electric field strength characteristic need not be recorded simultaneously.

The electric field characteristic of the equipment is independent of the load current.

The magnetic field characteristic of the equipment is independent of the voltage.

NOTE General guidance on measurement procedures for electric and magnetic fields can also be found in IEC 62110 and IEC 61786.

5.2 Measuring instruments

Instruments for measuring electric and magnetic fields shall meet the requirements of specification and calibration given by IEC 61786. The calibration report shall be traceable to national or International Standards. These instruments should be used in appropriate conditions, in particular with regard to

- electromagnetic immunity according to IEC 61000-6-2,
- immunity of power-frequency electric field on magnetic field measurement,
- temperature and humidity ranges as recommended by the instrument manufacturer.

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A three-axis instrument measures r.m.s. values of resultant field F_r. A single-axis instrument may be used to obtain F_r by measuring F_x, F_y, and F_z, using Equation (1), where F_x, F_y and F_z are r.m.s. values of the orthogonal three-axis components of electric or magnetic field.

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$$F_r = \sqrt{F_x^2 + F_y^2 + F_z^2} \quad (1)$$

The use of a three-axis instrument with three concentric sensors is preferred. However, if a single-axis instrument is used, special attention should be paid to the orientation of the sensor along three orthogonal directions. The orientation of the sensor shall be changed without moving the position of its centre.

In the case of non-concentric sensors, the locations and orientations of the sensors that are contained within the housings of field meters shall be clearly indicated on the instrument or in the instruction manual.

During the evaluation of the magnetic field generated by HV switchgear assemblies and HV/LV prefabricated substations, the distance between the field source and the measuring instrument is relatively short (in comparison to other AC power equipment like overhead lines). In general, the measurements will be carried out in non-uniform fields. In case of the magnetic field measurement, it is necessary to consider the ratio of distance (d_{sc}) from the field source and sensor radius (a). For measurements with a three-axis instrument, a minimum ratio of 4 is considered suitable.

NOTE When using a probe with radius 5 cm the minimum distance to the field source should be at least 20 cm considering a ratio of 4. More information about this topic can be found in IEC 61786.

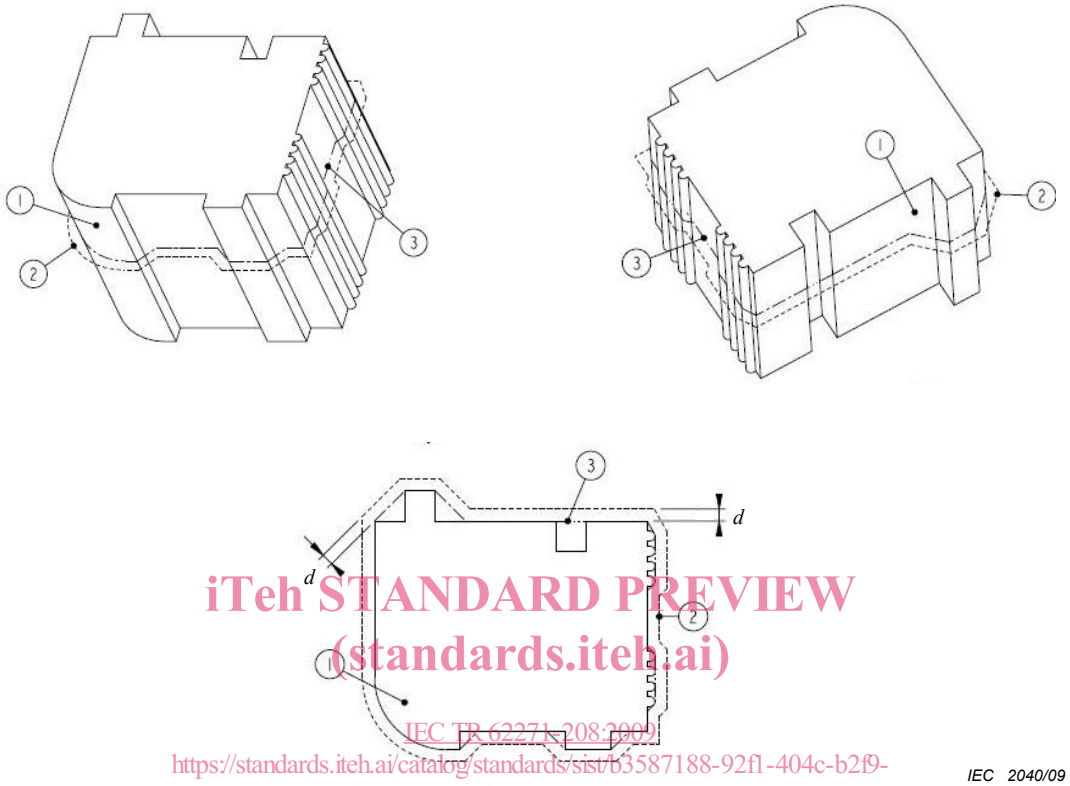
5.3 Measurement procedures

5.3.1 General

To consider equipment of all kinds of shape, a virtual envelope containing the equipment is defined as the reference surface (RS); see Figure 2. The purpose of the RS is to integrate

irregularities and to eliminate abrupt changes in the measurement surface (MS). The MS is defined outside the RS at 20 cm distance.

Protruding elements (for example handles) shall be disregarded.



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Key

1 Equipment surface

2 Measurement surface

3 Reference surface

d Distance between equipment and measurement surface (20 cm)

Figure 2 – Reference surface (RS) for equipment of irregular shape

5.3.2 Electric field

The maximum value(s) of the electric field over the accessible measurement surface shall be found by first scanning on a coarse grid to find the regions of maximum field and then refining the grid for the hot spot locations. See also Figure 3.