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Interested committees:

Title: BS IEC 60310 Railway applications - Traction transformers and inductors on board rolling stock

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## Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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## UK Vote

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| 1  | 2                                          | (3)                          | 4               | 5                                                                                                                                  | (6)                                                                      | 7                                                  |
|----|--------------------------------------------|------------------------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------|
| MB | Clause No./ Subclause No./Annex (e.g. 3.1) | Paragraph/Figure/ Table/Note | Type of comment | Commend (justification for change) by the MB                                                                                       | Proposed change by the MB                                                | Secretariat observations on each comment submitted |
|    | 3.1                                        | Definition 1                 | ed              | Definition is ambiguous and needs clarifying.                                                                                      | Amend to read '...so that the mains connector to which no connection...' |                                                    |
|    | 6.4                                        | Paragraph 2                  | te              | The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK. | Delete reference to UV photometer.                                       |                                                    |

|                                           |                                                 |
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|                                                                                                                                                                      |                                                                                                                                                          |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| IEC TC 9 : ELECTRICAL EQUIPMENT AND SYSTEMS FOR RAILWAYS                                                                                                             |                                                                                                                                                          |
| SECRETARIAT:<br>France                                                                                                                                               | SECRETARY:<br>Mr Denis MIGLIANICO                                                                                                                        |
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TITLE:

**Railway applications – Traction transformers and inductors on board rolling stock**

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# INTERNATIONAL ELECTROTECHNICAL COMMISSION

## RAILWAY APPLICATIONS – TRANSFORMERS AND INDUCTORS ON BOARD ROLLING STOCK

### FOREWORD

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IEC 60310 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways. It is an International Standard.

This fifth edition cancels and replaces the fourth edition published in 2016-01-27. This edition constitutes a technical revision.

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

- a) typical circuits for transformer and inductors are added;
- b) letter symbols for cooling methods are added;
- c) dielectric test table is modified;

- d) Subclauses for the tests of transformers and inductors are restructured;
- e) temperature test for dry type transformer and dry type inductors are separated in different Sub-clauses;
- f) requirements for shock and vibration tests are updated according to IEC 61373:202X.

The text of this **International Standard** is based on the following documents:

| Draft       | Report on voting |
|-------------|------------------|
| 9/XXXX/FDIS | 9/XXXX/RVD       |

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 International Standard 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](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/publications](http://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](http://webstore.iec.ch) in the data related to the specific document. At this date, the document will be

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

# RAILWAY APPLICATIONS – TRANSFORMERS AND INDUCTORS ON BOARD ROLLING STOCK

## 1 Scope

This document specifies the terms and definition, classification, service condition, characteristics and test methods for transformers and inductors on board rolling stock.

This document is applicable to traction and auxiliary power transformers installed on board rolling stock and to the various types of power inductors inserted in the traction and auxiliary circuits of rolling stock, of dry or liquid-immersed design.

This document is also applicable to the traction transformers of three-phase a.c. line-side powered vehicles and to the transformers inserted in the single-phase or poly-phase auxiliary circuits of vehicles, after agreement between purchaser and manufacturer.

This document does not apply to instrument transformers, transformers of a rated output below 1 kVA single-phase or 5 kVA poly-phase, and reactors of a rated output below 1 kVAR single-phase or 5 kVAR poly-phase on board rolling stock.

## 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 60060-1, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60060-2, *High-voltage test techniques – Part 2: Measuring systems*

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

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

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

IEC 60076-4, *Power transformers – Part 4: Guide to the lightning impulse and switching impulse testing – Power transformers and reactors*

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

IEC 60076-6:2007, *Power transformers – Part 6: Reactors*

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

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

- 35 IEC 60076-11, *Power transformers – Part 11: Dry-type transformers*
- 36 IEC 60076-12:2008, *Power transformers – Part 12: Loading guide for dry-type transformers*
- 37 IEC 60076-14, *Power transformers – Part 14: Liquid-immersed power transformers using high-*  
38 *temperature insulation materials*
- 39 IEC 60076-18, *Power transformers – Part 18: Measurement of frequency response*
- 40 IEC 60077-1, *Railway applications – Electric equipment for rolling stock – Part 1: General*  
41 *service conditions and general rules*
- 42 IEC 60085, *Electrical insulation – Thermal evaluation and designation*
- 43 IEC 60270, *High-voltage test techniques – Partial discharge measurements*
- 44 IEC 60296, *Fluids for electrotechnical applications – Unused mineral insulating oils for*  
45 *transformers and switchgear*
- 46 IEC 60836, *Specifications for unused silicone insulating liquids for electrotechnical purposes*
- 47 IEC 60850, *Railway applications – Supply voltage of traction systems*
- 48 IEC 60944, *Guide for the maintenance of silicone transformer liquids*
- 49 IEC 61039, *Classification of insulating liquids*
- 50 IEC 61099, *Insulating liquids – Specifications for unused synthetic organic esters for electrical*  
51 *purposes*
- 52 IEC 61373:2010, *Railway applications – Rolling stock equipment – Shock and vibration tests*
- 53 IEC 61378-1:2011, *Convertor transformers – Part 1: Transformers for industrial applications*
- 54 IEC 62497-1, *Railway applications – Insulation coordination – Part 1: Basic requirements –*  
55 *Clearances and creepage distances for all electrical and electronic equipment*
- 56 IEC 62498-1, *Railway applications – Environmental conditions for equipment – Part 1:*  
57 *Equipment on board rolling stock*
- 58 ISO 3746, *Acoustics – Determination of sound power levels and sound energy levels of noise*  
59 *sources using sound pressure – Survey method using an enveloping measurement surface over*  
60 *a reflecting plane*
- 61 ISO 9614-1, *Acoustics – Determination of sound power levels of noise sources using sound*  
62 *intensity – Part 1: Measurement at discrete points*
- 63 ISO 9614-2, *Acoustics – Determination of sound power levels of noise sources using sound*  
64 *intensity – Part 2: Measurement by scanning*
- 65 ISO 9828, *Railway applications — Fire protection on railway vehicles [under preparation]*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60076-1 and the following apply.

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

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

NOTE When the term “transformer” is used alone, it applies to both traction and auxiliary transformers.

The term “transformer(s)/inductor(s)” appears in clauses applicable to both transformers and inductors to avoid duplication of text.

The term “inductor” is used in this standard with the same meaning as the term “reactor” mentioned in IEC 60050-421, IEC 60050-811 and IEC 60076-6.

#### 3.1 General definitions

##### 3.1.1 traction transformer

traction transformers to supply the propulsion circuits, and optionally also other equipment

##### 3.1.2 auxiliary transformer

auxiliary transformers to supply electrical equipment except propulsion circuits. In the energy storage system, if the transformer supplying the propulsion circuits, is a traction transformer, if the transformer supplying electrical equipment except propulsion circuits, is a auxiliary transformer

##### 3.1.3 inductor

two-terminal device characterized essentially by its inductance

[SOURCE: IEC 60050-151:2001, 151-13-25]

##### 3.1.4 load profile

component output power / current versus time under specified conditions including voltage, rectifier, configuration, harmonic content, etc.

Note 1 to entry: efficiency for the transformer has to be agreed between the manufacture and user.

##### 3.1.5 load profile condition

cooling system configuration versus time, train speed versus time and any conditions with impact on cooling efficiency

##### 3.1.6 short time emergency loading

unusually heavy loading of a transient nature (less than one time constant of the transformer) occurring during degraded mode, such as a loss of one traction converter, etc.

[SOURCE: IEC 60076-12:2008, 3.2, modified]

**3.1.7****cooling medium**

cooling medium used to extract the heat out of the transformer/inductor e.g. air, water, oil, heat sink, etc.

**3.1.8****rated insulation voltage** $U_{Nm}$ 

r.m.s. withstand voltage value assigned by the manufacturer to the equipment or a part of it, characterising the specified permanent (over 5 min) withstand capability of its insulation

Note 1 to entry:  $U_{Nm}$  is a voltage between a live part of equipment and earth or another live part. For rolling stock, earth refers to the car body.

Note 2 to entry: For circuits, systems and sub-systems in railway applications this definition is preferred to "highest voltage for equipment" which is widely used in international standards.

Note 3 to entry:  $U_{Nm}$  is higher than or equal to the working voltage. As a consequence, for circuits directly connected to the contact line,  $U_{Nm}$  is equal to or higher than  $U_{max1}$  as specified in IEC 60850. For circuits connected to electronic converter  $U_{Nm}$  is higher than or equal to the d.c. link voltage.

Note 4 to entry:  $U_{Nm}$  is not necessarily equal to the rated voltage which is primarily related to functional performance.

**3.1.9****nominal voltage** $U_n$ 

suitable approximate voltage used to designate or identify a given supply system

**3.1.10****rated voltage** $U_r$ 

value of voltage assigned for a specific operating condition

**3.1.11****rated impulse voltage** $U_{Ni}$ 

impulse voltage value, characterizing the specified withstand capability of its insulation against transient over-voltages

**3.1.12****test voltage** $U_a$ 

r.m.s. value derived from  $U_{Nm}$  used for separate source voltage, induced voltage, voltage between terminals withstand, depending on test carried out

**3.1.13****recurring peak voltage** $U_{mT}$ ,  $U_{mG}$ 

maximum peak value of periodic excursions of the voltage waveform between terminals ( $U_{mT}$ ) or between terminals and ground ( $U_{mG}$ )

## 3.2 Definitions for transformers

### 3.2.1

#### voltage transmission ratio

##### VTR

ratio between the secondary voltage and the primary voltage when a specified impulse or a.c. square voltage is applied on the primary.

The VTR is expressed as a percentage of this applied voltage.

### 3.2.2

#### impedance voltage

voltage applied to reach the rated current in short-circuit.

This is expressed as a percentage of this applied voltage to the rated voltage at reference temperature.

Note 1 to entry: When expressed as a percentage or per unit, this is equal to the short circuit impedance referred in IEC 60076-1:2011, 3.7.

### 3.2.3

#### tolerance

permitted deviation between the declared value of a quantity and the measured value

[SOURCE: IEC 60050-411:2007, 411-36-19]

## 3.3 Definitions for inductors

Values of inductance for inductors are related to the different classes of utilisation and are defined as follows, with the understanding that they include an indication of the nature and value of the current used in their measurement.

### 3.3.1

#### a.c. inductance

inductance derived from the measurement of the alternating current carried by the inductor when it is supplied by a sinusoidal alternating voltage of specified value and frequency

### 3.3.2

#### differential inductance

inductance defined from the derivative of the linked flux as a function of current (equal to the slope of the magnetic characteristic)

Note 1 to entry: It is derived from the transient record of instantaneous voltage and current in the inductor or from the measurement of the variation of magnetic flux.

### 3.3.3

#### incremental inductance

inductance seen by the a.c. current of a particular value and frequency superimposed on a direct current through the inductor

Note 1 to entry: It should be mentioned that the ripple factor of a pulsating current, expressed as a percentage, is conventionally defined by the formula:

$$\frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} \times 100$$

where  $I_{\max}$  and  $I_{\min}$  respectively represent the maximum and minimum values of the current wave.

Note 2 to entry: It is derived from a record of the terminal voltage.

## 4 Classification

### 4.1 General

The traction transformer and auxiliary transformer could be integrated, i.e., the traction transformers could have several secondary windings, such as traction windings, auxiliary windings. Traction windings supply power to traction circuits. Auxiliary windings supply power to auxiliary equipment.

NOTE: In this document, the load side windings that feed the propulsion circuit and/or the auxiliary circuit used for other purposes are collectively called "secondary windings".

The typical circuits are described in this document to show the functions of each component. Figure 1 shows the typical circuit diagram for traction transformer with auxiliary windings, and Figure 2 shows that of separated traction and auxiliary transformers, while the traction transformer is fed by AC power supply system, and the auxiliary transformer is fed by DC intermediate link. Figure 3 shows the typical circuit diagram for auxiliary transformer fed by DC power supply system. Figure 4 shows the typical circuit diagram for traction transformer (Medium Frequency Transformer) fed by Energy Storage System such as fuel cell battery system.

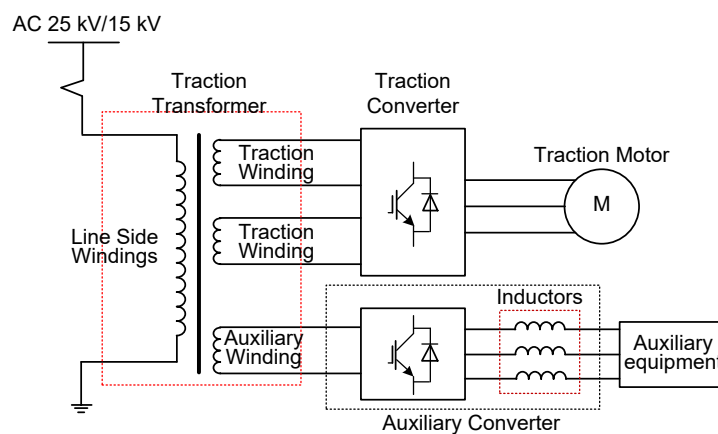


**Figure 1 – Traction transformer with auxiliary windings fed by AC power supply system**

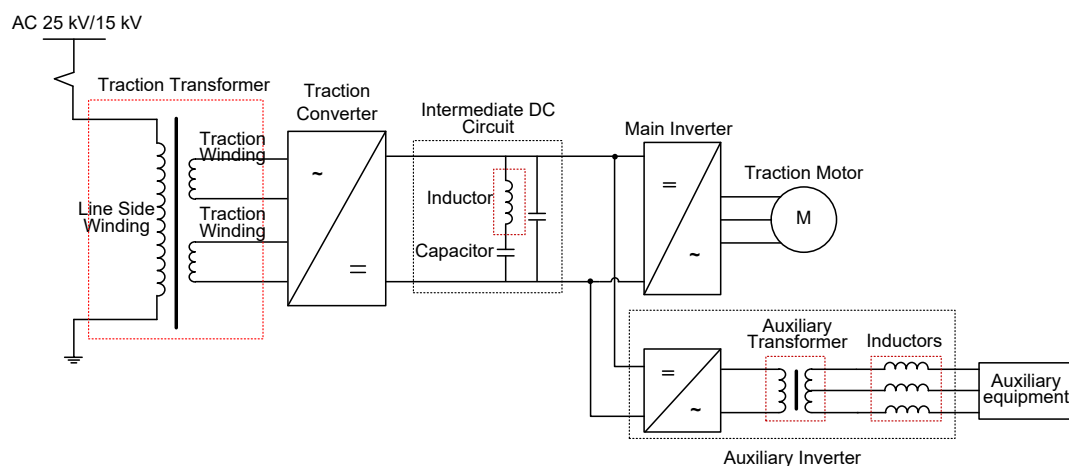


**Figure 2 – Traction transformer without auxiliary windings fed by AC power supply system**

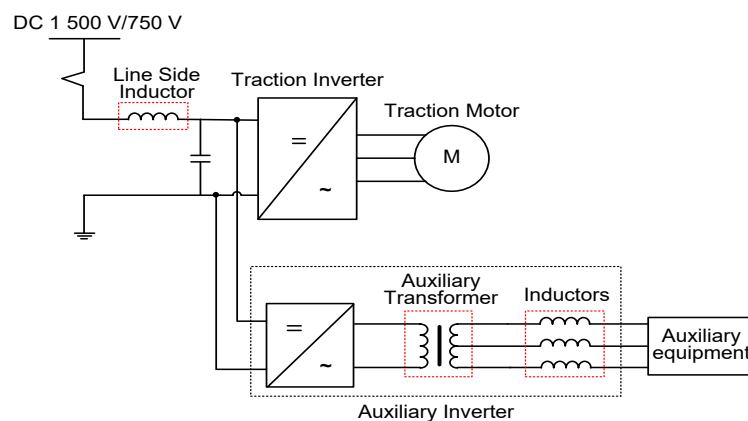


**Figure 3 – DC locomotive typical circuit diagram**

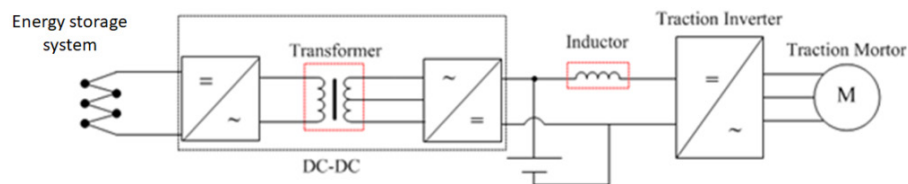


**Figure 4 – Energy storage system typical circuit diagram**

## 4.2 Classification of transformers

The transformers mentioned above may be:

- traction transformers to supply the traction circuits, and optionally also other equipment;
- auxiliary transformers to supply electrical equipment except traction circuits.

Windings mentioned in the standard may be:

- line side windings which are directly connected to the power supply line;
- traction windings which supply the traction circuits;
- auxiliary windings which are used for other purposes.

## 4.3 Classification of inductors

According to their use, inductors can be classified as follows:

- inductors for alternating current:
  - inductors that carry alternating current, such as transition inductors used for transition between tapings of tap changers, inductors for a.c. commutator motor braking circuits, interference suppression inductors, tuned filter inductors, etc.;
- inductors for direct current:
  - inductors that carry direct current with small or negligible a.c. components, such as d.c. line filter inductors, inductive shunts for traction motors, inductors for d.c. motor braking circuits, etc.;
- inductors for pulsating current:

inductors that carry direct or alternating current with a significant periodic ripple, such as smoothing inductors for traction motors, sinusoidal filter inductors in auxiliary converters, etc.

## 5 Service conditions

The normal service conditions for transformers and inductors shall be in accordance with IEC 62498-1. The pollution degree shall be specified in accordance with IEC 62497-1. Special service conditions shall be agreed between the purchaser and manufacturer.

## 6 Rated current and load profile

### 6.1 Load profile

A transformer/inductor is designed to operate on the train in steady-state and transient (surge) conditions, both in normal and overload conditions.

The purchaser should specify the load profile according to Annex E (informative). The current frequency spectrum shall be specified by the responsible party.

### 6.2 Rated current

The rated current of a winding is the current this winding can sustain permanently at the reference temperature for continuous load.

The rated current shall be calculated according to following methods:

- a) r.m.s. current derived from the load profiles;
- b) considering thermal ageing of insulating materials according to Annex B (informative);
- c) directly specified by the purchaser.

Special attention should be paid to varying cooling modes and to the averaging time window.

The reference temperature for continuous load is the cooling medium temperature at the external interface of the transformer/inductor. It shall:

- d) either be directly specified by the purchaser;  
Specified values should be based on the air temperature external to vehicle as defined in IEC 62498-1.
- e) or calculated by the manufacturer based on the temperature histogram provided by the purchaser and the method of Annex B (informative): see cooling medium reference temperature for lifetime calculation in B.4.2.

For a traction winding, the rated current shall correspond to the principal tapping. This definition of rated current applies when other windings, which are normally on load, deliver their rated loads.

## 7 Rated voltage and power of transformer windings

### 7.1 Rated line-side voltage

The rated line-side voltage is the r.m.s. voltage applicable in normal operating conditions to the line-side winding group. If this winding has tapplings, the rated voltage shall be referred to the principal tapping.

269 Unless otherwise agreed between purchaser and manufacturer, the rated line-side voltage is  
270 specified as being equal to the nominal voltage of the traction system.

271 NOTE IEC 60850 gives the list of the nominal voltages of traction systems.

## 272 **7.2 Rated secondary voltage**

273 The rated voltage of a secondary winding of a transformer is the r.m.s. no-load voltage at the  
274 terminals of the winding when the principal tapping of the line-side winding of the transformer  
275 is fed at its rated voltage and frequency.

## 276 **7.3 Rated power of transformer**

277 The rated power of a transformer winding is defined as the product of the rated voltage of this  
278 winding and its rated current.

279 NOTE Transformers usually have several secondary windings (e.g. traction, auxiliaries, train heating). The rated  
280 power of the line-side winding of a transformer can be less than the sum of the rated powers of its various secondary  
281 windings.

## 282 **8 Transformer tapings**

283 In order to permit variation of the voltage ratio of the transformer, one or more of its windings  
284 may be equipped with intermediate tapings, which shall be indicated on the diagram and in  
285 the specification, with a statement of their maximum operating characteristics.

286 The principal tapping is that which enables the rated traction motor voltage to be obtained at  
287 the terminals of the motors when they are taking their rated current, the transformer line-side  
288 winding being supplied at rated voltage and frequency.

289 When both line-side windings and traction windings have intermediate tapings, the principal  
290 tapings shall be indicated.

291 For multi-system vehicles, the principal tapings may be different for each system.

292 The no-load voltage ratio shall be defined for the principal tapping and for other tapings.

## 293 **9 Cooling**

### 294 **9.1 Identification of transformers and inductors according to cooling method**

295 Transformers and inductors shall be identified according to the cooling method employed. Letter  
296 symbols for use in connection with each cooling method shall be as given in Table 1.

297 **Table 1 – Letter symbols for cooling method**

| Type of cooling medium                                               | Symbol |
|----------------------------------------------------------------------|--------|
| Mineral oil or other insulating liquid with fire-point $\leq 300$ °C | O      |
| Insulating liquid with fire-point $> 300$ °C                         | K      |
| Insulating liquid having a fire-point greater than its boiling-point | L      |
| Gas                                                                  | G      |
| Water                                                                | W      |
| Air                                                                  | A      |

| Type of circulation for liquid-immersed type | Symbol |
|----------------------------------------------|--------|
| Natural                                      | N      |
| Forced non-directed                          | F      |
| Forced-directed                              | D      |
| Type of circulation for dry type             | Symbol |
| Natural                                      | N      |
| Forced                                       | F      |

In transformers and inductors with forced-directed circulation, a certain portion of the forced flow is channelled so as to pass through the windings. Some windings, however, may have a non-directed flow, for instance separate tapping windings, auxiliary windings and stabilizing windings.

The type of coolant shall be subject to approval by the purchaser.

## 9.2 Arrangement of symbols

### 9.2.1 Enclosed transformers and inductors

Transformers and inductors shall be identified by symbols of four letters for each cooling method for which a rating is specified by the manufacturer.

The order in which the symbols shall be used is given in Table 2. Oblique strokes shall be used to separate the group symbols for different cooling methods.

**Table 2 – Order of symbols**

| 1 <sup>st</sup> letter                                            | 2 <sup>nd</sup> letter | 3 <sup>rd</sup> letter                                                            | 4 <sup>th</sup> letter |
|-------------------------------------------------------------------|------------------------|-----------------------------------------------------------------------------------|------------------------|
| Indicating the cooling medium that is in contact with the winding |                        | Indicating the cooling medium that is in contact with the external cooling system |                        |
| Type of cooling medium                                            | Type of circulation    | Type of cooling medium                                                            | Type of circulation    |

Example: a liquid-immersed transformer with forced-directed liquid circulation and forced-air circulation would be designated by ODAF or KDAF.

For oil-immersed transformers in which the alternatives of natural or forced cooling with non-directed oil flow are possible, typical designations are: ONAN/ONAF, ONAN/OFAF.

For a dry-type transformer in a non-ventilated protective enclosure with natural air cooling inside and outside the enclosure, the designation is: ANAN.

### 9.2.2 Non-enclosed transformers and inductors

Dry-type transformers and inductors without protective enclosures are identified by two symbols only for the cooling medium that is in contact with the windings or the surface coating of windings with an overall coating (e.g. epoxy resin).

The cooling method of a dry-type transformer without a protective enclosure or with a ventilated enclosure and with natural air cooling is designated by: AN.

### 9.2.3 Air cooling

When transformers or inductors are cooled by the draught of air caused by the motion of the vehicle or by a forced-air cooling system which is not tested with the transformer or inductor, the air flow (or velocity) on which the rated power of the equipment is based shall be indicated by the purchaser.

## 10 Temperature limits

### 10.1 Classification of insulating materials

The different classes of solid materials (EIM – Electrical Insulating Material) and systems (EIS – Electrical Insulating System) used at present for the insulation of the windings of transformers and inductors to which this document applies are defined in IEC 60085 and listed in Table 3.

For a given solid insulation material the thermal class may be different depending on the surrounding medium (air, mineral oil, ester fluids, etc.).

The thermal class of the solid materials used for the insulation of the windings shall be indicated by the manufacturer.

### 10.2 Temperature limits of solid insulation

The maximum temperature of the transformer and inductor components shall not exceed the limits given in Table 3.

Temperature limits apply to short time maximum temperature considering hot spot.

These absolute temperatures are related to the worst case specified operating conditions.

For the long-time operation temperature limits refer to 14.4.11.6

**Table 3 – Temperature limits of solid insulation**

| RTE (Relative Thermal Endurance)<br>or<br>ATE (Assessed Thermal Endurance)                                                                                                                                                                                                                                                                                                                                                                                                            | Thermal class | Maximum<br>temperature<br>Immersed type °C<br>a) | Maximum<br>temperature<br>Dry-type °C<br>b) |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|--------------------------------------------------|---------------------------------------------|
| RTE or ATE < 90                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 70            | No guidance                                      | No guidance                                 |
| $90 \leq \text{RTE or ATE} < 105$                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 90 (Y)        | No guidance                                      | No guidance                                 |
| $105 \leq \text{RTE or ATE} < 120$                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 105 (A)       | 120 <sup>c)</sup>                                | 130                                         |
| $120 \leq \text{RTE or ATE} < 130$                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 120 (E)       | 135                                              | 145                                         |
| $130 \leq \text{RTE or ATE} < 155$                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 130 (B)       | 170                                              | 155                                         |
| $155 \leq \text{RTE or ATE} < 180$                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 155 (F)       | 195                                              | 180                                         |
| $180 \leq \text{RTE or ATE} < 200$                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 180 (H)       | 220                                              | 205                                         |
| $200 \leq \text{RTE or ATE} < 220$                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 200 (N)       | 240                                              | 225                                         |
| $220 \leq \text{RTE or ATE} < 250$                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 220 (R)       | 260                                              | 245                                         |
| $250 \leq \text{RTE or ATE}$                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 250           | No guidance                                      | No guidance                                 |
| <sup>a)</sup> For immersed type insulation systems, temperature limits are higher than for dry-type because of reduced oxidation of insulation materials. The exceptions are insulation systems based on cellulose (105 and 120 class), for which the temperature limits are based on IEC 60076-7.<br><sup>b)</sup> Dry-type limits are according to IEC 60076-12:2008, Table 2.<br><sup>c)</sup> If conductor is insulated with aramid paper or thermostabilized paper, up to 125°C. |               |                                                  |                                             |

Note 1: For hybrid insulation system, limits shall be according to the thermal class of each insulating material taken separately. Therefore, there are two maximum temperature limits for a hybrid insulation, one for high thermal class and one for conventional thermal class. For example, hybrid insulation system is mixing class 105(A) and class 155(F) solid insulation. In accordance with Table 3, the temperature limit for all class 105(A) solid insulation shall be 120°C and the temperature limit for all class 155(F) solid insulation shall be 195°C.

Other limits may be adopted by agreement between purchaser and manufacturer when certain combinations of insulating materials are used. It becomes especially important when materials of different thermal classes are combined within one insulation system. Then, thorough evaluation of the thermal capacity of such created system is necessary.

To estimate lifetime refer to Annex B (informative) and Annex C (informative).

### 10.3 Temperature limits for liquid

The temperature of the liquid shall not exceed the limits of Table 4. Short time emergency loading shall be agreed between user and manufacturer.

**Table 4 – Temperature limits for liquid**

|                                                                                      | Mineral oil<br>(IEC 60296) | Synthetic ester fluid<br>(IEC 61099) | Silicon fluid<br>(IEC 60836, IEC 60944) |
|--------------------------------------------------------------------------------------|----------------------------|--------------------------------------|-----------------------------------------|
| Fire point class (IEC 61039)                                                         | O                          | K                                    | K                                       |
| Maximum temperature for long term load, bulk fluid breathing or sealed °C            | 105                        | 130                                  | 155                                     |
| Maximum temperature for short-time emergency load, bulk fluid breathing or sealed °C | 115                        | 140                                  | 165                                     |

The values of temperature are based on IEC 60076-14. The recommended temperature limits are valid for the specific environment for insulation systems. Sealed systems limit the impact of oxygen and moisture as typical aging factors. For the free breathing system, maintenance has to be adapted.

### 10.4 Temperature limits for other parts

The temperature of the cores and other parts of the transformer or inductor shall in no case reach a value which will cause damage to these parts or adjacent ones, or undue ageing of the insulating liquid.

## 11 Mechanical design

The mechanical behaviour can be proved by Finite Element Analysis (FEA) calculation (method, model calibration and fatigue limits) to be agreed between the purchaser and manufacturer, or by the shock and vibration test. If the FEA method is chosen it should at least include the static load cases, the modal analysis up to 60 Hz and a relevant fatigue analysis that is based on the spectral power density defined by the IEC 61373 test conditions as input signal. A relevant damage evaluation shall be made with a recognized standard method (e.g. Single moment, Rayleigh, etc.). The material data have to be taken in accordance with this standard. The calculation shall take the welds into account and safety coefficient applied in accordance with the relevant standard agreed with the purchaser shall be used. The liquid has to be taken into account and the way it has been simulated has to be demonstrated.

## 12 Fire protection

For transformer/inductor, non-metalized materials outside the enclosed closure shall be in accordance with ISO 9828 (EN 45545).

Note: ISO 9828 is under preparation based on EN 45545.

## 13 Rating plates

### 13.1 General

The identification plate shall be placed in such a way that it will be easily inspected and cleaned in normal maintenance operations once the transformer is installed in the final application.

Each transformer/inductor shall be provided with a rating plate of weatherproof material, fitted in a visible position. The entries on the plate shall be indelibly marked (that is, by etching, engraving, stamping or by a photo-chemical process).

### 13.2 Rated plates for transformer

Each unit that can be handled independently shall be provided with its own rating plate, for different units which were putted in one container, the information of different units can be handled in one rating plate. Nameplates should contain at least the following information unless otherwise agreed between purchaser and manufacturer:

- manufacturer's name;
- manufacturer's type designation or number;
- manufacturer's serial number;
- date and place of manufacturing (at least include year information);
- connection diagram;
- tapplings;
- rated power, voltage and frequency of each winding;
- rated current (r.m.s. value, or mean direct current);
- volume of cooling medium and type (only for the liquid filled);
- identification of cooling method;
- name of cooling fluid (only for the liquid filled);
- total mass.

### 13.3 Rated plates for inductor

Each unit that can be handled independently shall be provided with its own rating plate, for different units which were putted in one container, the information of different units can be handled in one rating plate. Nameplates should contain at least the following information unless otherwise agreed between purchaser and manufacturer:

- manufacturer's name;
- manufacturer's type designation or number;
- manufacturer's serial number;
- date and place of manufacturing (at least include year information);
- connection diagram;
- tapplings;

- 413 – rated current (r.m.s. value, or mean direct current) ;
- 414 – value of the inductance (at one or more specified reference current values);
- 415 – volume of cooling medium and type (only for the liquid filled);
- 416 – identification of cooling method;
- 417 – name of cooling fluid (only for the liquid filled);
- 418 – total mass.

## 419 **14 Tests**

### 420 **14.1 Categories of tests**

#### 421 **14.1.1 General**

422 There are three categories of tests:

- 423 – type tests;
- 424 – routine tests;
- 425 – investigation tests.

426 Descriptions of the different tests belonging to each category are given below.

#### 427 **14.1.2 Type tests**

428 Type tests are carried out on a single piece of equipment of a given design. The test shall be  
429 carried out on one unit chosen among the first batch produced.

430 Bulk production equipment shall be deemed to have passed the type tests and shall be  
431 exempted from them if the manufacturer produces duly signed certificates of type tests already  
432 carried out on identical equipment constructed on a previous occasion.

433 Optional type tests are to be carried out only if they have been expressly specified in the order.

#### 434 **14.1.3 Routine tests**

435 Routine tests are carried out on all equipment of the same order. For certain equipment, after  
436 agreement between purchaser and manufacturer, the routine tests may be replaced by tests  
437 carried out on a few items of equipment taken at random from the order.

438 Optional routine tests are to be carried out only if they have been expressly specified in the  
439 order.

#### 440 **14.1.4 Investigation tests**

441 Investigation tests are special tests of an optional character carried out on a single equipment  
442 in order to obtain additional information on its performance; they are only to be carried out if  
443 they have been expressly specified in the order.

444 The results of these tests shall not influence the acceptance of the equipment unless agreement  
445 to the contrary has been specified in the order.

## 14.2 List of checks and tests

The checks, measurements and tests to be made on transformers and/or inductors are indicated in Table 5, which also stipulates the category of the test and the clauses to which reference should be made.

As far as practicable, the tests on differential inductors which cannot be dissociated from the transformer shall be carried out together with the tests on the latter. Purchaser and manufacturer shall agree on the tests to be made, if necessary, on these inductors as separate equipment, so as to ensure that they fulfil all requirements of this document.

When tap changers are an integral part of the transformers, they cannot be separated while the latter are tested.

**Table 5 – List of checks and tests to be made on transformers and/or inductors**

| Nature of test                                               | Subclause | Transformer |   |   |     |   |   | Inductor |   |   |     |   |   |
|--------------------------------------------------------------|-----------|-------------|---|---|-----|---|---|----------|---|---|-----|---|---|
|                                                              |           | liquid      |   |   | dry |   |   | liquid   |   |   | dry |   |   |
|                                                              |           | T           | R | I | T   | R | I | T        | R | I | T   | R | I |
| Visual checks                                                | 14.4.1    | M           | M | - | M   | M | - | M        | M | - | M   | M | - |
| Functional tests                                             | 14.4.2    | O           | O | - | O   | O | - | -        | - | - | -   | - | - |
| Mass                                                         | 14.4.3    | M           | O | - | M   | O | - | M        | O | - | M   | O | - |
| Measurement of winding resistance                            | 14.4.4    | M           | M | - | M   | M | - | M        | M | - | M   | M | - |
| Measurement of voltage ratios, polarities and vector groups  | 14.4.5    | M           | M | - | M   | M | - | -        | - | - | -   | - | - |
| Measurement of impedance voltage or short-circuit impedances | 14.4.6    | M           | M | - | M   | M | - | -        | - | - | -   | - | - |
| Measurement of a.c. inductance                               | 14.4.7.2  | -           | - | - | -   | - | - | M        | M | - | M   | M | - |
| Measurement of incremental inductance                        | 14.4.7.3  | -           | - | - | -   | - | - | M        | M | - | M   | M | - |
| Measurement of differential inductance                       | 14.4.7.4  | O           | O | - | O   | O | - | M        | M | - | M   | M | - |
| Measurement of no-load primary current and losses            | 14.4.8    | M           | M | - | M   | M | - | -        | - | - | -   | - | - |
| Measurement of fundamental load losses                       | 14.4.9    | M           | M | - | M   | M | - | -        | - | - | -   | - | - |
| Determination of losses                                      | 14.4.10   | M           | - | - | M   | - | - | M        | - | - | M   | - | - |
| Temperature-rise test                                        | 14.4.11   | M           | - | - | M   | - | - | M        | - | - | M   | - | - |
| Insulation resistance test                                   | 14.4.12   | O           | O | - | O   | O | - | O        | O | - | O   | O | - |
| Wet dielectric tests                                         | 14.4.13.2 | -           | - | - | O   | O | O | -        | - | - | O   | O | O |
| Induced voltage withstand test                               | 14.4.13.3 | M           | M | - | M   | M | - | -        | - | - | -   | - | - |
| Separate source voltage withstand test                       | 14.4.13.4 | M           | M | - | M   | M | - | M        | M | - | M   | M | - |
| Lightning impulse voltage withstand test                     | 14.4.13.5 | M           | - | - | M   | - | - | M        | - | - | M   | - | - |
| Voltage between terminals withstand test                     | 14.4.13.6 | O           | - | - | O   | - | - | M        | M | - | M   | M | - |