

Railway applications — Power converters installed on board rolling stock —

Part 1: Characteristics and test methods

The European Standard EN 61287-1:2006 has the status of a British Standard

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National foreword

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Power convertors installed on board rolling stock
Part 1: Characteristics and test methods
(IEC 61287-1:2005)**

Applications ferroviaires -
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Partie 1: Caractéristiques
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CENELEC

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Foreword

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- | | | |
|--|-------|------------|
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Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61287-1:2005 was approved by CENELEC as a European Standard without any modification.

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RAILWAY APPLICATIONS – POWER CONVERTORS INSTALLED ON BOARD ROLLING STOCK –

Part 1: Characteristics and test methods

1 Scope

This International Standard is applicable to power electronic convertors 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 convertor assembly together with its mounting arrangements containing

- semiconductor device assemblies;
- integrated cooling systems;
- components of the intermediate d.c. link, including any necessary filters associated with the d.c. link;
- semiconductor drive units (SDU) and related sensors;
- incorporated protection circuits.

The following types of power sources are taken into consideration:

- a.c. contact lines,
- d.c. contact lines,
- on-board supplies such as generators, batteries and other electric power sources.

This standard excludes convertors which provide the electronic control supply for SDU and other supplies relevant to the convertor operation such as sensors.

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

This standard defines terminology, service conditions, general characteristics and test methods of electronic power convertors onboard of rolling stock.

2 Normative references

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

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

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

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

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 60349-1:1999, *Electric traction – Rotating electrical machines for rail and road vehicles – Part 1: Machines other than electronic convertor-fed alternating current motors*
Amendment 1 (2002)

IEC 60349-2:2002, *Electric traction – Rotating electrical machines for rail and road vehicles – Part 2: Electronic convertor-fed alternating current motors*

IEC 60384 (all parts), *Fixed capacitors for use in electronic equipment*

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

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

IEC 60571, *Electronic equipment used on rail vehicles*

IEC 60587, *Test method for evaluating resistance to tracking and erosion of electrical insulating materials used under severe ambient conditions*

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

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 convertor equipment*

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

IEC 61881, *Railway applications – Rolling stock equipment – Capacitors for power electronics*

IEC 61991:2000, *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)*

ISO 9001:2000, *Quality management systems – Requirements*

3 Terms and definitions

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

3.1 Definitions related to equipment

3.1.1

convertor (electronic) (power)

electronic device, based on power semiconductors, which changes one or more of the following parameters: voltage, current, frequency and/or the phase number of the power passing through it

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

NOTE 2 The convertor is a part of the propulsion (or auxiliary) equipment. The convertor may include, for example, a line circuit breaker, filter, transformer, cooling system, etc.

3.1.2**traction convertor**

convertor providing power for the traction motors

3.1.3**auxiliary convertor**

convertor providing power for auxiliary services, for example, lighting, battery charging, air conditioning, cooling (main service), control circuits, etc.

3.1.4**direct a.c./d.c. convertor**

convertor which converts the input energy into the output energy without an intermediate link

3.1.5**indirect a.c./d.c. convertor**

convertor which converts the input energy into the output energy with an intermediate link

3.1.6**convertor system**

system consisting of several convertors required to operate connected together, each having different input and/or output characteristics and which also have different functional connections and defined by a system specification in addition to the individual specification of each different convertor making up the system

3.1.7**current stiff intermediate link**

circuit linking at least two convertors by a reactor connected in series

3.1.8**voltage stiff intermediate link**

circuit linking at least two convertors and a capacitor connected in parallel

3.1.9**transformer intermediate link**

transformer linking two convertors

3.1.10**convertor windings**

windings of a transformer connected to the terminals of the convertor

3.1.11**auxiliary windings**

windings of a transformer connected to the terminals of any auxiliary power supply or auxiliary equipment

3.1.12**semiconductor device**

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

3.1.13

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

3.1.14

port

particular interface of the specified apparatus with the external electromagnetic environment

3.1.15

enclosure port

physical boundary of the apparatus through which electromagnetic fields may radiate or impinge

3.1.16

cable port

point at which a conductor or a cable is connected to the apparatus. Examples are signal, control and power ports

3.1.17

armature convertor

convertor connected to the armature of a d.c. motor to control the current or the voltage of the armature

3.1.18

field convertor

convertor connected to the field winding of a d.c. or a synchronous motor to control the current in the field circuit

3.1.19

unidirectional chopper

chopper which transfers the energy only in one direction.

3.1.20

step-down chopper

chopper of which the output voltage is lower than the input voltage

3.1.21

step-up chopper

chopper of which the output voltage is higher than the input voltage

3.1.22

armature chopper

chopper connected with the armature of a d.c. motor to control the current or the voltage of the armature

3.1.23

field chopper

chopper connected with the field of a d.c. motor to control the current of the field

3.1.24

rheostatic chopper

chopper connected in parallel with all or a part of a rheostat or in series with a rheostat to control the current of the rheostat

3.1.25**line convertor with voltage stiff intermediate d.c. link**

convertor which transforms the d.c. or a.c. input voltage to a d.c. voltage

3.1.26**line convertor with current stiff intermediate d.c. link**

convertor which transforms a d.c. or a.c. input voltage into a d.c. current

3.1.27**line convertor with transformer intermediate a.c. link**

convertor which transforms a d.c. input voltage into an a.c. voltage

3.1.28**second harmonic filter**

filter which absorbs the difference between the power from the a.c. single-phase supply (which pulsates with twice the line frequency) and the power supplied to the load (which practically is constant, within several periods of the line current)

3.2 Definitions related to electrical parameters**3.2.1****full wave control (burst firing control)**

synchronous multi-cycle control in which the starting instant is synchronized at voltage zero, and current flows for an integral number of complete half-cycles

3.2.2**duty cycle of vehicle/load profile**

speed and mass of train and track over time

NOTE 1 The load profile for a convertor is calculated by the engineering from the duty cycle of vehicle.

NOTE 2 Load profile (current/power versus time) is the repetitive cycle of the load current/power under specified conditions such as starting and braking; the voltage is also considered

3.2.3**maximum instantaneous input current**

maximum specified input current which the convertor can commute for a specified voltage

3.2.4**maximum instantaneous output current**

maximum specified output current which the convertor can commute for a specified voltage

3.2.5**transient (adjective or nominative)**

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

3.2.6**harmonic components**

components of order greater than 1 of the Fourier series of a periodic quantity

3.2.7

ripple/ripple factor for d.c. current

function obtained by subtracting the d.c. component from a periodic function

$$\text{ripple factor (\%)} = ((I_{\max} - I_{\min}) / (I_{\max} + I_{\min})) \times 100$$

where $I_{\max}$ and $I_{\min}$ are the maximum and minimum values assumed by the periodic function

3.2.8

total rated apparent power on the line side

product of the rated r.m.s line voltage and the total rated r.m.s. line current calculated from the rated average direct current of the convertor and allowing also for the load of the auxiliary windings

3.2.9

nominal value

suitable approximate quantity value used to designate or identify a component, device or equipment

3.2.10

rated value

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

3.2.11

operating point value

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

NOTE See IEC 60077-1, Annex B.

3.2.12

special value

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

4 Common clauses

4.1 General

4.1.1 Design

All design shall proceed according to the regime laid down in ISO 9001.

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

- manufacturer's mark (type-designation);
- 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 convertor 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 must be treated as special waste, when they are removed from service (either alone or with the convertor).

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.

NOTE Requirements have to be clear and univocal. Statements which are not quantified like "Equipment must 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 convertor shall be agreed between the manufacturer and the user. When the manufacturer intends to use components with a known life less than the useful life of the convertor, 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 60077-1 shall be applied unless different classes are specified by the user.

4.2.2 Altitude

The altitude above sea-level, at which the equipment shall perform as specified, shall be as given in IEC 60077-1, unless otherwise specified.

4.2.3 Temperature

4.2.3.1 Ambient temperature

The different classes of ambient temperature, at which the equipment shall perform as specified, are given in IEC 60077-1. The ambient temperature of the vehicle and of the convertor shall be agreed between the user and the manufacturer.

4.2.3.2 Start-up temperatures

This subclause applies to parked vehicles which are not connected to any power source. The initial maximum ambient temperature from which the equipment shall be able to start up without suffering any damage shall be 70 °C and the minimum temperature as specified in 4.2.3.1.

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 convertor. 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 convertors have to perform immediately after connection to the supply.	

4.2.4 Other environmental conditions

The convertor shall be designed for the conditions of humidity and pollution specified in IEC 60077-1.

4.2.5 Mechanical stress

4.2.5.1 Shock and vibration

The convertor, 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.

If a convertor-mass is higher than 500 kg, one may test subassembly only. For a convertor with higher mass, a shock and vibration test has to be agreed between manufacturer and user (optional type test). If no shock and vibration test is performed, an FEM stability calculation is to be provided by the manufacturer.

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 convertor, 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 customer 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 convertor or convertor components, the load profile shall always be specified. This profile shall be calculated by the duty cycle and agreed by manufacturer and user.

In the case of electric braking, the load becomes a power source.

NOTE The duty cycle can be a typical theoretical traction cycle (acceleration, constant speed, braking and stop) or a specified cycle for the vehicle in which the convertor 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.

This profile is used to calculate the worst-case conditions for the components involved and to define the conditions for the temperature-rise test (4.5.3.11).

4.2.7 Supply-system characteristics

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

4.2.7.1 AC supply systems

4.2.7.1.1 Main characteristics of the a.c. line voltage

The main characteristics of the different a.c. 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.

4.2.7.1.2 Step change of line voltage

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

4.2.7.1.3 Distortion of a.c. line voltage

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

The equipment shall perform when the steady-state a.c. line voltage contains levels of harmonic and inter-harmonic voltages less than, or equal to, the values agreed between manufacturer and the user (customer).

4.2.7.1.4 Overvoltage in a.c. systems

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

4.2.7.1.5 AC system impedance

Since the a.c. 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 a.c. 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.

4.2.7.2 DC supply system

4.2.7.2.1 Main characteristics of the d.c. line voltage

The main characteristics of the different d.c. supply systems 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 d.c. voltage converted from a three-phase sinusoidal voltage by full-wave six-pulse rectification.

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

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 convertor shall be agreed between the manufacturer and the user.

4.2.7.2.3 Overvoltage in d.c. systems

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

4.2.7.2.4 DC system inductance and resistance

Since the d.c. 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.

4.2.7.2.5 Distortion of d.c. line voltage

The equipment shall perform when the steady-state d.c. line voltage distortion is less than, or equal to, the values agreed by the manufacturer and the customer.

4.2.7.3 On-board supply systems

Where the convertor is supplied by an on-board supply such as

- battery;
- generators;
- 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 a.c. supply, the frequency and wave form.

4.2.8 Interference

The convertor 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 convertor normally contains harmonic and inter-harmonic components. These are due to harmonics present in the traction supply or are generated by the convertor. Where a convertor 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.

4.2.8.1 Interference with the supply system (emission)

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

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

4.2.8.2 Interference with radio and telecommunication systems

The convertors 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.

4.2.8.3 Interference with signalling systems

The responsibility for compatibility between the convertor, the vehicle and the signalling system is shared among the convertor manufacturer, the system engineer 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 infrastructure operator/authority.

For example:

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

NOTE 1 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 infrastructure operator/authority.

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

NOTE 2 When 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 3 Trackside sensors may 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 convertor 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	N2	N3	N4	N5	
Noise level L_{pA}	80	75	70	65	60	dB _A
Class	N6	N7	N8			
Noise level L_{pA}	95	90	85			dB _A

The noise level is defined by the parameter L_{pA} = A-weighted surface sound pressure level.

Test methods are defined in 4.5.3.10 (IEC 60076-10).

In the case of a convertor with a separate cooling system, if this system is used only for the convertor cooling, it is considered as a part of the convertor 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 convertor 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 convertor, when the convertor is mounted on the vehicle, is the responsibility of the main contractor (vehicle contractor).