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TECHNICAL REPORT

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A method of temperature-rise verification of low-voltage switchgear and controlgear assemblies by calculation

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A METHOD OF TEMPERATURE-RISE VERIFICATION OF LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES BY CALCULATION

FOREWORD

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IEC TR 60890 has been prepared by subcommittee 121B: Low-voltage switchgear and controlgear assemblies, of IEC technical committee 121: Switchgear and controlgear and their assemblies for low-voltage. It is a Technical Report.

This third edition cancels and replaces the second edition published in 2014. This edition constitutes a technical revision.

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

- alignment with IEC 61439-1:2020;
- addition of individual annexes for guidance of technical explanations related to:
  - effect of an uneven power distribution;
  - additional temperature-rise due to solar radiation;
  - effect of different enclosure materials;
  - effect of different natural ventilation management;
  - forced ventilation management;

  – power losses calculation;
  – impact of an adjacent wall can have on the assembly cooling surface(s);
- maximum internal ambient temperature limit into an assembly;
- validity area of the calculation extended from 3 150 A to 3 200 A;
- addition of an algebraic equation to the different curves included in the document.

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

Draft	Report on voting
121B/136/DTR	121B/147/RVDTR

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

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

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INTRODUCTION

In the series of design verifications of IEC 61439-1 a temperature-rise verification of low-voltage power switchgear and controlgear assemblies is specified. This can be by test, however, alternatives are acceptable under defined circumstances. Selection of the method used for temperature-rise verification is the responsibility of the original manufacturer. Where applicable this document can also be used for temperature-rise verification of similar products in accordance with other standards (e.g. IEC 60204-1). The method of calculation can also be used to determine the thermal power dissipation capability of an enclosure in accordance with IEC 62208 for a given internal air temperature-rise. The factors and coefficients, set out in this document have been derived from measurements on numerous assemblies and the method has been verified by comparison with test results.

A METHOD OF TEMPERATURE-RISE VERIFICATION OF LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR ASSEMBLIES BY CALCULATION

1 Scope

This document specifies a method of air temperature-rise calculation inside enclosures for low-voltage switchgear and controlgear assemblies or similar products in accordance with their respective standard.

The method is primarily applicable to enclosed assemblies or partitioned sections of assemblies without forced ventilation. However, some technical guidance to adapt it for the use of forced ventilation is given in this document. The results obtained by using this method are directly influenced by the accuracy of the evaluation of power losses used as inputs to perform the thermal calculations.

NOTE The air temperature within the enclosure is equal to the ambient air temperature outside the enclosure plus the temperature-rise of the air inside the enclosure caused by the power losses of the installed equipment.

For the method to be applied, the maximum daily average ambient air temperature outside the assembly at the place of installation is specified between 10 °C and 50 °C. The maximum daily temperature does not exceed the maximum daily average temperature by more than 5 K.

Several annexes in this document provide guidance on how temperature-rise within assemblies can be affected by influences which are not considered in the calculation method included in this document, for example, when the assembly is subject to solar radiation. In such cases, different means of verification to that given in this document can be applied to ensure a definitive result and verification of the design.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61439 (all parts), *Low-voltage switchgear and controlgear assemblies*

IEEE C37.24-2017, *IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61439 (all parts) apply.

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

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

4 Verification conditions

When this method of calculation is applied to low-voltage switchgear and controlgear assemblies the following conditions shall be fulfilled:

– the assembly is designed for AC currents and frequencies up to and including 1 600 A, 60 Hz. For higher current ratings or frequencies, the method could be used with additional verifications taking into account the effect of eddy-currents on the temperature distribution inside the assembly as required by the relevant product standards.

  NOTE 1 In IEC 61439-2, additional requirements for currents in excess of 1 600 A are specified to take into account the considerably increased power losses due to magnetic effects (eddy currents, proximity effect, skin effect)

– the assembly is designed for DC currents up to and including 3 200 A. For higher current ratings the method could be used with additional verifications as required by the relevant product standards;
– conductors carrying currents in excess of 200 A AC, and the adjacent structural parts are so arranged that eddy-current and hysteresis losses are negligible;
– there is an approximately even distribution of power losses inside the enclosure;
– the power losses data for all built-in components are available or can be calculated (see Clause 5);
– the installed equipment is so arranged that air circulation is not significantly impeded.

NOTE 2 When this method is used to determine the thermal power dissipation capability of an empty enclosure in accordance with IEC 62208, the above conditions do not apply.

5 Calculation method

5.1 Assumptions made in this calculation

To use the calculation method of this document, the following assumptions are deemed valid:

– the enclosure is made of metal (steel, aluminium, stainless steel) coated (both sides, inside and outside), insulating material like thermoplastic or thermoset or similar (see Annex D);
– the enclosure is made of a single layer material or multiple layers without air-gap;
– for enclosures with or without natural ventilation, there are no more than five horizontal partitions in the assembly or in a section of it;
– the enclosure is designed without ventilation openings or;
– the enclosure is designed with free air inlet and outlet ventilation openings, without the inclusion of any additional filter (see Annex E);
  • the cross-section of the air outlet openings is at least 10 % bigger than that of the inlet openings to permit the chimney effect;
  • the minimum cross section of air inlet openings is 10 cm^2;

  NOTE 1 Figure 3 and the formula given in Table 7 are not usable for lower cross sections. Assemblies with a sum of the air inlet openings less than 10 cm^2 are considered as assemblies without an air inlet.

  • if the enclosure has air inlet and outlet openings with filters for an IP5X rating or higher then these openings are not considered for the calculation;
  • for IP ratings lower than IP5X the effective free air cross section of the openings shall be used for calculation (see Annex E);
– where enclosures with natural ventilation openings have compartments, the surface of each horizontal partition shall be provided with free air ventilation openings of at least 50 % of the horizontal cross-section of the partition (see Clause B.1);
– power losses are considered as a sum of the followings:
  • power losses of low-voltage switchgear and controlgear (see Clause G.2);

  - power losses of conductors connecting low-voltage switchgear and controlgear (see Clause G.3);
  - power losses of busbars (see Clause G.4);
  - power losses of electronic devices (see Clause G.5);
- the enclosure is not subject to solar radiation.

5.2 Necessary information

The following data shall be used to calculate the temperature-rise of the air inside an enclosure:

- dimensions of the enclosure: height/width/depth;
- type of installation of the enclosure according to Figure 4;
- design of enclosure, i.e. with or without ventilation openings;
- number of internal horizontal partitions;
- effective power loss of equipment installed in the enclosure, see Annex G;
- effective power loss (P_v) of conductors according to Annex I.

5.3 Calculation procedure

5.3.1 General

For the enclosures specified in columns 4 and 5 of Table 1, the calculation of the temperature-rise of the air inside the enclosure is carried out using the formulae laid down in columns 1 to 3 of Table 1.

The pertinent factors and exponents (characteristics) are obtained from columns 6 to 10 of Table 1.

The symbols, units and designations are stated in Table 2.

For enclosures having more than one section with vertical partitions, the temperature-rise of the air inside the enclosure shall be determined separately for each section.

Where enclosures without vertical partitions or individual sections have an effective cooling surface greater than 11,5 m^2 or a width greater than about 1,5 m, they should be divided for the calculation into fictitious sections, whose dimensions approximate to the foregoing values.

NOTE The template (see Figure 9) can be used as a calculation aid.

5.3.2 Determination of the effective cooling surface A_e of the enclosure

The calculation is carried out according to Formula (1) in column 1 of Table 1.

The effective cooling surface A_e of an enclosure is the sum of the individual surfaces A_o multiplied by the surface factor b. This factor takes into account the heat dissipation of the individual surfaces according to the type of installation of the enclosure (see Annex H for additional explanations).

5.3.3 Determination of the internal temperature-rise $\Delta t_{0,5}$ of the air at mid-height of the enclosure

The calculation is carried out according to Formula (2) in column 2 of Table 1.

In Formula (2) the enclosure constant k allows for the size of the effective cooling surface for enclosures without ventilation openings and, in addition, for the cross-section of the air inlet openings for enclosures with ventilation openings.

The dependence of the temperature-rise occurring in the enclosure on the effective power loss P is expressed by the exponent x.

The factor d allows for the dependence of the temperature-rise on the number of internal horizontal partitions.

5.3.4 Determination of the internal temperature-rise $\Delta t_{1,0}$ of air at the top of the enclosure

The calculation is made according to Formula (3) in column 3 of Table 1.

Factor c allows for the temperature distribution inside an enclosure. Its determination varies with the design and installation of the assembly as follows:

a) For enclosures without ventilation openings and with an effective cooling surface:

$$A_e > 1{,}25\ \text{m}^2$$

The factor c from Figure 4, depends on the type of installation and the height/base factor f, where:

$$f = \frac{h^{1,35}}{A_b}$$

b) For enclosures with ventilation openings and with an effective cooling surface:

$$A_e > 1{,}25\ \text{m}^2$$

The factor c from Figure 6, depends on the cross-section of air inlet openings and the height/base factor f, where:

$$f = \frac{h^{1,35}}{A_b}$$

c) For enclosures without ventilation openings and with an effective cooling surface:

$$A_e \leq 1{,}25\ \text{m}^2$$

The factor c from Figure 8, depends on the height/width factor g, where:

$$g = \frac{h}{w}$$

where

h is the enclosure height, in m;

A_b is the surface area of the enclosure base, in m^2;

w is the enclosure width, in m.

5.3.5 Characteristic curve for temperature-rise of air inside enclosure

5.3.5.1 General

To evaluate the design according to Clause 7, the calculated results of 5.3.3 and 5.3.4 shall be applied with the proper characteristic curve for temperature-rise of air inside the enclosure as a function of the enclosure height. The air temperatures within horizontal levels are practically constant.

5.3.5.2 Temperature-rise characteristic curve for enclosures with an effective cooling surface A_e exceeding 1,25 m²

As a general rule, the characteristic curve of temperature-rise is adequately well defined by a straight line which runs through the points $\Delta t_{1,0}$ and $\Delta t_{0,5}$ (see Figure 1).

The internal air temperature-rise at the bottom of the enclosure is close to zero, i.e. the characteristic curve flattens out towards zero. In practice, the dotted part of the characteristic curve is of secondary importance.

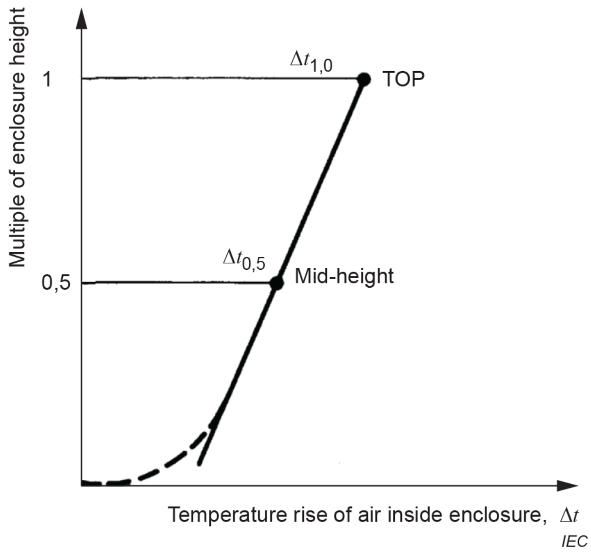

Figure 1 – Temperature-rise characteristic curve for enclosures with A_e exceeding 1,25 m²

5.3.5.3 Temperature-rise characteristic curve for enclosures with an effective cooling surface A_e not exceeding 1,25 m²

For this type of enclosure, the maximum temperature-rise in the upper quarter is constant and the values for $\Delta t_{1,0}$ and $\Delta t_{0,75}$ are identical (see Figure 2).

The characteristic curve is obtained by connecting the temperature-rise values at an enclosure level of 0,75 and 0,5 (see Figure 2).

The internal air temperature-rise at the bottom of the enclosure is close to zero, i.e. the characteristic curve flattens out towards zero. In practice, the dotted part of the characteristic curve is of secondary importance.

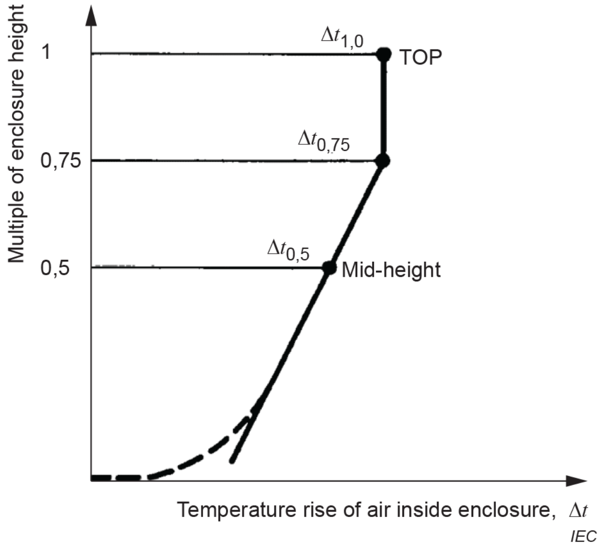

Figure 2 – Temperature-rise characteristic curve for enclosures with A_e not exceeding 1,25 m^2

5.4 Maximum internal air temperature limits

This document contains a method to calculate the internal air temperature within an enclosure. The resulting temperature shall not exceed the maximum absolute temperature allowed by different types of devices and products installed inside.

The user of this document should refer to the manufacturer's instructions regarding the maximum operational temperature allowed for the devices used inside the assembly.

NOTE The value of internal air temperature has a direct influence on the ageing and operation of built-in components.

6 Further considerations

6.1 General

The means of temperature-rise calculation in this document relate to specific arrangements of assembly in the conditions as defined. These arrangements and conditions do not cover all designs of assembly or the conditions in which some are installed. Where good practises are applied the calculation methods in this document can lead to conservative results.

Annex B, Annex C, Annex D, Annex E, Annex F, Annex H, Annex J and Annex K detail good practice that can lead to an improvement in thermal performance or some aspects not considered in the calculation method in this document. However, when using these additional considerations, to ensure a defined performance of an assembly, further verification, e.g. test, shall be performed.

6.2 Guidance on the effects of an uneven power distribution

The aim of Annex B is to determine the temperature-rise where there is not an even power distribution within an assembly using as a starting point the temperature-rise of a reference design or calculation in accordance with Clause 5.