

BS EN 61287-1:2014

Incorporating corrigendum December 2014



BSI Standards Publication

Railway applications — Power converters installed on board rolling stock

Part 1: Characteristics and test methods

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National foreword

This British Standard is the UK implementation of EN 61287-1:2014, incorporating corrigendum December 2014. It is identical to IEC 61287-1:2014. It supersedes BS EN 61287-1:2006 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/9, Railway Electrotechnical Applications.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Applications ferroviaires - Convertisseurs de puissance
embarqués sur le matériel roulant - Partie 1:
Caractéristiques et méthodes d'essais
(CEI 61287-1:2014)

Bahnanwendungen - Stromrichter auf Bahnfahrzeugen -
Teil 1: Eigenschaften und Prüfverfahren
(IEC 61287-1:2014)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 9/1918/FDIS, future edition 3 of IEC 61287-1, prepared by IEC/TC 9 "Electrical equipment and systems for railways" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61287-1:2014.

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This document supersedes EN 61287-1:2006.

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The text of the International Standard IEC 61287-1:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

| | | |
|------------------|------|---|
| IEC 60112 | NOTE | Harmonized as EN 60112. |
| IEC 60146-1-1 | NOTE | Harmonized as EN 60146-1-1. |
| IEC 60216 | NOTE | Harmonized in EN 60216 series (not modified). |
| IEC 60384-1 | NOTE | Harmonized as EN 60384-1. |
| IEC 60587 | NOTE | Harmonized as EN 60587. |
| IEC 60664-1:2007 | NOTE | Harmonized as EN 60664-1:2007 (not modified). |
| IEC 60747-15 | NOTE | Harmonized as EN 60747-15. |
| IEC 61377-1 | NOTE | Harmonized as EN 61377-1. |
| IEC 61377-2 | NOTE | Harmonized as EN 61377-2. |
| IEC 61377-3 | NOTE | Harmonized as EN 61377-3. |
| IEC 62520 | NOTE | Harmonized as EN 62520. |

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

| <u>Publication</u> | <u>Year</u> | <u>Title</u> | <u>EN/HD</u> | <u>Year</u> |
|--------------------|-------------|---|--------------|-------------|
| IEC 60050-551 | 1998 | International Electrotechnical Vocabulary (IEV) - Part 551: Power electronics | - | - |
| IEC 60050-811 | 1991 | International electrotechnical vocabulary (IEV) - Chapter 811: Electric traction | - | - |
| IEC 60076-10 | 2001 | Power transformers - Part 10: Determination of sound levels | EN 60076-10 | 2001 |
| IEC 60077-1 (mod) | 1999 | Railway applications - Electric equipment for rolling stock - Part 1: General service conditions and general rules | EN 60077-1 | 2002 |
| IEC 60270 | - | High-voltage test techniques - Partial discharge measurements | EN 60270 | - |
| IEC 60310 | - | Railway applications - Traction transformers and inductors on board rolling stock | EN 60310 | - |
| IEC 60322 | - | Railway applications - Electric equipment for rolling stock - Rules for power resistors of open construction | EN 60322 | - |
| IEC 60349-1 | - | Electric traction - Rotating electrical machines for rail and road vehicles - Part 1: Machines other than electronic converter-fed alternating current motors | EN 60349-1 | - |
| IEC 60349-2 | - | Electric traction - Rotating electrical machines for rail and road vehicles - Part 2: Electronic converter-fed alternating current motors | EN 60349-2 | - |
| IEC 60349-4 | - | Electric traction - Rotating electrical machines for rail and road vehicles - Part 4: Permanent magnet synchronous electrical machines connected to an electronic converter | EN 60349-4 | - |

| <u>Publication</u> | <u>Year</u> | <u>Title</u> | <u>EN/HD</u> | <u>Year</u> |
|---------------------|--------------|--|--------------|-------------|
| IEC 60384-4 | - | Fixed capacitors for use in electronic equipment - Part 4: Sectional specification - Aluminium electrolytic capacitors with solid (MnO ₂) and non-solid electrolyte | EN 60384-4 | - |
| IEC 60529 | - | Degrees of protection provided by enclosures (IP Code) | EN 60529 | - |
| IEC 60571 | - | Railway applications - Electronic equipment used on rolling stock | - | - |
| IEC 60721-3-5 | - | Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities - Section 5: Ground vehicle installations | EN 60721-3-5 | - |
| IEC 60747 | series | Semiconductor devices | EN 60747 | series |
| IEC 60850 | - | Railway applications - Supply voltages of traction systems | - | - |
| IEC 61148 | - | Terminal markings for valve device stacks and assemblies and for power conversion equipment | EN 61148 | - |
| IEC 61373 | - | Railway applications - Rolling stock equipment - Shock and vibration tests | EN 61373 | - |
| IEC 61881 | series | Railway applications - Rolling stock equipment - Capacitors for power electronics | EN 61881 | series |
| IEC 61991 | - | Railway applications - Rolling stock - Protective provisions against electrical hazards | - | - |
| IEC 62236-3-1 | - | Railway applications - Electromagnetic compatibility - Part 3-1: Rolling stock - Train and complete vehicle | - | - |
| IEC 62236-3-2 | - | Railway applications - Electromagnetic compatibility - Part 3-2: Rolling stock - Apparatus | - | - |
| IEC 62278 | - | Railway applications - Specification and demonstration of reliability, availability, maintainability and safety (RAMS) | - | - |
| IEC 62497-1 + A1 | 2010 2013 | Railway applications - Insulation coordination - Part 1: Basic requirements - Clearances and creepage distances for all electrical and electronic equipment | - | - |
| IEC 62498-1 | 2010 | Railway applications - Environmental conditions for equipment - Part 1: Equipment on board rolling stock | - | - |

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RAILWAY APPLICATIONS – POWER CONVERTERS INSTALLED ON BOARD ROLLING STOCK –

Part 1: Characteristics and test methods

1 Scope

This part of IEC 61287 defines terminology, service conditions, general characteristics and test methods of electronic power converters onboard of rolling stock.

This International Standard is applicable to power electronic converters mounted on board railway rolling-stock and intended for supplying

- traction circuits;
- auxiliary circuits of power vehicles, coaches and trailers.

The application of this standard extends as far as possible to all other traction vehicles, including trolley-buses, for example.

This standard covers the complete converter assembly together with its mounting arrangements containing

- semiconductor device assemblies;
- integrated cooling systems;
- integrated components like inductors, capacitors, transformers, resistors, contactors, switches;
- semiconductor drive units (SDU) and related sensors;
- incorporated protection circuits.

The following types of power sources are taken into consideration:

- AC contact lines,
- DC contact lines,
- on-board supplies such as generators, batteries and other electric power sources.

This standard excludes converters which provide the electronic control supply for semiconductor drive units (SDU) and other supplies relevant to the converter operation such as sensors.

NOTE 1 Electronic control equipment of converters and those sensors not related to semiconductor drive units and the printed circuit board assemblies of semiconductor drive units (SDU) are covered by IEC 60571.

NOTE 2 Combined tests with the whole traction system or auxiliary supply system are not within the scope of this standard. E.g. rules for combined tests of a motor fed by a converter are given in the IEC 61377 series.

2 Normative references

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

IEC 60050-551:1998, *International Electrotechnical Vocabulary (IEV) – Part 551: Power electronics*

IEC 60050-811:1991, *International Electrotechnical Vocabulary – Chapter 811: Electric traction*

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

IEC 60077-1:1999, *Railway applications – Electric equipment for rolling stock – Part 1: General service conditions and general rules*

IEC 60270, *High-voltage test techniques – Partial discharge measurements*

IEC 60310, *Railway applications – Traction transformers and inductors on board rolling stock*

IEC 60322, *Railway applications – Electric equipment for rolling stock – Rules for power resistors of open construction*

IEC 60349-1, *Electric traction – Rotating electrical machines for rail and road vehicles – Part 1: Machines other than electronic converter-fed alternating current motors*

IEC 60349-2, *Electric traction – Rotating electrical machines for rail and road vehicles – Part 2: Electronic converter-fed alternating current motors*

IEC 60349-4, *Electric traction – Rotating electrical machines for rail and road vehicles – Part 4: Permanent magnet synchronous electrical machines connected to an electronic converter*

IEC 60384-4, *Fixed capacitors for use in electronic equipment – Part 4: Sectional specification – Aluminium electrolytic capacitors with solid (MnO₂) and non-solid electrolyte*

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

IEC 60571, *Railway applications – Electronic equipment used on rolling stock*

IEC 60721-3-5, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 5: Ground vehicle installations*

IEC 60747 (all parts), *Semiconductor devices – Discrete devices*

IEC 60850, *Railway applications – Supply voltages of traction systems*

IEC 61148, *Terminal markings for valve device stacks and assemblies and for power conversion equipment*

IEC 61373, *Railway applications – Rolling stock equipment – Shock and vibration tests*

IEC 61881 (all parts), *Railway applications – Rolling stock equipment – Capacitors for power electronics*

IEC 61991, *Railway applications – Rolling stock – Protective provisions against electrical hazards*

IEC 62236-3-1, *Railway applications – Electromagnetic compatibility – Part 3-1: Rolling stock – Train and complete vehicle*

IEC 62236-3-2, *Railway applications – Electromagnetic compatibility – Part 3-2: Rolling stock – Apparatus*

IEC 62278, *Railway applications – Specification and demonstration of reliability, availability, maintainability and safety (RAMS)*

IEC 62497-1:2010, *Railway applications – Insulation coordination – Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment*
IEC 62497-1:2010/AMD1:2013

IEC 62498-1:2010, *Railway applications – Environmental conditions for equipment – Part 1: Equipment on board rolling stock*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-551:1998 and IEC 60050-811:1991, as well as the following, apply.

3.1 General

3.1.1

user

party which is responsible for the specification and the integration of the power converter into the railway vehicle

3.1.2

manufacturer

party which designs and manufactures the power converter

3.1.3

railway authority

organization which allows vehicle operators to operate railway vehicles and defines rules for safe operation

3.1.4

test specification

document that specifies the requirements for one or more tests

Note 1 to entry: For instance test acceptance criteria, test conditions, test methods.

Note 2 to entry: According to the specific terminologies used in the quality management systems of various organisations that perform tests on power converters for rolling stock, this document may have another title e.g. test plan.

3.2 Terms and definitions related to equipment

3.2.1

(electronic) (power) converter

an operative unit for electronic power conversion, comprising one or more electronic valve devices, transformers and filters if necessary and auxiliaries if any

Note 1 to entry: A converter is defined by the input and output electrical characteristics. The converter may comprise a discrete chopper, inverter, etc. or a combination of these not necessarily in one cubicle.

Note 2 to entry: The converter is a part of the propulsion (or auxiliary) equipment. The converter may include, for example, a line circuit breaker, filter, transformer, cooling system, etc.

[SOURCE: IEC 60050-551:1998, 551-12-01]

3.2.2**traction converter**

converter providing traction power

3.2.3**auxiliary converter**

converter providing power for auxiliary services

Note 1 to entry: For example, lighting, battery charging, air conditioning, cooling (main service), control circuits, etc.

3.2.4**direct converter**

an electronic converter without an intermediate link

3.2.5**indirect converter**

an electronic converter with an intermediate link

3.2.6**converter system**

system consisting of several converters required to operate connected together, each having different input and/or output characteristics and which also have different functional connections

Note 1 to entry: A converter system is defined by a system specification in addition to the individual specification of each different converter making up the system.

3.2.7**converter windings**

windings of a transformer connected to the terminals of the converter

3.2.8**auxiliary winding**

a winding or part of a transformer winding which supplies the auxiliary circuits

[SOURCE: IEC 60050-811:1991, 811-26-12]

3.2.9**semiconductor device**

device whose essential characteristics are due to the flow of charge carriers within a semiconductor

Note 1 to entry: The definition includes devices whose essential characteristics are only in part due to the flow of charge carriers in a semiconductor but that are considered as semiconductor devices for the purpose of specification.

[SOURCE: IEC 60050-521:2002, 521-04-01]

3.2.10**input and output**

input is the side which absorbs active power in motoring operation, the output side being that which delivers active power in motoring operation

Note 1 to entry: Electrical isolation. If individual electrical circuits (for example, input, output, control circuit) are specified as isolated, then the circuits are galvanically separated.

3.3 Terms and definitions related to electrical parameters

3.3.1

load profile

curve to illustrate the variance of current/power versus time under specified conditions such as

- for traction converter: starting and braking of the vehicle;
 - for auxiliary converter: starting and steady state running periods of the auxiliary loads;
- the line voltage is also considered

3.3.2

maximum instantaneous current

maximum specified current which the converter can commutate for a specified voltage

3.3.3

transient

pertaining to, or designating, a phenomenon or quantity which varies between two consecutive steady states during a time interval short compared with the time-scale of interest

[SOURCE: IEC 60050-702:1992, 702-07-78]

3.3.4

harmonic component

sinusoidal component of a periodic quantity having a harmonic frequency

[SOURCE: IEC 60050-551:1998, 551-20-07]

3.3.5

DC ripple factor

the ratio of half the difference between the maximum and minimum value of a pulsating direct current to the mean value of this current

Note 1 to entry: With low values of the DC ripple factor this quantity is approximately equal to the ratio of the difference to the sum of the maximum and the minimum value.

Note 2 to entry: $\text{DC ripple factor} = (I_{\max} - I_{\min}) / 2 \times I_{\text{mean}}$

[SOURCE: IEC 60050-551:1998, 551-17-29]

3.3.6

nominal value

value of a quantity used to designate and identify a component, device, equipment, or system

Note 1 to entry: The nominal value is generally a rounded value.

[SOURCE: IEC 60050-151:2001, 151-16-09]

3.3.7

rated value

value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

Note 1 to entry: Generally defined by the manufacturer.

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

3.3.8**operating point value**

quantity value assigned, generally by the user, for a specified operating condition of a component, device or equipment

3.3.9**special value**

quantity value assigned, generally by the user, for expected fault conditions within the supply or the load of a converter

4 Common clauses**4.1 General****4.1.1 Design**

The design process shall be visible and audible.

If the user requires details of this process for tender evaluation, the user shall define this in the tender documents.

4.1.2 Marking**4.1.2.1 Nameplate**

The converter shall be provided with a nameplate which shall be readable during the useful life of the converter and on which at least the following is inscribed:

- manufacturer's mark;
- number of main drawing and revision number and/or type designation;
- serial number;
- year of manufacture;
- mass.

4.1.2.2 Main terminals

The marking of the main terminals shall comply with the specifications given in IEC 61148.

4.1.3 Technical documentation**4.1.3.1 Documentation supplied by the manufacturer**

Documentation about the use and maintenance of the converter shall be provided by the manufacturer and shall include the following:

- device description (including functional description and technical data);
- type and routine test specification (list of tests, test methods, limits, tolerances, test conditions, acceptance criteria);
- results of the specified tests (test certificate);
- commissioning instructions;
- operating instructions;
- maintenance instructions;
- repair instructions;
- description of special tools for maintenance and repair purposes, if any;

- training programme and supporting media, to be detailed by agreement between the manufacturer and the user;
- declaration of materials which are required to be treated as special waste, when they are removed from service (either alone or with the converter).

4.1.3.2 Documentation to be supplied by the user

The user shall, if necessary, furnish a specification, which is primarily intended to give details of the agreements listed in Annex B. It is only necessary to enter an item in the specification if it differs from the normal requirement in this standard. The specification may also contain:

- general technical description of the application;
- special service conditions;
- supply system characteristics;
- load profile and duty cycles;
- EMC requirements;
- cooling requirements;
- ambient conditions;
- safety measures including fire behaviour requirements;
- features of electrical and mechanical design;
- details of the available maintenance and repair facilities.

Requirements shall be clear and univocal.

For example, statements which are not quantified like “Equipment shall not interfere with signalling and telecommunication facilities.” are not acceptable.

4.1.4 Reliability, availability, maintainability and safety

4.1.4.1 Reliability

The user may require the manufacturer to predict the reliability figure or meet the user’s reliability target. The method of calculation shall be agreed between the manufacturer and the user at the time of tendering.

The specification and verification of the reliability requirements shall be in accordance with IEC 62278.

4.1.4.2 Availability

The user may require the manufacturer to predict the availability figure or meet the user’s availability target. The method of calculation shall be agreed between the manufacturer and the user at the time of tendering.

The specification and the method of calculation and verification shall be in accordance with IEC 62278.

4.1.4.3 Maintainability

Maintenance requirements shall be defined by the user at the time of tendering. In addition, the equipment manufacturer shall define what maintenance procedures are necessary or prohibited. The maintenance procedure shall be agreed between the manufacturer and the user.

The specification and verification of these requirements shall be in accordance with IEC 62278.

4.1.4.4 Safety

Safety requirements shall be defined by the user at the time of tendering and agreed with the manufacturer.

The specification and verification of the safety requirements shall be in accordance with IEC 62278.

4.1.5 Useful lifetime

At the time of tendering, the useful lifetime of the converter shall be agreed between the manufacturer and the user. If the manufacturer intends to use components with a known life less than the useful life of the converter, their use and procedures for their regular replacement shall be agreed.

Recommendation of spare parts is given by the manufacturer.

4.2 Service conditions

4.2.1 General

The classes of service conditions described in IEC 62498-1 shall be applied unless different classes are specified by the user. The user shall specify clearly in his specification the class to consider, otherwise class with suffix 1 shall be assumed.

In the event of other conditions applying these should be selected from IEC 60721-3-5 if appropriate.

4.2.2 Altitude

The class of altitude above sea-level, at which the equipment shall perform as specified, shall be as given in IEC 62498-1, unless otherwise specified.

NOTE Altitude is relevant, in particular for air pressure level and its consequence on cooling systems and insulation.

4.2.3 Temperature

4.2.3.1 Ambient temperature

The class of ambient temperature, at which the vehicle, the converter and its components will operate, shall be given according to IEC 62498-1:2010, Table 2 unless otherwise specified.

For lifetime calculations a temperature histogram should be provided by the user for the ambient air external to the vehicle or for the converter cooling medium. Otherwise the reference temperature TR1 according to IEC 62498-1:2010, Table 3 shall be applied.

A reference temperature is considered as being the permanent temperature for which the effects on material ageing are equivalent to those of the climatic temperature during the lifetime.

NOTE Thermal ageing is an exponential function of temperature (e.g. see the IEC 60216 series for insulating materials), i.e. the reference temperature is usually higher than the arithmetic mean temperature.

For altitude class AX, the dependency between altitude and temperature shall be provided by the user through a temperature histogram for each relevant altitude range (e.g. 0 m to 1 000 m and 1 000 m to 2 000 m).

4.2.3.2 Start-up temperatures

This subclause applies to parked vehicles which are not connected to any power source.

The maximum start-up temperature for converters directly exposed to the ambient external to the vehicle shall be as specified in 4.2.3.1.

For converters installed inside a vehicle compartment the maximum start-up temperature shall be 70 °C.

Table 1 gives the different classes of start-up load characteristics at which the equipment shall perform as specified. There is no preferred class; the class should be chosen to be appropriate to the use of the converter. The choice of class of start-up temperature shall be agreed between the manufacturer and the user.

Table 1 – General classes of start-up load characteristics

| Load class | Start-up power |
|---|--|
| SU1 | Rated voltage, no load until within specified temperature range ^a |
| SU2 | 50 % rated power until within specified temperature range ^a |
| SU3 | 100 % rated power immediately ^b |
| SU4 | Other specified conditions |
| ^a For example, the traction power of a locomotive may not necessarily be available immediately after connection to the supply. The equipment can be brought to the working temperature by auxiliary equipment. | |
| ^b For example, in some cases, auxiliary converters have to perform immediately after connection to the supply. | |

4.2.4 Other environmental conditions

The converter shall be designed for the conditions of humidity and pollution specified in IEC 62498-1.

4.2.5 Mechanical stress

4.2.5.1 Shock and vibration

The converter, when supported at its designed fixings (including anti-vibration mounts when fitted), shall be able to withstand vibration and shock as stated in IEC 61373.

4.2.5.2 Other accelerations

When a vehicle is passing through a curve or is stopped on a curve, the allowable net acceleration components acting perpendicularly to the vertical axis of the vehicle shall not exceed the values given in IEC 61373. The converter, including the cooling system, shall continue to perform as specified under transverse and longitudinal accelerations as specified in IEC 61373. These requirements shall be agreed between user and manufacturer.

4.2.6 Load profile

In view of the fact that the characteristics of the load profile may affect the operating characteristics of a converter or converter components, the load profile shall always be specified. This profile shall be calculated by the duty cycle and agreed by manufacturer and user.

NOTE 1 The profile is used to calculate the worst-case conditions for the components involved and to define the conditions for the temperature-rise test (4.5.3.13).

NOTE 2 For traction converters the duty cycle can be a typical theoretical cycle (acceleration, constant speed, braking and stop) or a specified cycle for the vehicle in which the converter is mounted. Generally, this cycle is defined for the nominal input voltage for traction and in other cases, such as braking at a specified voltage.

NOTE 3 For auxiliary converters, see 7.2.3.3.

4.2.7 Supply-system characteristics

4.2.7.1 General

The user should define the characteristics of the supply system in motoring and in braking operation and under possible fault conditions.

4.2.7.2 AC supply systems

4.2.7.2.1 Main characteristics of the AC line voltage

The main characteristics of the different AC supply systems in use are described in IEC 60850. The equipment shall perform as specified when it is used within the system(s) for which it is intended.

4.2.7.2.2 Step change of line voltage

The step change of the line voltage shall be specified by the user; the corresponding performance of the converter shall be agreed between the manufacturer and the user.

4.2.7.2.3 Distortion of AC line voltage

The line voltage of the traction system shall be assumed to be sinusoidal to a great extent.

The equipment shall perform as specified when the steady-state AC line voltage contains levels of harmonic and inter-harmonic voltages less than, or equal to, the values agreed between manufacturer and the user.

4.2.7.2.4 Overvoltage in AC systems

The converter, including its protective devices, connected to the transformer and input filter (if any) shall be able to withstand the input over voltages and transient energies given in IEC 60850. These are considered as normal conditions; any substantial deviations shall be specified by the user.

4.2.7.2.5 AC system impedance

Since the AC supply impedance affects the performance characteristics of the equipment and may vary with the position of the vehicle, the characteristics including the maximum and minimum values of this impedance shall be specified by the user.

If necessary and where possible, resonant frequencies of the AC system shall be specified by the user, either directly or by means of a model of the system.

The effect of the presence of other vehicles on supply impedance and resonance frequencies should also be taken into account.

4.2.7.3 DC supply system

4.2.7.3.1 Main characteristics of the DC line voltage

The main characteristics of the different DC supply systems in use are given in IEC 60850. The equipment shall perform as specified when it is used within the system(s) for which it is intended.

It will be assumed that the line voltage of the traction system is the DC voltage converted from a three-phase sinusoidal voltage by full-wave rectification with a pulse number of six or more.

The user shall state any other arrangement, for example, pulse number other than 6, use of phase-controlled rectification, presence of regenerative braked vehicles on the system or harmonic filters in the substations.

4.2.7.3.2 Step change of line voltage

The step change of the line voltage shall be specified by the user; the corresponding performance of the converter shall be agreed between the manufacturer and the user.

4.2.7.3.3 Overvoltage in DC systems

The converter including its input filter and protective devices, if any, shall be able to withstand the input over voltages and transient energies given in IEC 60850. Any substantial deviations shall be specified by the user.

4.2.7.3.4 DC system inductance and resistance

Since the DC supply impedance and resistance affects the performance characteristics of the equipment and may vary with the position of the vehicle, the characteristics including maximum and minimum values of this impedance and resistance shall be specified by the user.

The presence of other vehicles should also be taken into account.

4.2.7.3.5 Distortion of DC line voltage

The equipment shall perform as specified when the steady-state DC line voltage distortion is less than, or equal to, the values agreed by the manufacturer and the user.

4.2.7.4 Other supply systems

Where the converter is supplied by a supply such as

- battery;
- generators;
- shore supply (workshop supply);
- other electric power sources,

the user shall specify rated values and limit values for the voltage and impedance of the supply, and in the case of AC supply, the frequency and wave form.

4.2.8 Interference

4.2.8.1 General

The converter will produce interference by conduction or radiation which may affect the supply, telecommunication or signalling systems, or other equipment in the vehicle or neighbourhood of the transportation system. The input current of the converter normally contains harmonic and inter-harmonic components. These are due to harmonics present in the traction supply or are generated by the converter. Where a converter supplies other equipment on the train, interference with other equipment on the train (for example, coach heating supplies) should be considered.

The equipment shall comply with the requirements given in IEC 62236-3-1 and IEC 62236-3-2.

4.2.8.2 Interference with the supply system (emission)

The responsibility for compatibility between the converter, the vehicle and the supply system is shared among the converter manufacturer and the user. The process to verify compatibility shall be agreed upon at the time of contract.

The permissible AC harmonic current contents of the whole system shall be defined by the user.

4.2.8.3 Interference with radio and telecommunication systems

The converters may cause disturbance in the radio and telecommunication systems. The requirements in IEC 62236-3-2, concerning protection of radio networks and telecommunication lines against interferences shall apply. IEC 62236-3-1 should be considered.

4.2.8.4 Interference with signalling systems

The responsibility for compatibility between the converter, the vehicle and the signalling system is shared among the converter manufacturer and the user. The process to verify compatibility shall be agreed upon at the time of contract.

Detailed requirements regarding interference with the signalling system shall be defined by the railway authority and referred to in the specification of the user.

For example:

- the maximum allowable currents at signalling frequencies with a specified bandwidth and duration in the supply system caused by the converter. Signalling frequencies are usually in the frequency range below 150 kHz, whereby harmonic content of switching transients can lie within this range.

The manufacturer should take into account that the total interference current from the line and from the vehicles should not exceed the level specified by the railway authority and referred to in the specification of the user;

- the minimum input impedance for the vehicle at the signalling frequencies.

If rolling stock is intended to run on several railway networks, the agreement should take into account the requirements applicable to each network;

- the maximum allowable trackside magnetic fields.

NOTE Trackside sensors could be affected in their working frequency range by magnetic fields.

4.2.9 Input current limitations

Any limitation of the steady-state and in-rush or switch-on current shall be stated by the user.

The user shall also state the short-term current capability of the supply system and the nature of the protection network.

4.2.10 Influence on the environment

4.2.10.1 Acoustic noise

Table 2 defines the acoustic classes. The maximum level of acoustic noise emitted by the converter shall comply with one of these classes.

Lower values may be stated in the specification (see 4.1.3.2).

Table 2 – Classes of acoustic noise

| Class | N1 dB _A | N2 dB _A | N3 dB _A | N4 dB _A | N5 dB _A | N6 dB _A | N7 dB _A | N8 dB _A |
|---------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|------------------------------|
| Noise level $L_{\overline{pA}}$ | 80 | 75 | 70 | 65 | 60 | 95 | 90 | 85 |

The noise level is defined by the parameter $L_{\overline{pA}}$ = A-weighted surface sound pressure level at 1 m distance.

Test methods are defined in 4.5.3.12.

In the case of a converter with a separate cooling system, if this system is used only for the converter cooling, it is considered as a part of the converter to define the acoustic class. The maximum noise level of the acoustic noise for the complete propulsion system or the complete auxiliary equipment is not covered in this standard. It is necessary to take into account that, after mounting the converter on the vehicle, the emitted noise level will depend upon its location and precautionary measures, if any. Classes N6, N7, N8 are allowed only if the noise is decreased by installation or by operating methods. The choice of class of acoustic noise shall be agreed between the manufacturer and the user. The noise of the converter, when the converter is mounted on the vehicle, is the responsibility of the main contractor (vehicle contractor).

4.2.10.2 Maximum temperature of accessible parts

The maximum temperature of accessible parts shall be in accordance with Table 3 of IEC 60077-1:1999.

4.3 Characteristics

4.3.1 Characteristics of components

4.3.1.1 Specifications

Components shall comply with specifications which define their functional and physical parameters with sufficient precision to allow subsequent redesign or sourcing of an interchangeable device from an alternative supplier.

4.3.1.2 Quality system

Suppliers of components shall have a compliant quality system.

4.3.2 Characteristics of semiconductor devices

Semiconductor devices of power circuits shall comply with the specifications given in the IEC 60747 series and their function under the conditions specified in the present standard shall be ensured.

4.3.3 Characteristics of transformers, reactors and capacitors

The characteristics of power transformers and reactors used in converters shall comply with the requirements of IEC 60310. Those of capacitors shall comply with the requirements of IEC 61881 and IEC 60384-4.

Where there is a contradiction between the service conditions specified in IEC 60384 and IEC 61881 and this standard, this standard takes precedence. Special attention is particularly to be given to shock, vibration, operating conditions, and tests.

4.3.4 Characteristics of converters

4.3.4.1 Geometrical characteristics – conformity to drawings

The converter shall be defined by means of drawings which specify in particular:

- components;
- fixing points;
- accessibility requirements;
- gripping points for handling;
- electrical connections and air ducts or connections to the cooling system;
- dimensions and tolerances;
- total calculated mass of converter assembly and cooling medium;
- calculated position of the centre of gravity.

The specification and the design shall be agreed between the manufacturer and the user.

4.3.4.2 Characteristics of cooling systems

The essential parameters of the cooling system shall be defined in the specification agreed upon which may include the following:

- kind of cooling medium;
- flow rates for steady-state and transient conditions;
- inlet and outlet temperatures;
- pressure of operation (rated value and test value);
- pressure drops;
- power dissipation;
- additional information (for example, air distances to adjacent parts, power losses), if the surface is used for cooling purposes;
- impermeability of closed-circuit cooling systems (if employed);
- type of filter and its maintenance requirements (if any);
- maintenance information for cooling medium (for example, additives for water cooling).

4.3.4.3 Degree of protection

If specified, the degree of protection shall be selected from those defined in IEC 60529.

4.3.4.4 Electrical characteristics

4.3.4.4.1 Input quantities

The converter shall be capable of being connected to one or more of the supplies specified in 4.2.7. The converter may be connected to the supply directly or through intermediate equipment, for example, a transformer or input filter.

The user shall specify the supply characteristics, taking into account the requirements of 4.2.8.

The converter, including its protective devices, if any, shall be able to withstand the input over voltages given in 4.2.7.2.4 and/or 4.2.7.3.3 without damage. The user shall state whether or not the protective devices used are required to be re-settable.

4.3.4.4.2 Output quantities

4.3.4.4.2.1 General

Rated values refer to the converter and operating point values refer to the application.

4.3.4.4.2.2 Rated values

The rated values of the following output quantities shall be defined in the specification:

- voltage (fundamental r.m.s. or mean value);
- current (fundamental r.m.s. or mean value);
- turn-off current;
- power factor of the fundamental frequency wave;
- frequencies (fundamental, carrier, and modulation frequency).

4.3.4.4.2.3 Operating point values

The output quantities shall be defined by the manufacturer in a specification containing particular operating points in accordance with 4.2.7. The specification should include:

- power (active, reactive);
- voltage (fundamental r.m.s. or mean value);
- voltage waveform;
- current (fundamental r.m.s. or mean value);
- current peak value;
- admissible time of operation at each particular operating point;
- frequencies (fundamental, carrier, modulation).

This should be agreed between the manufacturer and the user.

4.3.4.4.2.4 Special values

The characteristics on short circuit and open circuit shall be described according to 4.1.3.2. Any particular requirements from the user shall be specified according to 4.1.3.2.

This should be agreed between the manufacturer and the user.

4.3.4.4.3 Power efficiency

The power efficiency shall be determined for nominal supply system characteristics (see 4.2.7) at least at one of the operating points of 4.3.4.4.2.3 preferably at rated operation conditions.

Power efficiency shall be determined for both directions of energy flow through the converter, if applicable.

This should be agreed between the manufacturer and the user.

NOTE Definition of power efficiency is given in IEC 60146-1-1.

4.3.4.4.4 Electrical isolation

If the converter ensures electrical isolation between the supply and the load, this shall be stated in the specification of the converter.

4.3.4.4.5 Interfaces between converter and control unit

Where the converter (power part) and the control unit are separated, the functional interfaces between them shall be specified.

4.4 Technical requirements

4.4.1 Insulation co-ordination

The minimum clearances and creepage distances shall comply with and be verified according to IEC 62497-1:2010/AMD1:2013.

The basis for the determination of the minimum clearances is the rated impulse voltage and the environment.

For altitudes higher than 2 000 m above sea-level, the altitude correction factors for clearances according to IEC 62497-1:2010/AMD1:2013, Table A.9 and Table A.10 shall be applied. Linear interpolation is allowed.

The basis for the determination of minimum creepage distances is the rated insulation voltage, the environment and the insulation material.

The user shall provide the information required by the manufacturer for the definition of the insulation co-ordination.

4.4.2 EMC requirements for converters

4.4.2.1 General

The EMC requirements for converters are given in IEC 62236-3-2.

The user shall declare devices from which high disturbances and/or low susceptibility may be expected.

4.4.2.2 Electromagnetic fields

4.4.2.2.1 Interference with trackside equipment

Magnetic fields of the vehicle due to the converter, which can affect the trackside equipment, shall be limited according to either IEC 62236-3-2 or an individual EMC plan of the project.

This permitted field is one which is tolerable to trackside communication circuits and sensors.

4.4.2.2.2 Effects on human beings

The magnetic fields and induced voltages allowed in driver and passenger compartments (in general, all environments where passengers may be present) shall be specified by the user. The user and the manufacturer shall agree on the requirements on converter level.

For information, see Annex C.

4.4.3 Fault effects

The effects which faults in the converter have on components, such as the motor, the transformer, the filter etc. which are connected to it, shall be considered. Similarly, the effects which faults in the motor, the transformer, the filter etc. have on the converter shall also be considered. These fault effects shall be specified and agreed between the manufacturer and the user.

Unless specified, failure mode effects analysis is not required.

4.5 Tests

4.5.1 General

4.5.1.1 Overview

The aim of the tests is to prove conformity with the relevant specification.

It is recommended that the number of expensive tests be limited to those which are necessary. This standard is so framed that most of the tests can normally be carried out in the manufacturer's workshop.

If it is not possible to test the equipment in the manufacturer's workshop by methods defined and agreed on, the tests can also be carried out in a special laboratory or on a vehicle. The tests concern mainly the power part of the converter including the semiconductor drive units (SDU).

The test procedure and the test parameters shall be specified by agreement between the manufacturer and the user.

For the converter tests it is possible to use an electronic control unit (vehicle control unit) different from the production equipment.

4.5.1.2 Categories of test

4.5.1.2.1 General

There are three categories of tests:

- type tests;
- routine tests;
- investigation tests.

NOTE Combined tests are not covered by this standard.

4.5.1.2.2 Type tests

Before executing the type tests the equipment shall be checked by the routine test (see Table 3).

Type tests shall be carried out to verify that a product will meet the requirements specified and agreed upon between the manufacturer and the user.

The type tests shall be performed on a single unit of a given design and manufacturing procedure. For this test, in principle, all parts of the converter should be identical to the series production equipment unless the restriction of 4.5.1.1 concerning the electronic control unit is applied.

If significant modifications to the converter are made after the type test, there should be an agreement between the manufacturer and the user about repeating parts or all of the test.

If the methods of test necessitate the use of some components or a control unit different from those of series production, it is necessary to have an agreement between the manufacturer and the user.

If a complete converter or one of its components is identical with, or similar to, one previously tested, the manufacturer may supply a certificate of previous tests which shall at least cover the contractual requirements. In such cases, unless otherwise agreed, it is not necessary to repeat the test.

In the case of production of a great number of identical converters, subject to previous agreement between the manufacturer and the user, some of these tests may be repeated on converters, or on one of their components, drawn from current production or deliveries, so as to confirm that the product quality still meets the specified requirements.

Type tests which are subject to agreement between the manufacturer and the user are to be carried out only if it is so stated in the specification.

4.5.1.2.3 Routine tests

Routine tests are carried out to verify that the converter is correctly assembled and that all components function properly and safely. Routine tests shall be performed by the manufacturer on each item of a given type. The manufacturer and the user may agree to adopt an alternative test procedure. This may permit reduced routine testing of all converters or may require the full tests on a portion of converters chosen at random from those produced within the frame of the contract.

Routine tests which are subject to agreement between the manufacturer and the user are to be carried out only if it is so stated in the specification.

4.5.1.2.4 Investigation tests

Investigation tests, the object of which is to obtain additional information on the use of the converter, shall be subject to previous agreement between the manufacturer and the user. The performance of these tests is required only if they are expressly specified in the contract.

The results of investigation tests may not be used as reason for refusing acceptance of the equipment or to invoke penalties.

NOTE Investigation tests are not described in this standard.

4.5.2 Converter tests

4.5.2.1 General

Type tests and routine tests intended to verify the general characteristics of converters shall be carried out in accordance with the subclauses given in Table 3 and detailed in 4.5.3.1 to 4.5.3.22.

The routine test shall be carried out in the workshop. The location where tests are generally carried out should be as given in Table 3.

All these tests on converters may be carried out at the ambient temperature of the workshop or vehicle. Ambient temperature during each type test shall be recorded.

Type tests and routine tests intended to verify the characteristics of a particular type of converter shall be carried out in accordance with the requirements of this clause and (if applicable) Clauses 5 to 8 of this standard. In particular, tests with specified load are given in Clause 5 or 7.

Separate tests of different outputs: in the case of a converter with multiple outputs, it is necessary to carry out the electrical routine and type test for each output.

4.5.2.2 Tests of converter components and subassemblies

4.5.2.2.1 General

The converter components and subassemblies listed below shall be subjected to tests according to the following standards, before assembly in the converter:

- power semiconductor devices: IEC 60747;
- control electronic and low-current components: IEC 60571;
- semiconductor drive units (SDU): IEC 61287-1 and IEC 60571;
- power transformers and reactors: IEC 60310;
- power electronics capacitors: IEC 61881, IEC 60384-4;
- semiconductor device assemblies: if any, shall be tested in accordance with a test specification provided by the manufacturer of the semiconductor device assembly;
- power-resistors: IEC 60322.

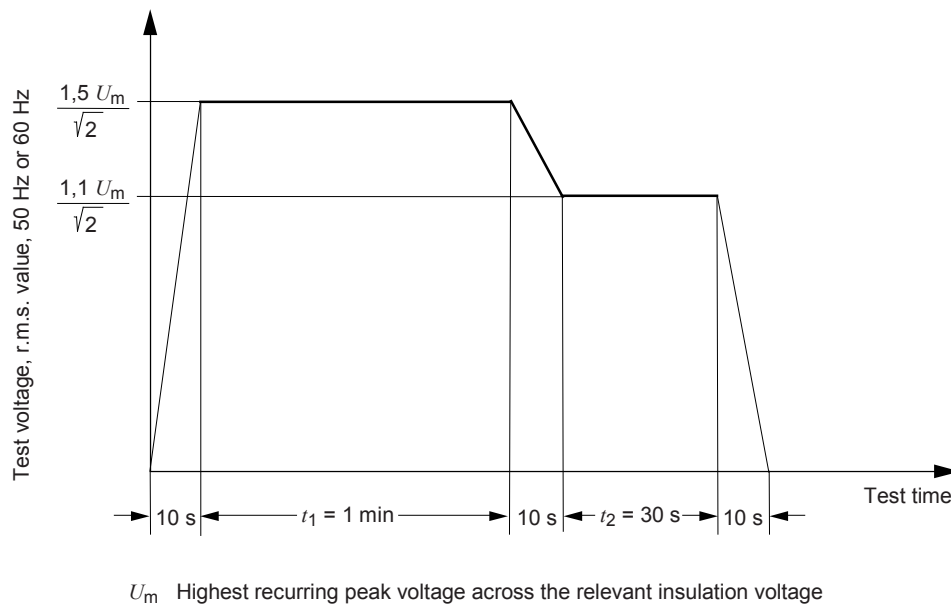
4.5.2.2.2 Partial discharge test

This is a component test. The execution of the test is subject to the relevant component standard.

This test is carried out to verify the insulation of elementary components or subassemblies.

It is recommended to perform this test for equipment working at 1 500 V or more, especially for new components and for semiconductor device assemblies with new insulating technology.

IEC 60270 gives test and calibration methods and describes some types of test circuits. Among these test methods, it is recommended to use the following.



IEC 1882/14

Figure 1 – Partial discharge test – Voltage versus time

An AC r.m.s. voltage (50 Hz or 60 Hz) equal to $1,5 U_m / \sqrt{2}$ or higher is applied. The voltage is ramped up to $1,5 U_m / \sqrt{2}$ in 10 s and is maintained for $t_1 = 1$ min (see Figure 1). During this time t_1 , some partial discharges may be observed.

After t_1 , the voltage is decreased to $1,1 U_m / \sqrt{2}$ in 10 s. The voltage $1,1 U_m / \sqrt{2}$ is applied for $t_2 = 30$ s. During the last 5 s of t_2 , the level of partial discharge is measured.

Acceptance criteria: Acceptance is based on the measured level of partial discharge as specified by the manufacturer.

EXAMPLE For a component, a typical value to pass the test is 10 pC and for a subassembly 50 pC.

4.5.2.3 List of converter tests

The list of general tests to be performed on a complete converter and their classification is given in Table 3 below. This list contains a minimum of tests.

Table 3 – List of tests

| Nature of test | Location | Type test | Routine test | Subclause |
|---|----------|----------------|----------------|-----------|
| Visual inspection | W.S. | | X | 4.5.3.1 |
| Verification of dimensions and tolerances | W.S. | X | ^b | 4.5.3.2 |
| Weighing | W.S. | X | | 4.5.3.3 |
| Marking inspection | W.S. | | X | 4.5.3.4 |
| Cooling system performance tests | W.S./V | X | | 4.5.3.5 |
| Leakage test | W.S./V | | X | 4.5.3.5.4 |
| Test of the degree of protection | W.S. | X ^a | | 4.5.3.6 |
| Dielectric test | W.S. | | X | 4.5.3.7 |
| Insulation resistance test | W.S. | | X ^a | 4.5.3.8 |
| Tests of mechanical and electrical protection and measuring equipment | W.S. | X | X | 4.5.3.9 |
| Light load test | W.S. | | X | 4.5.3.10 |
| Commutation test | W.S./V | X | | 4.5.3.11 |
| Acoustic noise measurement | W.S. | X | | 4.5.3.12 |
| Temperature-rise test | W.S. | X | | 4.5.3.13 |
| Power loss determination | W.S. | X | | 4.5.3.14 |
| Supply overvoltage and transient energy test | W.S./V | X | | 4.5.3.15 |
| Sudden variations of load | W.S./V | X ^a | | 4.5.3.16 |
| Safety requirements inspection | W.S. | X | | 4.5.3.17 |
| Tests for withstanding vibration and shock | W.S. | X | | 4.5.3.18 |
| Test of electromagnetic compatibility | W.S./V | X | | 4.5.3.19 |
| Step change of line voltage test | W.S./V | X ^a | | 4.5.3.20 |
| Short-time supply interruption test | W.S./V | X ^a | | 4.5.3.21 |
| Current sharing | W.S./V | X ^a | | 4.5.3.22 |
| W.S.: The test shall be made in the workshop. | | | | |
| W.S./V: The test can be made in the workshop or on the vehicle. | | | | |
| NOTE The tests listed in this table and carried out on the vehicle are considered as converter tests but can also form part of a combined test. | | | | |
| ^a The execution of the test is subject to agreement between the manufacturer and the user. | | | | |
| ^b Some sizes and tolerances may be checked by a routine test, according to the requirements of the specification. | | | | |

4.5.3 Description of tests

4.5.3.1 Visual inspection

This is a routine test.

The object of the visual inspection is to prove that the converter is free from physical defects and that surface treatments have been duly carried out.

It includes checking for the presence of all internal and interface electrical and mechanical components and their connections.

The visual inspection also includes checking that the electrical and mechanical connectors have been assembled correctly and that the connections between components follow the specified routes.

If visual inspection is not sufficient to verify that the specified safety requirements of the converter are met, then appropriate additional tests shall be carried out.

Acceptance criteria: The converter shall be free from physical defects, all electrical and mechanical components shall be as specified and assembled correctly, and the safety requirements are met as agreed between the manufacturer and the user.

4.5.3.2 Verification of dimensions and tolerances

This is a type test.

Dimensions and their tolerances shall be checked.

Acceptance criteria: All dimensions which are chosen for the check shall be within the specified tolerances.

4.5.3.3 Weighing

This is a type test.

If the mass is specified in the contract, the converter shall be weighed.

Acceptance criteria: The mass shall correspond to the specified value within the allowed tolerances.

4.5.3.4 Marking inspection

This is a routine test.

Acceptance criteria: The marking shall comply with the requirements of 4.1.2.

4.5.3.5 Cooling system performance tests

4.5.3.5.1 General

This is a type test.

This test may be performed either on a complete converter or on a partially finished converter which is representative of a finished converter.

There are two possible cases: a converter with an integrated cooling system and a converter with a separate cooling system.

4.5.3.5.2 Converter with integrated cooling system

The object of this test is to measure the flow of the cooling medium passing through the various components concerned and to verify whether it complies with the specified flow. If the fan, pump or radiator set(s) form(s) part of the converter, the test shall be carried out:

- with the converter having specified input and output cooling conditions;
- with power supplied to the cooling system at the following conditions:
 - at the nominal voltage and/or nominal frequency of the power supply of fan or pump;

at the voltage and/or frequency corresponding to the minimum value specified.

Acceptance criteria: The quantities of all parameters which are listed for checking in the test specification shall be within the specified limits. An allowance for tolerances in the test equipment shall be permitted.

NOTE In some cases, the flow can be variable, for example, when using braking energy to supply the cooling system.

4.5.3.5.3 Converter with separate cooling system

In the case of a converter without an integrated cooling system, the object of this test is to verify that the pressure drop across the converter is in accordance with the specified range of values, to measure the flow of cooling medium passing through the various components concerned and to verify the increase of temperature (ΔT) of the cooling medium under specified load conditions of the converter. This test may be performed on an adequate model of the converter.

If the fan, pump, or radiator sets do not form part of the converter, the tests shall be carried out with a suitable fan, pump or radiator set. The flow and pressure of the cooling medium shall comply with the values specified by the manufacturer of the converter or in the specification. The pressure drop shall be measured and the inlet temperature of the cooling medium shall be noted.

Acceptance criteria: The quantities of all parameters which are listed for checking in the test specification shall be within the specified limits. An allowance for tolerances in the test equipment shall be permitted.

4.5.3.5.4 Leakage test

This is a routine test.

Where closed-circuit fluid cooling is employed, a leakage test shall be performed to prove that no leakage occurs in the complete cooling system.

Acceptance criteria: The test method and its acceptance criteria shall be subject to an agreement between the manufacturer and the user.

Heat pipe devices should be tested before they are installed in the converter. In this case, a special test with the converter is not necessary.

4.5.3.6 Test of the degree of protection

This is a type test. The execution of the test is subject to agreement between the manufacturer and the user.

If a test of the degree of protection is stipulated in the specification, it shall be performed according to IEC 60529, for the degree of protection specified in 4.3.4.3. For dust tests (IP 5X and IP 6X) on large units (complete high-power converters), the use of other methods, as described in IEC 60529, is allowed.

4.5.3.7 Dielectric test

4.5.3.7.1 General

This is a routine test.

Dielectric tests are carried out to verify the correct state of a completely assembled converter. They are not carried out to verify the insulation of elementary components or clearances and creepage distances.

The converter main terminals and component terminals within the same circuit, such as the device terminals described in 8.1 shall be connected to each other.

Switchgear and contactors shall be closed or bridged.

No circuit part of the converter shall be left floating during the test.

Components or subassemblies not metallically connected to the circuit under test (for example control circuits, motors or fans) shall be grounded during the dielectric test.

If components or subassemblies ensure the insulation between circuits of different voltage levels (for example, pulse transformers, transducers), the terminals which are not connected to the circuit under test shall be connected to the ground.

If any component or subassembly is not submitted to the dielectric test of the converter, its terminals shall be grounded.

Components or subassemblies may be disconnected during the test such as:

- voltage limiters protecting the basic insulation of the converter;
- Y-capacitors in EMC filters;
- Grounding resistors, if any;
- Pre-tested subassemblies and components.

The disconnection of components shall be cited in the test specification and the test report.

The test shall be carried out at ambient workshop temperature.

Acceptance criteria: The test is declared successful if no dielectric fault occurs while the test voltage according to 4.5.3.7.4 is applied.

4.5.3.7.2 Dielectric test of converter equipment with parts installed separately

All equipment parts shall either be tested separately according to the relevant product standard or be connected with each other and then tested according to 4.5.3.7.3.

4.5.3.7.3 Dielectric test of a converter arranged in a single housing

- Direct converter

The test voltage, in accordance with 4.5.3.7.4, is applied between the terminals connected together and the housing.

- Indirect converter and converter system

Each part of the converter may be tested separately with a different test voltage. The test voltage, in accordance with 4.5.3.7.4, is applied between terminals connected together for the purpose of the test and the housing (ground). All other terminals are connected to ground during the test.

4.5.3.7.4 Test voltage

The test voltage level shall be selected according to Annex B of IEC 62497-1:2010/AMD1:2013 for Power-frequency or DC test, which is based on the rated impulse voltage.

In order to prevent pre-damages of increasingly used solid insulation, the test voltage should be applied for only 10 s.

If the chosen test method is power frequency and if the test has to be repeated, the test voltage shall be reduced to 80 % of the initial test voltage.

Specifications applying to components or subassemblies should draw attention to the repeated dielectric test on the complete converter.

4.5.3.8 Insulation resistance test

This is a routine test. The execution of the test is subject to agreement between the manufacturer and the user.

One minute after the dielectric test according to 4.5.3.7, the insulation resistance shall be measured by applying a DC voltage of at least 500 V. The insulation resistance shall be not less than 1 M Ω for rated insulation voltages (U_{Nm}) not exceeding 1 000 V.

For higher values of U_{Nm} , the insulation resistance shall exceed 1 000 Ω/V .

Grounding resistors, if any, shall be disconnected during the insulation tests as far as necessary.

4.5.3.9 Tests of mechanical and electrical protection and measuring equipment

4.5.3.9.1 General

This is a type and routine test.

4.5.3.9.2 Routine test

The object of this test is to verify that the mechanical and electrical protection and measuring equipment functions correctly. The power circuits of the converter are not necessarily energized for this test.

Acceptance criteria: The test method and its acceptance criteria are the responsibility of the manufacturer and shall be agreed with the user.

4.5.3.9.3 Type test

The object of this test is to verify that the mechanical and electrical protection and measuring equipment functions correctly in the whole range of operating conditions according to its design specification. The converter should normally be energized for this test.

Acceptance criteria: The test method and its acceptance criteria are the responsibility of the manufacturer and shall be agreed with the user

4.5.3.10 Light load test

This is a routine test.

This test is to verify that the power circuits of the converter function properly. During the test the complete converter (or its line-side, generator-side, or load-side parts) is supplied according to the nominal input voltage and is operated with an output current to be agreed upon (exceptions are defined in 5.2.2.5 and 6.2.3.2). A suitable load is chosen. This load can be the specified load or a substitute load such as resistors and inductors. All signal and power outputs of the converter shall be checked.

Where components are connected in series their correct voltage sharing shall be in accordance with the specified tolerances.

This test is a short-time test at less than rated output power and is not intended for temperature rise.

In the case of an indirect converter, the line-side, generator-side and load-side converter may be tested independently.

Acceptance criteria: All functions which are described in the test specification shall be performed without difficulties. The quantities of all parameters, which are listed for checking in the test specification, shall be within the specified limits.

4.5.3.11 Commutation test

This is a type test.

This test is carried out to verify that the converter will commute the specified maximum instantaneous current. The input voltage is chosen to apply the worst-case conditions to the semiconductors (maximum voltage for turn-off power devices, for example, GTO and IGBT, and minimum voltage for a forced-commutated thyristor circuit).

Acceptance criteria: The test is declared successful if the switched output current is equal to, or higher than, the maximum value specified for the converter, without damage to any of the components.

4.5.3.12 Acoustic noise measurement

4.5.3.12.1 General

This is a type test.

4.5.3.12.2 Test methods

The method is defined by IEC 60076-10:2001 in which the term “transformer” shall be replaced by “converter” and in which Clauses 3, 4, 6 (6.2 and 6.3 are excluded), 7 (7.3 is excluded), and 11, as well as 10.3 and Annex A are relevant.

NOTE IEC 60076-10:2001 specifies the determination method of sound power level. For the purpose of this standard, only a part of IEC 60076-10:2001 related to sound pressure measurement method at 1 m distance from the principal radiating surface is used.

4.5.3.12.3 Operating conditions

During the test, the converter shall be in operation. For an auxiliary converter, the operating point shall be defined by the rated output power. If there are some particular operating modes, for example, a starting motor compressor, the mode corresponding to the maximum noise level will be defined by a preliminary test and shall be chosen as the operating point. For a traction converter, the operating point shall be agreed between the manufacturer and the user.

4.5.3.12.4 Particular conditions

In some cases, it is possible to have particular conditions such as:

- emergence of fixed audible frequency;
- cooling system with several speeds.

The related test conditions shall be defined by agreement between the manufacturer and the user.

4.5.3.13 Temperature-rise test

4.5.3.13.1 General

This is a type test.

The manufacturer shall define in the type-test specification a list of components whose temperature shall be measured. The user may modify this list.

The temperature, of listed components shall be measured when the converter is subjected to the load profile or to equivalent conditions. Test conditions shall be agreed between manufacturer and user. For an auxiliary-converter, see 7.5.7.

The method of measurement for each component in this list shall be specified: direct (4.5.3.13.2), indirect (4.5.3.13.3) or by calculation with respect to a measured reference point (4.5.3.13.4). It shall also be agreed if the test is to be carried out on a sub circuit or on the whole circuit.

The temperature rise is defined as the temperature difference between the inlet temperature of the cooling medium to the converter and the temperature of the component of concern. The ventilation conditions or the circulation conditions of a liquid cooling medium to be used for this test shall be in accordance with those given in 4.5.3.5.

In the case of cooling by natural air convection or by supported convection due to the movement of the vehicle, the test is to be carried out by simulation of the specified cooling conditions.

In the case of very high power converters whose duty cycle may not be reproduced in the workshop, tests may be performed at reduced load or on sub circuits (part of converter). The methods of performing these tests shall be stated in the type-test specification.

The maximum temperature of any component shall be calculated from the results of the temperature rise test by extrapolation considering the difference between the temperature rise test conditions and the specified operating conditions.

Acceptance criteria: This test is declared successful if the extrapolated maximum temperature of any component does not exceed the specified limit.

4.5.3.13.2 Direct temperature measurement

The temperature may be measured directly with a temperature sensor (resistive thermometer, thermocouple, temperature sensitive sticker, infrared camera, etc.) for instance on:

- bus bars;
- resistors;
- capacitors;
- dry type transformers and inductors (IEC 60310);
- connecting junctions;
- heat sinks.

4.5.3.13.3 Indirect temperature measurement

The temperature is derived from the measurements of other physical parameters such as voltage, current, resistance, etc. For instance:

- the average temperature of a winding by measuring the variation of the DC resistance;

- the average temperature of a braking resistor by measuring the variation of the voltage and current.

4.5.3.13.4 Calculation method of temperature

With components having high internal power dissipation density, especially under surge conditions, the zone where the critical temperature may be exceeded is often not accessible for direct measurement of the temperature.

Examples are:

- junction of power semi-conductors (IEC 60747-15);
- active part of voltage arrestors;
- fuse wire of fuses;
- immersed transformers and inductors (IEC 60310).

In such cases, the temperature is directly measured at a point close to the critical zone.

The temperature difference from this point to the critical zone shall be calculated. The calculation is based on data provided by the manufacturer of the component or by the manufacturer of the converter, who shall be able to furnish test results to confirm these data.

4.5.3.14 Power loss determination

This is a type test.

This test is carried out to calculate the power efficiency. Converter power losses may be determined, either by calculation or by measurement. At the user's request, the arguments leading to the choice of method shall be given by the manufacturer.

For parts of equipment already tested and in current use, it is permissible to replace the test by calculation based on previous measurements.

Acceptance criteria: The power efficiency shall be in accordance with the requirements of 4.3.4.4.3.

NOTE This test is not applicable to converters where it is not possible to verify the power efficiency by measurement due to limited measurement accuracy. This is typically valid for converters without integrated filters or transformers.

4.5.3.15 Supply overvoltage and transient energy test

This is a type test.

It shall be confirmed that the converter is able to withstand overvoltage and transient energy surges, as specified in 4.2.7.

If the user agrees, this test may be replaced by calculation.

4.5.3.16 Sudden variations of load

This is a type test. The execution of the test is subject to agreement between the manufacturer and the user.

The self-protection, if any, shall be functioning.

The test voltage shall be chosen by agreement between the manufacturer and the user.

Test conditions are described in 5.1.3.5, 5.2.2.7 and 7.5.8.

Two kinds of test can be performed:

- short-circuit test;
- load-break test.

The acceptance criteria shall be stated in the test specification.

4.5.3.17 Safety requirements inspection

This is a type test.

The inspection is provided to check that the design of the converter meets the safety standards which are specified in the contract. The methods of performing the inspection shall be specified and should be agreed between the manufacturer and the user.

Attention should be paid to the fact that dangerous voltages may be present in the capacitors for a certain time after switching off the converter. Minimum requirements are given in IEC 61991. The specification shall state the relevant arrangements including the acceptance criteria.

4.5.3.18 Tests for withstanding vibration and shock

This is a type test.

See IEC 61373 and 4.2.5.1.

If a converter-mass is higher than 500 kg, one may test subassembly only. If a converter-mass is higher than 500 kg, a shock and vibration test may be agreed between manufacturer and user (optional type test). If no shock and vibration test is performed, a Finite Element Method (FEM) stability calculation shall be provided by the manufacturer.

4.5.3.19 Test of electromagnetic compatibility

This is a type test.

Tests for the electromagnetic compatibility of the converter are specified in IEC 62236-3-2.

4.5.3.20 Step change of line voltage test

This is a type test. The execution of the test is subject to agreement between the manufacturer and the user.

This test is provided to verify the agreed performance of the converter under sudden line-voltage variations as specified in 4.2.7.3.2. If the user agrees, this test may be replaced by calculation.

Acceptance criteria: The deviation of currents and voltages listed for checking in the test specification shall not be outside the specified tolerances.

4.5.3.21 Short-time supply interruption test

This is a type test. The execution of the test is subject to agreement between the manufacturer and the user.

This test is provided to verify that a line voltage supply interruption of any duration does not damage the converter and the current consumption remains within the specified limits, independent of the load conditions of the converter. The test condition should be agreed between manufacturer and user. If the user agrees, this test may be replaced by calculation.

Acceptance criteria: The deviation of currents and voltages listed for checking in the test specification shall not be outside the specified tolerances.

4.5.3.22 Current sharing

This is a type test. The execution of the test is subject to agreement between the manufacturer and the user.

The object of this test is to verify the correct current sharing of subassemblies connected in parallel. The measurement of the current sharing of directly in-parallel connected semiconductor devices in a subassembly is not part of the converter type test.

It is allowed to replace the normal connection to these components by a special connection containing a current sensor.

Acceptance criteria: The test is passed successfully if the current-sharing is better than, or equal to, the tolerances specified.

4.5.4 Failure of components during type tests

If failures of components occur during any of the type tests, the manufacturer shall replace the failed components at his own expense and, before the test concerned is repeated, the manufacturer shall make an investigation to verify that the specification of this component is in accordance with the application. It is not necessary to repeat the test, if the failure of the component mentioned above is obviously not attributable to the type test concerned. If no failure occurs in the course of the repeated test, the type test shall be considered as passed.

If, however, a further failure occurs, the type test shall be considered as not passed and the manufacturer shall investigate the cause of failure and correct the design before a new type test can be made.

5 Direct traction converters

5.1 Line-commutated converters for DC motors

5.1.1 General

The converter is a line-commutated rectifier (with thyristors) and may be connected to a line, a line transformer, or a generator.

5.1.2 Characteristics

5.1.2.1 Interface between motor and converter

The characteristics of traction motors are dealt with in IEC 60349-1.

It is necessary to state in a detailed specification the interface between the motor and the converter including the following characteristics.

The characteristic values of the converter output quantities (rated values, variations, etc.):

- rated direct current;

- maximum direct current, considering the load profile;
- DC voltage (no load direct voltage, rated direct voltage);
- harmonic content of the DC voltage (especially under control conditions where high values of low-order components are expected);
- DC ripple factor (current), for control conditions giving maximum values related to specified smoothing reactors.

The characteristic values of the motor (rated values, variations, etc.):

- rated power;
- voltage or e.m.f. (various speeds for traction and braking);
- current;
- maximum ripple admissible considering the load profile;
- type of DC motor (series, compound, etc.);
- impedance or equivalent scheme as a function of frequency and current;
- field characteristics;
- voltage between motor terminals and earth.

5.1.2.2 Interface between main transformer and converter

The characteristics of main transformers are dealt with in IEC 60310.

It is necessary to state in a detailed specification the interface between the transformer and the converter including the following characteristics:

- supply system characteristics as defined in 4.2.7;
- characteristic values of the converter AC input quantities (rated values, variations, tolerances, etc.):
 - number of converter windings;
 - no-load voltage on converter side;
 - rated AC current on the converter side;
 - maximum AC current on the converter side, considering the load profile;
 - commutation inductance;
 - frequency of the line voltage;
 - harmonic components of the AC current under specified conditions;
 - short-circuit current after a commutation failure.

5.1.3 Tests

5.1.3.1 General

No modification of the power circuit of the converter is allowed, but the test control method can be changed ensuring at least the same stress to the converter as in the intended application. A test bench control equipment can be used provided that the working of the converter is not altered.

Tests specified in this subclause are in addition to those specified in 4.5.

For these tests, the smoothing reactor shall be considered as a part of the converter.

The tests given in Table 4 are type tests and can be carried out in the workshop or in the vehicle.

Table 4 – Additional tests for direct traction converters

| Nature of test | Location | Type test | Routine test | Subclause |
|---|----------|----------------|--------------|-----------|
| Measurement of direct voltage regulation | W.S./V | X | | 5.1.3.2 |
| Load ripple current test | W.S./V | X | | 5.1.3.3 |
| Short-circuit test | W.S./V | X ^a | | 5.1.3.4 |
| Load break test | W.S./V | X ^a | | 5.1.3.5 |
| Short-time supply interruption test in regenerative mode | W.S./V | X | | 5.1.3.6 |
| W.S./V: The test can be made in the workshop or on the vehicle. | | | | |
| ^a The execution of the test is subject to agreement between the manufacturer and the user. | | | | |

5.1.3.2 Measurement of direct voltage regulation

This is a type test.

The voltage is measured directly at the terminals of the converter, excluding smoothing reactor voltage drop, and at specified line voltage and impedance.

Acceptance criteria: The direct voltage regulation shall be within the limits specified by the manufacturer.

5.1.3.3 Load ripple current test

This is a type test.

For specified line voltage, for specified load and at points of operation corresponding to the maximum ripple current, the DC component, the r.m.s. and the minimum and maximum value of the ripple current shall be measured. The test shall be carried out with the specified smoothing impedance. The motor may be replaced by an adequate voltage source and impedance.

Acceptance criteria: This test is declared successful if the value of the ripple current is less than, or equal to, the characteristic value, specified in 5.1.2.1.

5.1.3.4 Short-circuit test

This is a type test. The execution of the test is subject to agreement between the manufacturer and the user.

This test is carried out to verify the protection of the converter against over-currents (for example, flashover of the motor).

The test specification is written by the manufacturer.

The test shall be made with:

- the highest rated line voltage;
- the equivalent input impedance;
- the maximum current;
- all necessary protective devices (components installed in the vehicle or having the same protective characteristics);
- a load simulating the DC motor including all effective smoothing reactance;

- a short-circuit device simulating the short-circuit path.

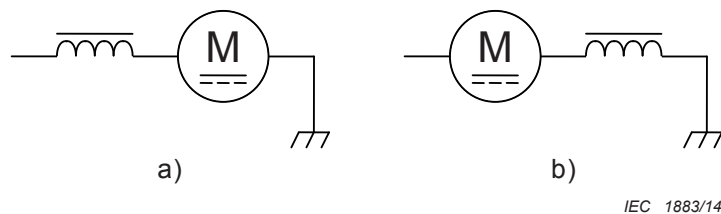
For series motors, it is possible to have the connections shown in Figure 2a) and 2b). In the case of Figure 2a), the flashover only affects the armature winding, and therefore only the resistor of the simulated load in Figure 2c) shall be short-circuited. In the case of Figure 2b), all simulated load shall be short-circuited as shown in Figure 2d).

After the current in the simulated load has reached steady-state conditions, the short-circuit device shall be closed. The resulting fault current shall be detected and cleared by protective and fault-clearing equipment in the total time specified for that equipment to function.

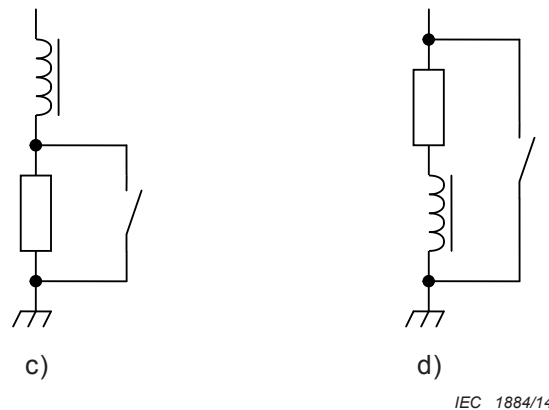
Fuses, if any, shall not blow during this test unless otherwise specified.

This test shall be made once and the over current waveform shall be recorded.

Acceptance criteria: The test is declared successful if no component is damaged during the test.



Figures 2a) and 2b) – Field/armature connections of series motors



Figures 2c) and 2d) – Short circuit connection of simulated load

Figure 2 – Configuration of series motors

5.1.3.5 Load break test

This is a type test. The execution of the test is subject to agreement between the manufacturer and the user.

This test is carried out to verify that the converter will not sustain any damage when the load is suddenly disconnected. The protection equipment shall be functioning.

This test shall be made with a voltage corresponding to the nominal line voltage.

The input and the output voltage waveforms shall be recorded.

Acceptance criteria: No damage during the test.

5.1.3.6 Short-time supply interruption test in regenerative mode

This is a type test.

The aim of the short-time supply interruption test is described in 4.5.3.21. It shall be especially verified that, independent of the interruption time, neither the motor voltage nor the motor current shall exceed a specified value.

Acceptance criteria: No damage during the test, no current or voltage shall exceed the specified values.

5.2 Choppers for DC motors

5.2.1 Characteristics

5.2.1.1 General

The supply system characteristics are defined in 4.2.7.

The characteristics of traction motors are dealt with in IEC 60349-1.

5.2.1.2 Interface between motor and converter

It is necessary to state in a detailed specification agreed between the motor and converter manufacturers the interface between the motor and the converter including the following characteristics:

- the characteristic values of the converter output quantities (rated values, variations, etc.):
 - additional impedance (smoothing reactors);
 - rated current;
 - maximum current, considering the load profile;
 - peak current;
 - voltage;
 - frequency;
 - load profile;
- the characteristic values of the motor (rated values, variations, etc.):
 - rated power;
 - voltage or e.m.f. (various speeds for traction and braking);
 - current;
 - maximum ripple admissible considering the load profile;
 - type of DC motor (series, compound, etc.);
 - impedance or equivalent scheme as a function of frequency and current;
 - field characteristics;
 - voltage between motor terminals and earth.

5.2.2 Tests

5.2.2.1 General

No modification of the power circuit of the converter is allowed, but the test control method can be changed ensuring at least the same stress to the converter as in the intended application. A test bench control equipment can be used provided that the working of the converter is not altered.

Tests specified in this subclause are in addition to those specified in 4.5.

For these tests the smoothing reactor shall be considered as a part of the converter.

The tests given in Table 5 can be carried out in the workshop or in the vehicle.

Table 5 – Additional tests for choppers for DC motors

| Nature of test | Location | Type test | Routine test | Subclause |
|---|----------|----------------|--------------|-----------|
| Output voltage test | W.S./V | X | | 5.2.2.2 |
| Maximum output voltage | W.S. | X | | 5.2.2.3 |
| Minimum output voltage | W.S. | X | | 5.2.2.4 |
| Light load test | W.S. | | X | 5.2.2.5 |
| Load ripple current test | W.S./V | X | | 5.2.2.6 |
| Load break test | W.S. | X ^a | | 5.2.2.7 |
| Short-circuit test | W.S./V | X ^a | | 5.2.2.8 |
| W.S.: The test shall be made in the workshop. | | | | |
| W.S./V: The test can be made in the workshop or on the vehicle. | | | | |
| ^a The execution of the test is subject to agreement between the manufacturer and the user. | | | | |

5.2.2.2 Output voltage test

This is a type test.

The voltage is measured directly at the terminals of the converter excluding smoothing reactor voltage drop.

Acceptance criteria: The test is declared successful when the output voltage remains within the specified limits under specified conditions.

5.2.2.3 Maximum output voltage

This is a type test.

For minimum input voltage and maximum output current the average output voltage of the converter shall meet the declared value under specific conditions (for example, frequency, minimum off-time, etc.).

Acceptance criteria: The output voltage shall be equal to, or higher than, the specified value.

5.2.2.4 Minimum output voltage

This is a type test.

For maximum input voltage and minimum output current, the average output voltage of the converter shall have a value equal to or lower than the minimum declared value under specified conditions (for example, frequency, minimum “on” time, etc.).

Acceptance criteria: The output voltage shall be equal to, or lower than, the specified value.

5.2.2.5 Light load test

This is a routine test.

The aim of the light load test is described in 4.5.3.10. In addition, for a multiphase chopper each phase may be tested separately.

Acceptance criteria: See 4.5.3.10.

5.2.2.6 Load ripple current test

This is a type test.

For specified supply voltage, for specified load and at points of operation corresponding to the maximum ripple, the value of the DC component, the r.m.s. value of the ripple component and the peak-to-peak value of the ripple shall be measured.

The test shall be carried out with the specified smoothing reactor.

Acceptance criteria: The test is declared successful if the value of the ripple current is equal to, or less than, the value given in 5.2.1.2.

For multiphase choppers, this test can be replaced by calculation, if agreed between the manufacturer and the user.

5.2.2.7 Load break test

This is a type test. The execution of the test is subject to agreement between the manufacturer and the user.

This test is carried out to verify that the converter will not sustain any damage when the load is suddenly disconnected. The protection equipment shall be functioning.

This test shall be made with a voltage corresponding to the nominal line voltage.

When the current in the line filter inductor has reached its maximum value (condition corresponding to the maximum load current with maximum value of the conduction ratio), the load break will be performed by abruptly blocking the converter via its control equipment.

The input and the output voltage waveforms shall be recorded. If dangerous overvoltages are expected on certain components, these voltages shall also be recorded.

Acceptance criteria: The maximum value of the overvoltage shall be lower than, or equal to, the specified value.

5.2.2.8 Short-circuit test

This is a type test. The execution of the test is subject to agreement between the manufacturer and the user.

This test is carried out to verify the protection of the converter against over currents (for example, a flashover of the motor).

The test shall be made with:

- the highest rated line voltage;
- the equivalent input impedance;
- the maximum current;
- all necessary protective devices (components installed in the vehicle or having the same protective characteristics);
- a load simulating the DC motor including all effective smoothing resistance;
- a short-circuit device simulating the short-circuit path.

For example, if the converter is intended to withstand such a short circuit, a short-circuit device shall be connected in parallel with this load in accordance with Figure 2. For series motors, it is possible to have the connections shown in Figures 2a) and 2b). In the case of Figure 2a), the flashover only affects the armature winding, and therefore only the resistor of the simulated load in Figure 2c) shall be short-circuited. In the case of Figure 2b), the whole of the simulated load shall be short-circuited as shown in Figure 2d).

After the current in the simulated load has reached steady-state conditions, the short-circuit device shall be closed. The resulting fault current shall be detected and cleared by protective and fault-clearing equipment in the total time specified for that equipment to function.

Fuses, if any, shall not blow during this test unless otherwise specified.

This test shall be made once and the over current waveform shall be recorded.

Acceptance criteria: The test is declared successful if no component is damaged.

5.3 Multiphase converters for AC motors (inverters)

5.3.1 General

Multiphase traction motors can be either rotating or linear motors. Converters for fixed-stator linear motors are excluded.

5.3.2 Characteristics

5.3.2.1 General

Characteristics of traction motors are dealt with in IEC 60349-2 and IEC 60349-4. The exchanges of information between the motor manufacturer, the converter manufacturer and the control manufacturer are specified in IEC 60349-2 and IEC 60349-4.

5.3.2.2 Interfaces between motor and converter (inverter)

The interface(s) between the motor and the converter shall be defined in a detailed specification, to be agreed between the motor and the converter manufacturers, and include the following:

- voltage or current harmonics which influence the performance of the motor (through additional power losses, torque ripple, etc.);
- electrical characteristics of the motor (its equivalent circuit, at the fundamental frequency and its inductance for the purpose of calculating di/dt , magnetizing current, harmonic currents, etc.);
- load profile;

- rated output power of inverter;
- range of fundamental frequency and modulation;
- output voltage of the inverter including repetitive peak voltage, voltage between inverter terminals and ground, rate of voltage rise;
- rated current;
- voltage between motor terminals and ground;
- behaviour of the motor including gears when there is a short circuit at the terminals of the motor.

These quantities shall be defined for each operating mode.

5.3.3 Tests

5.3.3.1 General

No modification of the power circuit of the converter is allowed, but the test control method can be changed ensuring at least the same stress to the converter as in the intended application. A test bench control equipment can be used provided that the working of the converter is not altered.

Tests specified in this subclause are in addition to those specified in 4.5.

5.3.3.2 Additional commutation test

This is a type test.

This test is carried out to verify the commutation capability at minimum “on” time and minimum “off” time.

Generally, to simulate the worst-case condition, it is necessary to choose different input and output conditions for the “on” time and “off” time tests.

Acceptance criteria: The test is considered satisfactory if the measured values of operating parameters in all parts of the commutation circuit (power semiconductor, snubber, inductance, etc.) are in accordance with the specified values.

6 Indirect traction converters

6.1 General

This clause applies to indirect converters supplying DC or multiphase motors. An indirect traction converter is composed of an input section called a line converter and an output section called a motor converter (inverter).

6.2 Line converter

6.2.1 General

A line converter is connected to the line or a line transformer or a generator and creates an intermediate link, mainly to supply a traction converter.

The intermediate link is a functional part of the line converter.

If an auxiliary converter is fed from the line converter, 7.2.2.2 is applicable to the auxiliary converter.

6.2.2 Characteristics

6.2.2.1 Input characteristics

The supply system characteristics are defined in 4.2.7.

In the case of a single-phase AC supply, the converter may be used to control the power factor and harmonic content on the AC side; the power factor and harmonic content shall be specified in the specification. The interface between transformer and converter shall be specified as given in 5.1.2.2, and the characteristics of the transformer, including its leakage inductance and mutual inductance, shall be specified according to IEC 60310.

6.2.2.2 Output characteristics

Output quantities related to the kind of intermediate link shall be specified.

It is necessary to specify as additional quantities, the rated values, variation, maximum and minimum values and ripple factor corresponding to the kind of intermediate link.

The DC components of these values are the input values of the traction converter which is connected to the intermediate link.

An auxiliary converter may be fed from the output of the main line converter.

6.2.2.3 Short-circuit protection

The user shall specify in the specification whether the converter is short-circuit-proof or not.

The behaviour of the converter in case of short circuit shall be described in the specification.

6.2.2.4 Choice of rated insulation voltage

If an isolating transformer is provided, the output voltage level shall be considered as relevant for design and safety of the output side.

If an isolating transformer is not provided, the input voltage level shall be considered as relevant for design and insulation.

In accordance with IEC 61991 the manufacturer can select a lower voltage level (for instance the output level) considering the following points:

- the design and protection of the converter (crowbar circuit or other equipment);
- the insulating levels of the load;
- the safety rules.

This shall be agreed between the manufacturer and the user.

6.2.3 Tests

6.2.3.1 General

The line converter may be tested separately from the motor converter. Subclause 5.3.3.1 applies to 6.2.3.2.

6.2.3.2 Light load test

This is a routine test.

For execution of the test and acceptance criteria, see 4.5.3.10.

If the line converter is tested independently from the converter system, the line converter may be fed either from the input or the output side.

If the line converter is fed from the output side, the line side may be simulated by a substitute load.

6.2.3.3 Temperature-rise test

This is a type test.

For execution of the test and acceptance criteria, see 4.5.3.13.

If a common cooling system is provided, the temperature-rise test shall be carried out with the complete indirect converter.

If it is not possible to build up the whole indirect converter for this test, the cooling conditions for each part of the indirect converter shall be the same as in the application.

6.3 Motor converter

6.3.1 Motor converter for DC motors (chopper or rectifier)

Subclauses 5.1 and 5.2 apply to this subclause.

6.3.2 Motor converter for AC motors (inverter)

Subclause 5.3 applies to this subclause.

7 Auxiliary converters

7.1 General

An auxiliary converter may be either a direct converter or an indirect converter, due to its input characteristics.

7.2 Characteristics

7.2.1 Auxiliary converter starting conditions

Generally the auxiliary converter is the first to start, so it is necessary to specify the starting conditions.

The main types of starting mode are as follows.

- Direct starting with input voltage
The energy used to start the converter is supplied by its input voltage.
- Starting by main vehicle battery
The energy used to start the converter is supplied by the main vehicle battery.
- Starting by auxiliary battery
The energy used to start the converter is supplied by an auxiliary battery specific to the converter.

The starting mode shall be agreed upon between the manufacturer and the user.

7.2.2 Input conditions and characteristics

7.2.2.1 Connection to the line

The converter is connected direct to the line supply or to an auxiliary winding of the main transformer; therefore, the characteristics of the input voltage are those which are defined in 4.2.7. The input characteristics are given in accordance with 4.3.4.4.1.

If the converter is not directly connected to the line, all power-supply characteristics shall be specified.

7.2.2.2 Connection to the traction converter

The auxiliary converter is connected to an intermediate link or to the main input filter. All input characteristics (steady-state and transient conditions) shall be specified.

7.2.2.3 Connection to a bus bar supplied by another auxiliary converter or by a battery

The input characteristics (steady-state and transient conditions) shall be specified (see 4.3.4.4.1).

7.2.3 Output characteristics

7.2.3.1 General

An auxiliary converter can have one output or multiple outputs.

7.2.3.2 List of output characteristics

An auxiliary converter can supply several output voltages which have different forms.

For each output at least the following characteristics shall be specified:

- DC output:
 - maximum continuous power (at specified voltage);
 - voltage and tolerance;
 - in case of battery charging: charging characteristics (e.g. charging current limitation, boost voltage, temperature compensation coefficient of charging voltage);
 - DC current and voltage ripple in rated conditions;
 - admissible overload;
 - maximum instantaneous peak current;
- AC output:
 - maximum continuous power (apparent power and fundamental power factor or active power);
 - fundamental voltage and static tolerance;
 - frequency and static tolerance;
 - total harmonic distortion ratio of voltage in specified conditions;
 - admissible overload;
 - maximum instantaneous peak current;
 - common mode voltage;
 - in case there is no output sine wave filter:

- a) voltage harmonic spectrum and total r.m.s. value in specified conditions;
- b) maximum peak voltage;
- c) maximum rate of rise of instantaneous voltage;
- possibility of asymmetrical load and loading of a star-point or neutral connection.

7.2.3.3 Output power

An auxiliary converter is designed for a maximum continuous output power and/or for a load profile. In addition to the maximum continuous power the auxiliary converter may have an overload capability. This overload is defined by a maximum current delivered during a specified time.

The power ratings of an auxiliary converter shall comply with the following characteristics:

- maximum continuous output power (rated power) or load profile;
- long time overload;
- short time overload.

The user should provide a compilation of all the loads and their duty to the manufacturer of the auxiliary power converter to enable its proper sizing. The load starting sequences and failure management strategies shall be developed such as to minimize the power requirements.

The user should provide the following information for winter and summer, normal and long time overload conditions:

- converter external ambient (or cooling medium) temperature histogram;
- load type (compressor motor, fan, non-linear load, etc.), voltage, 1 or 3 phase;
- locked rotor load (kVA, power factor);
- steady-state load (kVA, power factor);
- duty (short term, long term);
- starting sequence.

7.2.3.4 Voltage and frequency control

The AC output voltage of the converter can be of two types:

- fixed frequency;
- variable frequency: in this case additional control characteristics shall be specified such as:
 - range of variation of frequency;
 - whether the frequency varies continuously or by steps;
 - relation between voltage and frequency;
 - ramping time.

7.3 Short-circuit protection

The user shall specify in the specification whether the converter is short-circuitproof or not.

The behaviour of the converter in case of short circuit shall be described in the specification.

7.4 Choice of rated insulation voltage

If an isolating transformer is provided, the output voltage level shall be considered relevant for design and safety of the output side.

If an isolating transformer is not provided, the input voltage level shall be considered relevant for design and safety.

In accordance with IEC 61991, the manufacturer can select a lower voltage level (for instance the output level) considering the following points:

- the design and protection of the converter (crowbar circuit or other equipment);
- the insulating levels of the load;
- the safety rules.

This shall be agreed between the manufacturer and the user.

7.5 Tests

7.5.1 General

In addition to the tests listed in Table 3, the following tests shall be carried out.

All these additional tests given in Table 6 shall be carried out with a series production control unit.

Table 6 – Additional tests for auxiliary converters

| Nature of test | Location | Type test | Routine test | Subclause |
|---|-------------------|-----------|--------------|-----------|
| Output characteristics test | W.S. | X | | 7.5.2 |
| Starting and restarting test | W.S. | X | | 7.5.3 |
| Short-circuit test | W.S. ^a | X | | 7.5.4 |
| Voltage and frequency ranges verification | W.S. | X | | 7.5.5 |
| Overload capability test | W.S. | X | | 7.5.6 |
| Temperature rise test | W.S. | X | | 7.5.7 |
| Load break test | W.S. | X | | 7.5.8 |
| W.S.: The test shall be made in the workshop. | | | | |
| ^a If the converter is short-circuitproof, this test shall be carried out. This test shall demonstrate that the behaviour of the converter conforms with the values specified in 7.2. | | | | |

7.5.2 Output characteristics test

This is a type test.

This test is carried out to verify that the following electrical characteristics (where applicable) are in accordance with agreed test conditions:

- DC output:
 - voltage and tolerance;
 - in case of battery charging: charging characteristics (e.g. charging current limitation, boost voltage, temperature compensation coefficient of charging voltage);
 - DC current and voltage ripple;
 - current and voltage limitation (if any);
- AC output:
 - fundamental voltage and static tolerance;

- frequency and static tolerance;
- total harmonic distortion ratio of voltage in specified load conditions;
- common mode voltage;
- in case there is no output sine filter:
 - a) voltage harmonic spectrum and total r.m.s. value in specified conditions;
 - b) maximum peak voltage;
 - c) maximum rate of rise of instantaneous voltage.

Unless otherwise agreed, this test shall be carried out:

- at minimum, rated and maximum input voltages;
- at minimum, rated and overload power;
- with and without the specified asymmetrical load and/or loading of a star-point or neutral connection.

The load can be a substitute load. However the fulfilment of the requirements over the entire operating range with specified loads should be demonstrated by calculations.

Acceptance criteria: This test is declared successful if the measured values are in accordance with those specified.

7.5.3 Starting and restarting test

This is a type test.

This test is carried out to verify the characteristics described in 7.2.1.

This test shall be performed for minimum and maximum specified input characteristics.

Acceptance criteria: The converter starts successfully and the measured values are as specified.

7.5.4 Short-circuit test

This is a type test.

A short circuit test shall be carried out for all short-circuit protected outputs.

Acceptance criteria: No damage to any component in the converter occurs during the test.

7.5.5 Voltage and frequency ranges verification

This is a type test.

The combinations of input and output values to be tested shall be such that correct functioning over the whole range of operation is verified with a minimum of tests.

Acceptance criteria: When the output load(s) and the input voltage are at their limiting values, the output voltage(s), the fundamental frequency and the switching frequency shall remain within the specified range (7.2.3.4).

7.5.6 Overload capability test

This is a type test.

This test shall be carried out to verify the overload capability as defined in 7.2.3.3.

Acceptance criteria: The test is successful if the converter supplies the overload for the specified time without sustaining any damage and without exceeding any critical temperature (see 4.5.3.13 as well as 7.2.3.3).

7.5.7 Temperature rise test

This is a type test.

This test shall be carried out at rated output conditions according to 7.2.3.3.

The manufacturer and the user shall agree, before the test, on a list of measuring points (for example, inside cubicle, main heat sink, etc.) whose temperature is to be measured.

In the case of cooling by natural air convection or by supported convection due to the movement of the vehicle, the test shall be carried out with the specified cooling conditions.

In the case of very high power converters whose duty cycle may not be reproduced in the workshop, the appropriate values of temperature determined by calculation may be checked by reduced load tests or by sub circuit (part of converter) tests under controlled conditions.

Acceptance criteria: The methods of performing this test and the requirements for acceptance shall be stated in the test specification.

7.5.8 Load break test

This is a type test.

This test is carried out to verify that the converter does not sustain any damage when the load is suddenly disconnected.

A contactor is connected in series with the load. After the current in the load has reached steady-state condition, the contactor switches off the current. The resulting voltage variation shall be recorded.

Acceptance criteria: The test is declared successful if the voltage variation is in accordance with the specified values and no damage occurs to any component in the converter during the test.

In the case of multiple outputs, this test should be repeated for each output, and it is necessary to verify if the other output characteristics are in accordance with the specified values.

8 Semiconductor drive units (SDU)

8.1 Equivalent expressions

The following expressions are intended to be equivalent:

| | | |
|-------------------------|---------------|-----------|
| "Base" | equivalent to | "Gate" |
| "Source" and "Emitter" | equivalent to | "Cathode" |
| "Drain" and "Collector" | equivalent to | "Anode" |
| "Gate Drive Unit (GDU)" | equivalent to | "SDU" |

8.2 Printed circuit board assemblies

All printed circuit boards of the SDU are covered by IEC 60571, except for components responsible for isolation, which are covered by this standard.

8.3 Function of the SDU

The SDU transforms the switching commands which are created by the control electronics into gate current and gate-to-cathode voltage, which are suitable to drive the semiconductor connected to it.

Switching commands are transmitted e.g. electrically, magnetically or optically. Semiconductors may be controlled by current (for example, thyristors, bipolar transistors, gate-turn-off thyristors,) or by voltage (for example, field effect transistors, insulated gate bipolar transistors, MOS-controlled thyristors).

8.4 Particular requirements for the SDU

8.4.1 The SDU shall be able to force the semiconductor to switch the peak controllable on state current, of the application, without damage.

8.4.2 The manufacturer shall describe the behaviour of the SDU if the gate of the semiconductor is short-circuited to the cathode or is open-circuited.

8.4.3 The converter and the SDU shall not be damaged in the case of interruption of the SDU power supply. The manufacturer shall ensure that sufficient energy is available in the SDU to generate the necessary pulses to put the converter in a safe state.

8.5 Service conditions

The service conditions given in 4.2 shall be assumed.

8.6 Insulation requirements for the SDU

Special attention shall be paid to the fact that the SDU frequently has parts at ground, electronic and power potentials and has an isolating function. In applying the values given in 4.4.1, this fact shall be taken into account.

8.7 Electromagnetic compatibility requirements

Special attention shall be paid to the electromagnetic compatibility of the SDU. The responsibility for assessment of the electromagnetic compatibility between the SDU and other parts of the converter rests with the manufacturer of the converter. For ports between the SDU and components in the environment of the converter, the relevant EMC requirements are specified in IEC 62236-3-2.

8.8 Tests of the SDU

Before mounting the SDU into the converter, the SDU shall be tested in accordance with IEC 60571 (see 4.5.2.2).

The features of the SDU (which are not yet covered in IEC 60571) shall be proven by a type test according to the test specification.

After mounting into the converter the SDU shall perform at its interfaces (power supply, control electronics, and semiconductor) as specified under all service conditions.

The SDU shall successfully complete all type and routine tests of the converter according to 4.5.

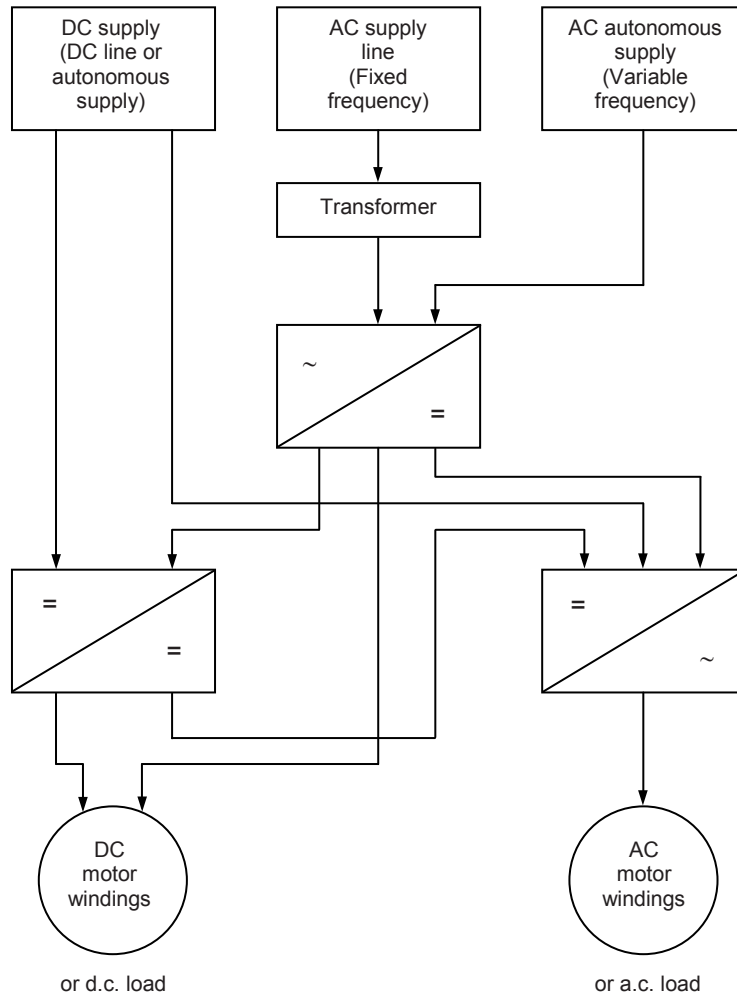
Special attention should be given if the SDU is part of the protection system.

Annex A
(normative)

Arrangement of basic circuit diagrams

Different combinations of the basic circuits are possible.

The diagram in Figure A.1 gives the most usual combinations of circuit diagrams between the power supply and the traction motor or other loads.



IEC 1885/14

NOTE Passive devices, such as filters and energy storage, are not shown.

Figure A.1 – Examples of combinations

Annex B (informative)

Recapitulation of agreements between the manufacturer and the user

**Table B.1 – Recapitulation of agreements
between the manufacturer and the user (1 of 3)**

| Subclause | Title | Comment |
|-------------|--|---|
| 4.1.1 | Design | Design process |
| 4.1.3.1 | Documentation supplied by the manufacturer | |
| 4.1.3.2 | Documentation to be supplied by the user | |
| 4.1.4.1 | Reliability | Reliability target |
| 4.1.4.2 | Availability | Availability target |
| 4.1.4.3 | Maintainability | Maintenance requirements |
| 4.1.4.4 | Safety | Safety requirements |
| 4.1.5 | Useful lifetime | |
| 4.2.1 | General | Particular service conditions class |
| 4.2.3.1 | Ambient temperature | |
| 4.2.3.2 | Start-up temperatures | |
| 4.2.5.2 | Other accelerations | |
| 4.2.6 | Load profile | |
| 4.2.7.1 | General | |
| 4.2.7.2.2 | Step change of line voltage | |
| 4.2.7.2.3 | Distortion of AC line voltage | |
| 4.2.7.2.4 | Overvoltage in AC systems | IEC 60850 |
| 4.2.7.2.5 | AC system impedance | |
| 4.2.7.3.1 | Main characteristics of the DC line voltage | |
| 4.2.7.3.2 | Step change of line voltage | |
| 4.2.7.3.3 | Overvoltage in DC systems | IEC 60850 |
| 4.2.7.3.4 | DC system inductance and resistance | |
| 4.2.7.3.5 | Distortion of DC line voltage | |
| 4.2.7.4 | Other supply systems | |
| 4.2.8.2 | Interference with the supply system (emission) | |
| 4.2.8.4 | Interference with signalling systems | |
| 4.2.9 | Input current limitations | |
| 4.2.10.1 | Acoustic noise | Lower values Choice of class |
| 4.3.4.1 | Geometrical characteristics – conformity to drawings | Contractual mass and corresponding test (4.5.3.2, 4.5.3.3) |
| 4.3.4.2 | Characteristics of cooling systems | |
| 4.3.4.4.1 | Input quantities | Input quantities according to 4.2.7 and 4.2.8 Supply characteristics Harmonic limit values and input impedance Resettable protective devices |
| 4.3.4.4.2.2 | Rated values | |

Table B.1 (2 of 3)

| Subclause | Title | Comment |
|-------------|---|---|
| 4.3.4.4.2.3 | Operating point values | |
| 4.3.4.4.2.4 | Special values | Short-circuit and open-circuit characteristics Particular requirements |
| 4.3.4.4.3 | Power efficiency | |
| 4.3.4.4.4 | Electrical isolation | |
| 4.3.4.4.5 | Interfaces between converter and control unit | |
| 4.4.1 | Insulation co-ordination | Rated impulse voltage Rated insulation voltage |
| 4.4.2.1 | General | High disturbances, low susceptibility devices |
| 4.4.2.2.2 | Effects on human beings | |
| 4.4.3 | Fault effects | |
| 4.5.1.1 | Overview | Test specification |
| 4.5.1.2.2 | Type tests | |
| 4.5.1.2.3 | Routine tests | |
| 4.5.1.2.4 | Investigation tests | |
| 4.5.2.3 | List of converter tests | |
| 4.5.3.1 | Visual inspection | |
| 4.5.3.5.4 | Leakage test | |
| 4.5.3.6 | Test of the degree of protection | |
| 4.5.3.8 | Insulation resistance test | |
| 4.5.3.9 | Tests of mechanical and electrical protection and measuring equipment | |
| 4.5.3.10 | Light load test | Output current |
| 4.5.3.12.3 | Operating conditions | |
| 4.5.3.12.4 | Particular conditions | |
| 4.5.3.13 | Temperature-rise test | |
| 4.5.3.14 | Power loss determination | |
| 4.5.3.15 | Supply overvoltage and transient energy test | |
| 4.5.3.16 | Sudden variations of load | |
| 4.5.3.17 | Safety requirements inspection | |
| 4.5.3.18 | Tests for withstanding vibration and shock | |
| 4.5.3.20 | Step change of line voltage test | |
| 4.5.3.21 | Short-time supply interruption test | |
| 4.5.3.22 | Current sharing | |
| 5.1.2.1 | Interface between motor and converter | |
| 5.1.2.2 | Interface between main transformer and converter | |
| 5.1.3.1 | General | |
| 5.1.3.4 | Short-circuit test | |
| 5.1.3.5 | Load break test | |
| 5.2.1 | Characteristics | Interface between motor and converter |
| 5.2.2.1 | General | |
| 5.2.2.6 | Load ripple current test | |

Table B.1 (3 of 3)

| Subclause | Title | Comment |
|------------------|---|--|
| 5.2.2.7 | Load break test | |
| 5.2.2.8 | Short-circuit test | |
| 5.3.2 | Characteristics | Interface between motor and inverter |
| 6.2.2.1 | Input characteristics | Power factor and harmonic content |
| 6.2.2.3 | Short-circuit protection | Short-circuit-proof Short-circuit behaviour |
| 6.2.2.4 | Choice of rated insulation voltage | Lower voltage level |
| 7.2.1 | Auxiliary converter starting conditions | Starting mode |
| 7.2.2 | Input conditions and characteristics | |
| 7.2.3.2 | List of output characteristics | |
| 7.2.3.3 | Output power | |
| 7.3 | Short-circuit protection | |
| 7.4 | Choice of rated insulation voltage | |
| 7.5.2 | Output characteristics test | |
| 7.5.7 | Temperature rise test | |

Annex C (informative)

Guidelines for magnetic field and induced voltage requirements

There are no IEC standards on this subject, but some national and other guidelines exist and, for example, one may consult the following documents.

- DIN VDE 0848-3-1, *Sicherheit in elektrischen, magnetischen und elektromagnetischen Feldern.*
- International commission on non-ionizing radiation protection (ICNIRP), *Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields up to 300 GHz.*
- IEC/TS 62597, *Measurement procedures of magnetic field levels generated by electronic and electrical apparatus in the railway environment with respect to human exposure.*

Bibliography

NOTE The following documents serve as guidance or are connected to this International Standard.

IEC 60050-151:2001, *International Electrotechnical Vocabulary – Part 151: Electrical and magnetic devices*

IEC 60050-702:1992, *International Electrotechnical Vocabulary – Chapter 702: Oscillations, signals and related devices*

IEC 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60146-1-1, *Semiconductor converters – General requirements and line commutated converters – Part 1-1: Specifications of basic requirements*

IEC 60216 (all parts), *Electrical insulating materials – Properties of thermal endurance*

IEC 60384-1, *Fixed capacitors for use in electronic equipment – Part 1: Generic specification*

IEC 60587, *Electrical insulating materials used under severe ambient conditions – Test methods for evaluating resistance to tracking and erosion*

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

IEC 60747-15, *Semiconductor devices – Discrete devices – Part 15: Isolated power semiconductor devices*

IEC 61377-1, *Railway applications – Rolling stock – Part 1: Combined testing of inverter-fed alternating current motors and their control system*

IEC 61377-2, *Railway applications – Rolling stock – Combined testing – Part 2: Chopper-fed direct current traction motors and their control*

IEC 61377-3, *Railway applications – Rolling stock – Part 3: Combined testing of alternating current motors, fed by an indirect convertor, and their control system*

IEC 62520, *Railway applications – Electric traction – Short-primary type linear induction motors (LIM) fed by power converters*

IEEE Std 1476, *IEEE Standard for Passenger Train Auxiliary Power Systems Interfaces*

CLC/TS 50535, *Railway applications – Onboard auxiliary power converter systems*

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