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REDLINE VERSION

INTERNATIONAL STANDARD

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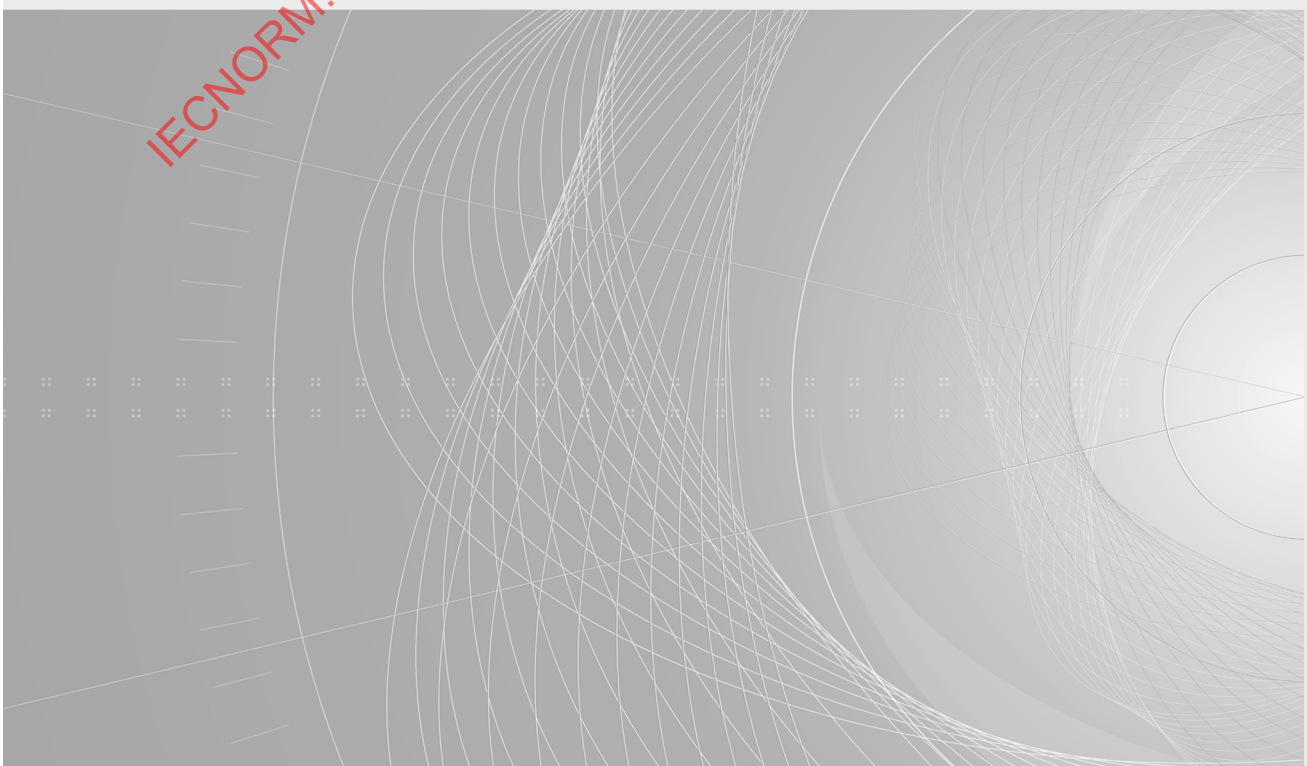
Railway applications – Rolling stock – Protective provisions against electrical hazards



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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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RAILWAY APPLICATIONS – ROLLING STOCK –

Protective provisions against electrical hazards

FOREWORD

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International Standard IEC 61991 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This second edition cancels and replaces the first edition, published in 2000. This edition constitutes a technical revision. It is based on EN 50153:2014.

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

a) Replacement of several reference standards.
b) Several terms and abbreviated terms are introduced;
c) Table 2 – Voltage bands for France is moved to Annex B as Table B.1, Table 3 – Voltage bands for Italy is deleted;
d) Annex B and Annex C are introduced.
e) Annex B includes special national conditions.

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

FDIS	Report on voting
9/2467/FDIS	9/2487/RVD

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

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

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

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- withdrawn,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

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INTRODUCTION

It is generally accepted that safety depends on human factors, based on the normal behaviour of the operators involved, as well as upon technical factors.

For these reasons, this document leaves a choice to the contracting parties between two alternatives in several instances. These alternatives consist of either the provision of operating rules, regulations and procedures, or the application of technical measures such as mechanical or electrical interlocking devices.

A list of the cases for which the contracting parties (e.g. user and manufacturer) shall reach agreement before signing the contract is included in Annex A.

RAILWAY APPLICATIONS – ROLLING STOCK –

Protective provisions against electrical hazards

1 Scope

This document ~~offers a set of rules that are~~ defines requirements applied in the design and manufacture of electrical installations and equipment to be used on rolling stock to protect persons from electric shocks.

~~The methods used to satisfy the rules may differ, in accordance with the procedures and practices of the operating organization.~~

This document is applicable to ~~vehicles~~ rolling stock of rail transport systems, road ~~vehicles~~ transport systems if they are powered by an external supply (e.g. trolley buses), magnetically levitated ~~vehicles~~ transport systems, and to the electrical equipment installed in these ~~vehicles~~ systems.

This document does not apply to:

– mine railways in ~~underground~~ mines,
– crane installations, moving platforms and similar transport systems on rails,
– funicular railways,
– temporary constructions.

~~Testing of vehicles against the requirements of IEC 61991 is not included. For this, refer to IEC 61133.~~

The requirements for the fixed installations about the protection against the vehicles' potential are not covered in this document.

2 Normative references

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

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

~~IEC 60364 (all parts), *Electrical installations of buildings*~~

~~IEC 60364-4-41:1992, *Electrical installations of buildings – Part 4: Protection for safety – Chapter 41: Protection against electric shock*~~

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

———————

~~1) To be published.~~

~~IEC 60439 (all parts), *Low-voltage switchgear and controlgear assemblies*~~

IEC TS 60479-1~~:1994~~, *Effects of current on human beings and livestock – Part 1: General aspects*

IEC 60529~~:1989~~, *Degrees of protection provided by enclosures (IP Code)*

~~IEC 60536 (all parts), *Classification of electrical and electronic equipment with regard to protection against electric shock*~~

~~IEC 60850, *– Railway applications – Supply voltages of traction systems* [1)]~~

IEC 61140:2016, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61310-1~~:1995~~, *Safety of machinery – Indication, marking and actuation – Part 1: Requirements for visual, ~~auditory~~ acoustic and tactile signals*

~~IEC 62128, *– Railway applications – Protective provisions against electrical hazards – Electric equipment for fixed installations* [1)]~~

IEC 62128-1:2013, *Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 1: Protective provisions against electric shock*

IEC 62313, *Railway applications – Power supply and rolling stock – Technical criteria for the coordination between power supply (substation) and rolling stock*

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

IEC 62995:2018, *Railway applications – Rolling Stock – Rules for installation of cabling*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

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

NOTE For more information relating to definitions of parts of the fixed installations, refer to IEC 62128-1 from which these definitions are derived.

~~NOTE In order to avoid risks of misunderstanding, definitions used in the text are written in italics.~~

~~1) To be published.~~

3.1.1 Definitions concerning persons ~~involved~~

3.1.1.1
<electrically> instructed person
~~person informed about the tasks assigned to him and about possible dangers involved in neglectful behaviour and who, if necessary, has been given a degree of training~~

person adequately advised or supervised by electrically skilled persons to enable him or her to perceive risks and to avoid hazards which electricity can create

[SOURCE: IEC 60050-195:1998, 195-04-02]

3.1.1.2
ordinary person
~~any person who cannot be defined either as a *skilled person* or as an *instructed person*~~

person who is neither a skilled person nor an instructed person

[SOURCE: IEC 60050-195:1998, 195-04-03]

3.1.1.3
<electrically> skilled person
~~person who can judge the work assigned to him and recognize possible dangers on the basis of his professional training, knowledge and experience and of his knowledge of the relevant requirements~~

person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which electricity can create

[SOURCE: IEC 60050-195:1998, 195-04-01]

3.1.2 Other definitions

3.1.2.1
closed electrical operating area
~~any~~ room or location which serves exclusively for the operation of electrical equipment and is kept secure by a means appropriate to the voltage and location

Note 1 to entry: Access to such areas is permitted only to (electrically) skilled persons and (electrically) instructed persons.

Note 2 to entry: The definition of closed electrical operating area can be suitable for underfloor or upperroof cabinets. Generally speaking, it is any location (inside or outside the car body) which is kept secured because of the voltage that can be assumed to be present on the equipment inside it. Access to such areas is not allowed ~~to~~ for ordinary persons.

3.1.2.2
contact line
conductor system for supplying electrical energy to ~~vehicles~~ rolling stock through current-collecting equipment

[SOURCE: IEC 60050-811:2017, 811-33-01, modified – The term “vehicle” has been replaced by “rolling stock” and Note 1 to entry has been omitted.]

3.1.2.3
contact wire
electric conductor of an overhead contact line with which the current collectors make contact

[SOURCE: IEC 60050-811:2017, 811-33-15]

3.1.2.4
direct contact
electric contact of persons or ~~livestock~~ animals with live parts

[SOURCE: IEC 60050-195:1998, 195-06-03]

3.1.2.5
double insulation
insulation comprising both basic insulation and supplementary insulation

[SOURCE: IEC 60050-195:1998, 195-06-08]

3.1.2.6
earth
conductive mass of the earth, whose electrical potential at any point is conventionally taken as equal to zero

3.1.2.7
electrical operating area
~~any~~ room or location which serves primarily for the operation of electrical equipment and is normally entered only by skilled persons or (electrically) instructed persons

~~NOTE The definition of *closed electrical operating area* can be suitable for underfloor or upper roof cabinets. Generally speaking it is any location (inside or outside the car body) which is kept secure because of the voltage that can assume the equipment inside it. Access to such areas is not allowed to *ordinary persons*.~~

Note 1 to entry: Generally speaking, an electrical operating area is any location (mainly inside the car body) where electrical equipment operates. The above is the main function of this area but not the only one. In fact, normally the area is not kept secured and protection against direct contact is achieved by other means (e.g. (electrically) protective obstacles).

3.1.2.8
electric shock
~~dangerous~~ physiological effect resulting from an electric current passing through a human or animal body

[SOURCE: IEC 60050-195:1998, 195-01-04]

3.1.2.9
extra-low voltage
voltage not exceeding the relevant voltage limit of band II specified in Table 1

[SOURCE: IEC 60050-826:2004, 826-12-30, modified – The term “band I” has been replaced by “band II” and “IEC 60449” has been replaced by “Table 1”.]

3.1.2.10
equipotential bond
electrical connection putting various exposed conductive parts at a substantially equal potential

Note 1 to entry: This can be abbreviated as ‘bond’ or ‘bonding’.

3.1.2.11
exposed conductive part <of electrical equipment>
~~any metallic or other form of conductive material which is not energized except in case of *failure*, and which may be accessible to touch~~

conductive part of electrical equipment, which can be touched and which is not normally live, but can become live when basic insulation fails

Note 1 to entry: A conductive part of electrical equipment which can only become live through contact with an exposed conductive part which has become live is not considered to be an exposed conductive part itself.

~~**3.2.9**~~
~~**failure**~~
~~termination of the ability of an item to perform a required function~~

~~**3.2.10**~~
~~**hazard**~~
~~condition that can lead to a potential accident or an actual accident~~

3.1.2.12
indirect contact
electric contact of persons or ~~livestock~~ animals with exposed conductive parts which have become live under fault conditions

[SOURCE: IEC 60050-195:1998, 195-06-04]

3.1.2.13
interlocking device
device which makes the operation of a switching device dependent upon the position or operation of one or more other pieces of equipment

[SOURCE: IEC 60050-441:2000, 441-16-49]

3.1.2.14
insulate, verb
prevent electric conduction between conductive elements by means of insulating materials

[SOURCE: IEC 60050-151:2001, 151-15-36]

3.1.2.15
insulation
all the materials and parts used to insulate conductive elements of a device

[SOURCE: IEC 60050-151:2001, 151-15-41]

3.1.2.16
live part <in electric traction>
conductor or conductive part intended to be energized in normal use~~, including a neutral conductor~~

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

Note 2 to entry: By convention, this does not include the running rails and parts connected to them.

[SOURCE: IEC 60050-811:2017, 811-36-23]

3.1.2.17
locking system
system which comprises interlocking devices and physically prevents access to live parts unless the supply of electrical energy to the live parts has been isolated and made safe

3.1.2.18
mechanical locking
use of a lock or bolted /screwed fixings to prevent access panels or doors being opened and require the use of a key or tool to remove

3.1.2.19
multi-stage insulation
insulation system having more than one stage of insulation and an intermediate frame between consecutive stages

[SOURCE: IEC 60322:2001, 3.4, modified – Notes have been deleted.]

3.1.2.20
nominal voltage <of a system>
~~voltage by which an installation or part of an installation is designated~~

suitable approximate value of voltage used to designate or identify a system

Note 1 to entry: The voltages are expressed by the value between poles, ripple-free for DC and by the RMS value between phases for AC.

Note 2 to entry: The actual voltage ~~may~~ can differ from the nominal voltage by a quantity within permitted tolerances. For further information about traction systems supply voltages, see IEC 60850.

[SOURCE: IEC 60050-601:1985, 601-01-21, modified – Notes to entry have been added.]

3.1.2.21
PELV system
electric system in which the voltage cannot exceed the value of extra-low voltage:

– under normal conditions and

– under single fault conditions, except earth faults in other electric circuits

[SOURCE: IEC 60050-826:2004, 826-12-32, modified – Note has been deleted.]

3.1.2.22
<electrically> protective obstacle
part preventing unintentional direct contact, but not preventing direct contact by deliberate action

[SOURCE: IEC 60050-195:1998, 195-06-16]

3.1.2.23
power circuit
circuit carrying the current of the machines and equipment, such as the converters and traction motors, which transmit the traction output

[SOURCE: IEC 60050-811:2017, 811-25-03]

~~**3.2.17**~~
~~**protective bonding**~~
~~equipotential connection for protective purposes~~

3.1.2.24
protective conductor
~~conductor used for some protective measures for protection against electric shock for electrically connecting any of the following parts:~~

~~– *exposed conductive parts*;~~

~~– main earthing terminal;~~

~~– *earth* electrode;~~

~~– earthed point of the source or artificial neutral.~~

conductor provided for purposes of safety, for example protection against electric shock

[SOURCE: IEC 60050-195:1998, 195-02-09]

3.1.2.25
protective-equipotential-bonding
equipotential bonding for the purposes of safety

[SOURCE: IEC 60050-195:1998, 195-01-15]

3.1.2.26
SELV system
electric system in which the voltage cannot exceed the value of extra-low voltage:

– under normal conditions and

– under single fault conditions, including earth faults in other electric circuits

[SOURCE: IEC 60050-826:2004, 826-12-31, modified – Note has been deleted.]

3.1.2.27

total insulation
insulation composed of basic insulation as provision for basic protection, and supplementary insulation as provision for fault protection, or providing basic and fault protection by reinforced insulation, in accordance with IEC 61140:2016, 7.4

[SOURCE: IEC 60050-851:2008/AMD1:2014, 851-15-11, modified – "equipment with" has been replaced with "insulation composed of" and "IEC 61140:2011,7.3" has been replaced with "IEC 61140:2016,7.4".]

3.1.2.28
Unit <electrically connected>
minimum operational formation comprising one or more vehicles coupled together

3.2 Abbreviated terms

AC Alternating Current
DC Direct Current
ELV Extra Low Voltage
EMU Electric Multiple Unit
PELV Protective Extra Low Voltage
RMS root-mean-square value (effective value)
SELV Safety Extra Low Voltage

4 Classification of voltage bands

4.1 General principles

In this document ~~is~~, the applicable protective measures are based on the ~~maximum~~ highest value of the nominal supply voltage~~s at~~ which the equipment or the electrical circuits are subjected to.

The voltages are classified into bands according to the nominal value as shown in Table 1 ~~to 3~~. Different ~~installation~~ rules apply to each of these bands.

The power supply of the various circuits installed in railway rolling stock ~~are of~~ can be from different ~~types~~ sources such as:

– batteries,

– transformers,
– voltage dividers,
– rotating machines,
– static converters,
– capacitors,
– special sources.

Table 1 – Voltage bands

Band	Nominal voltage U_n	
	AC V	DC V
I	$U \leq 25$	$U \leq 60$
II	$25 < U \leq 50$	$60 < U \leq 120$
III	$50 < U \leq 1\,000$	$120 < U \leq 1\,500$
IV	$U > 1\,000$	$U > 1\,500$

~~In some countries such as France, the following table 2 applies:~~

~~**Table 2 – Voltage bands**~~

~~Band~~	~~Nominal voltage~~	
	~~AC V~~	~~DC V~~
~~I~~	~~$U \leq 25$~~	~~$U \leq 60$~~
~~II~~	~~$25 < U \leq 50$~~	~~$60 < U \leq 120$~~
~~III~~	~~$50 < U \leq 500$~~	~~$120 < U \leq 750$~~
~~IV~~	~~$U > 500$~~	~~$U > 750$~~

~~In some countries such as Italy, the following table 3 applies:~~

~~**Table 3 – Voltage bands**~~

~~Band~~	~~Nominal voltage~~	
	~~AC V~~	~~DC V~~
~~I~~	~~$U \leq 25$~~	~~$U \leq 50$~~
~~III~~	~~$25 < U \leq 400$~~	~~$50 < U \leq 600$~~
~~IV~~	~~$U > 400$~~	~~$U > 600$~~

NOTE The special national conditions for France are listed in Annex B, Clause B.2.

4.2 Connections between circuits

Circuits operating at different nominal voltages connected by power conversion equipment which ~~does not~~ provides a ~~conducting path between them, or circuits which are linked only by a connection direct to the vehicle body external to the power conversion circuitry, shall be~~

sufficient insulation between them are individually classified at the nominal *voltage* of each circuit.

If the conducting paths referred to in this subclause include capacitive or inductive connections, whose impedance is low enough to induce hazardous voltages into any circuit under either normal or fault conditions, then all the circuits so connected ~~shall be~~ are classified at the nominal voltage of the highest voltage circuit.

NOTE This condition can apply to circuits connected, for example, by means of a chopper converter with impedance coupling.

Where circuits are linked conductively to a higher voltage source other than ~~simply~~ directly by circuit bonds connected to the vehicle body (for example by an auto-transformer or potential divider), all circuits in the group ~~shall be~~ are treated as if energized at the nominal voltage of the source, unless the conditions of 4.3 have been met.

4.3 Exceptions

If voltage conversion from one band to another involves overvoltage detection resulting in disconnection of the primary or the secondary circuit, or having other means capable of preventing excessive voltage in the secondary circuit, then the secondary circuit ~~shall~~ is permitted to be classified according to the highest voltage at which the detection equipment will operate. Where overvoltage detection is used the integrity of the equipment should be evaluated as appropriate.

~~NOTE The integrity of the detection equipment should be taken into account.~~

Circuits not connected to the vehicle body, for example floating supplies, ~~shall be classified as appropriate in order to ensure that the requirements of this standard are met, taking due account of the potentials possible in such circuits under normal or fault conditions~~ are permitted to be classified in any voltage band. The band selected should be appropriate, taking due account of the various potentials possible in such circuits under normal or fault conditions so as to ensure that the requirements of this document are met.

The limit between bands III and IV is allowed to be lowered to take account of special national conditions.

5 Protective provisions against direct contact

5.1 General

Live parts capable of causing an electric shock shall be protected against direct contact. All types of equipment shall be capable of being operated without loss of protection against direct contact. Protection against direct contact shall be provided, where possible, by at least one of the means described in 5.2 to 5.3~~, supplemented as necessary by *warning* labels as described in 5.4~~.

Where it is not possible to provide protective provisions in accordance with 5.2 or 5.3, then it is permitted to use protection by the use of band I voltage in accordance with the conditions of 5.4.

Additionally where required to ensure adequate protection against direct contact, warning labels as described in 5.5 shall be provided.

5.2 Protection by insulation

In addition to the requirements of ~~IEC 60077-1~~ IEC 62497-1, the insulating materials used to cover live parts shall be appropriate to the ~~*nominal*~~ rated equipment operating voltage and the

conditions of use. Further provisions should be considered in order to minimize the consequences of damage.

5.3 Protection by prevention of access

~~Access to *live parts* shall be prevented by placing them within *closed electrical operating areas* or by placing them out of reach. The rest of this standard explains the measures required.~~

5.3.1 Voltages in bands I to III

5.3.1.1 Protection by the use of closed electrical operating areas

Live parts within the vehicle, energized with voltages in bands I to III shall be contained within closed electrical operating areas.

Access to closed electrical operating areas containing energized live parts is permitted as follows:

– band I and II: access is permitted to (electrically) instructed persons and skilled persons;

– band III: access is only permitted to (electrically) instructed persons and skilled persons provided that ~~all reasonably practicable~~ precautions ~~are taken~~ against unintended direct contact are taken.

Prevention of access ~~can~~ shall be achieved ~~either~~ by mechanical locking ~~or by physical separation, supported by labels or procedures appropriate to the location and the equipment enclosed~~ supported with procedures and warning labels appropriate to the location and equipment enclosed.

Means of preventing access shall comply with the following:

- in areas within vehicles, accessible to ordinary persons, screens and covers shall conform to the degree of protection IP4X as set out in IEC 60529, or, where these are electrically connected to the vehicle body, to the degree of protection IP2XD as set out in IEC 60529; the requirements of this subclause do not apply to plug connectors, lamp holders without lamps ~~or~~ and fuse sockets for screw-in type fuses without inserts;
- in other areas where grid or mesh screens are used, these shall be placed at a sufficient distance to prevent any direct contact, taking into account possible buckling or warping.

5.3.1.2 Protection by the use of electrical operating areas

~~Where the conditions of 5.2.1.1 do not apply, then~~ For live parts ~~shall be~~ contained within an electrical operating area~~s and~~ the following shall apply:

~~– protection against *direct contact* is not required for *live parts* energized within bands I and II, provided that these meet the requirements of clause 8;~~

– live parts energized within bands I and II need no protection against direct contact provided that the requirements of 8.5.2 are met.

– the use of (electrically) protective obstacles to afford a limited protection against direct contact with live parts at band III voltages may be acceptable in electrical operating areas inaccessible to ordinary persons by their location (such as underframe cases, roofs, interiors of motor units, excluding driver's cabs), provided that the hazard is readily identifiable. For example, it is acceptable for fuses and isolating links of equipment at band III voltages, whose grips are protected with an insulating material, not to be protected. Such ~~units~~ components shall only be situated in electrical operating areas.

5.3.1.3 Protection by clearance

For live parts on the outside of the vehicle (e.g. current collectors, roof conductors, resistors) which are potentially accessible to persons in a straight line from any standing surface in, on

or by vehicles, protection against direct contact by means of clearance shall be provided if no other protective measures as defined in this document are used.

NOTE Accessible in a straight line implies that live parts can be touched from a standing surface without use of specially shaped objects.

Protection by clearance is considered to be provided, if at least the clearances from standing surfaces to live parts depicted in ~~IEC 62128 (under consideration)~~ IEC 62128-1:2013, Figure 3, are maintained, excepting the condition of shoe gear adjacent to the platform edge.

This protection is considered to be present, if contact with live parts is possible but clearance is afforded ~~by virtue~~ in case of the movement of the vehicle (e.g. on road and foot-crossings). Where only (electrically) instructed persons and skilled persons have access and where operation of the system makes protection by clearance impossible (e.g. systems using third and/or third and fourth rail power supplies) protection shall be afforded by procedure.

5.3.1.4 Protection against hazards from external power supply ~~bus lines~~

Access to live parts that may be energized with voltage band III when the supply system is likely to be energized from an external ~~source~~ power supply (e.g. another vehicle, preheating equipment, shed supply, etc.) shall be prevented by an interlocking device or a procedure.

Connectors in the power supply bus line shall be fitted with warning labels as set out in 5.5.

5.3.2 Voltages in band IV

5.3.2.1 Protection by the use of closed electrical operating areas

Access to live parts energized with voltages in band IV shall be excluded to all persons including skilled persons.

Access to live parts normally energized with voltages in band IV shall only be possible to (electrically) instructed persons and skilled persons after the live parts have been de-energized and made safe by one or more of the following methods:

– procedure;
– interlocking devices;
– protective-equipotential-bonding;
– safety or monitoring devices.

Means of preventing access and making live parts safe shall comply with the following:

- covers in areas accessible to ordinary persons in vehicles shall conform to the degree of protection IP4X as set out in IEC 60529; areas accessible to instructed persons and skilled persons shall conform to the degree of protection IP2X as set out in IEC 60529;

~~– protection of equipment requiring infrequent intervention may consist of screwed or bolted panels. It shall only be possible to remove these panels by use of a tool. No specific locking system is thus required in these cases;~~

~~– for equipment requiring frequent intervention, *interlocking devices* shall be provided to ensure that *live parts* become accessible only after their power supply has been cut off and the *live parts* have been made safe by *protective bonding*. Locks and *interlocking devices* shall allow off-load tests to be performed on control equipment.~~

- in cases where band III voltages are not eliminated after band IV live parts have been deenergized, the precautions of 5.3.1 shall be taken to prevent direct contact with live parts which remain energized with voltages in band III.

5.3.2.2 Protection by clearance

For live parts on the outside of the vehicle (e.g. current collectors, roof conductors, resistors ~~as well as those of overhead line systems~~), which are potentially accessible to persons in a straight line ~~from fixed platforms as well as~~ from any standing surface in, on or by vehicles, protection against direct contact by means of clearance shall be provided, except for the pantograph head, if no other protective measures as defined in this document are used.

NOTE Accessible in a straight line implies that live parts can be touched from a standing surface without use of specially shaped objects.

Protection by clearance is considered to be provided, if at least the clearances from standing surfaces to live parts depicted in ~~IEC 62128 (under consideration)~~ IEC 62128-1:2013, Figure 4, are maintained, except for the condition of shoe gear adjacent to the platform edge.

5.3.2.3 Protection against hazards from external power supply ~~bus line~~

Access to live parts when the supply system is likely to be energized from an external ~~source~~ power supply (e.g. another vehicle, preheating equipment, shed supply, etc.) shall be prevented by an interlocking device or procedure.

For equipment requiring frequent intervention, such as electric train supply jumpers, interlocking devices or procedures shall be provided to ensure that the live parts of the equipment become accessible only after their power supply has been ~~cut~~ switched off and the live parts have been made safe by protective bonding.

Connectors in the power supply bus line shall be fitted with warning labels as set out in 5.5.

5.4 Protection by the use of band I (ELV)

~~Where protective provisions in accordance with 5.1 or 5.2 are not possible, then protection by the use of band I voltage can be provided in accordance with the conditions of 5.3.1 or 5.3.2 below.~~

~~5.3.1 Unbonded from a safe source~~

~~Where a circuit at a voltage in band I is not bonded to the vehicle body, no further protective provision is required provided that the circuit meets the requirements of 411.1.2, 411.1.3 and 411.1.4 of IEC 60364-4-41 as well as the requirements of clause 8 of this standard.~~

~~5.3.2 Bonded from a safe source~~

~~Where a circuit at a voltage in band I is bonded to the vehicle body, no further protective provision is required provided that the *nominal voltage* does not exceed 6 V a.c. or 15 V d.c. and the circuit meets the requirements of 411.1.2, 411.1.3 and 411.1.5 of IEC 60364-4-41. If the voltage exceeds 6 V a.c. or 15 V d.c., protection in accordance with 411.1 of IEC 60364-4-41 is required only where *ordinary persons* have access.~~

5.4.1 Requirements for systems of band I (SELV and PELV)

Systems of band I shall meet the following requirements:

- the power sources for SELV and PELV shall meet the requirements of 414.3, power sources for SELV and PELV, of IEC 60364-4-41:2005;
- the system shall meet the requirements of 414.4, requirements for SELV and PELV system, of IEC 60364-4-41:2005;
- the system shall meet the requirements of Clause 8 of this document.

5.4.2 Additional requirements for SELV

A SELV system shall not be connected to the protective bonding circuit (vehicle body). For SELV system at a voltage in band I no further protective provision is required provided that the circuit meets the requirements of 5.4.1.

5.4.3 Additional requirements for PELV

One pole of the PELV system or one pole of the source of the supply of that PELV system shall be connected to the protective bonding circuit. No further protective provision is required provided that the nominal voltage does not exceed 6 V AC or 15 V DC and the system meets the requirements of 5.4.1.

If the voltage exceeds 6 V AC or 15 V DC and ordinary persons have access, protection as set out in 411.7.2 of IEC 60364-4-41:2005 is required.

5.5 Warning labels

Warning labels ~~especially~~ for electrical hazards shall be as set out in IEC 61310-1 ~~(WARNING: risk of *electric shock*)~~.

If a hazard is considered to exist, after all interlocking devices or design features have been operated to gain access to equipment, then warning labels shall be fitted to identify the hazard and provide any supplementary information necessary to avoid danger to persons. The labels shall be fitted in positions that ensure that they are clearly visible and will remain so throughout the life of the equipment.

Access to elevated vehicle standing surfaces, from which live parts of a contact line system can be reached, shall be marked by means of warning labels.

A warning label shall be placed on the access points to any closed electrical operating areas containing voltages in bands III or IV. It is ~~allowed~~ permitted not to provide warning labels where ~~*interlocking devices* are used~~ a locking system is used to ensure access is prohibited until the hazardous voltage is no longer present.

6 Protective provisions against indirect contact

6.1 General ~~principles~~

~~*Exposed conductive parts* shall be incapable of causing *electric shock* through induction or contact with *live parts* in the vicinity under *failure* conditions.~~

Clause 6 defines the allowable methods permitted for use in order to ensure that the potential of the vehicles body is kept sufficiently close to the potential of the protective conductor of the fixed installation.

The methods described in 6.2 to 6.5 shall ensure that exposed conductive parts are incapable of causing electric shock through induction or contact with live parts in the vicinity under failure conditions.

The aim ~~shall be~~ is to ensure that the exposed conductive parts which present such a risk are at the same potential. This aim may be achieved by protective bonding as set out in 6.2 alone or in conjunction with automatic disconnection of supply, or ~~other suitable means~~ exceptions as described in 6.5.

~~Bearings shall not be used to connect *exposed conductive parts* if there is a risk of damage to the bearings caused by electrical current.~~

Clarifications and exceptions are covered in 6.5.

Additional requirements are covered in 6.6.

6.2 Protective bonding

~~**6.2.1 Equipotential connections**~~

~~*Exposed conductive parts* (except where excluded by 6.5) shall be bonded to the vehicle body, or constituent part thereof, either directly or via *protective bonding* conductors.~~

~~All precautions shall be taken to prevent bonding resistance values from increasing with time, in particular due to corrosion effects or fatigue.~~

~~Conductors of a protective equipotential bonding system whether insulated or bare shall be readily distinguishable by shape, location, marking or colour. If identification by colour is used, it shall be the bicolour combination green-and-yellow.~~

6.2.1 General

Bonding to the protective conductor shall be provided for any exposed conductive parts which are capable of causing electric shock through induction, capacitive coupling or contact with live parts under foreseeable failure conditions.

6.2.2 Equipotential bond

All parts of the protective equipotential bonding shall be capable of withstanding all internal and external influences (including mechanical, thermal and corrosive) which can be expected.

Conductors of a protective equipotential bonding system shall be as set out in IEC 62995:2018, 4.6.

6.2.3 Protective bonding rating

Protective bonding shall be dimensioned to provide adequate strength and current carrying capacity to ensure that the exposed conductive parts are incapable of causing electric shock under failure conditions. See also 6.3.

For characteristic values to support the dimensioning of cross-section for protective bonding, see IEC 62313.

Due regard shall be paid to all currents flowing in the running rail which may affect the rating of the bonding connections.

6.2.4 Sliding contacts

Sliding contacts, e.g. ~~axle~~ earth-return brushes, shall conform to the other requirements of 6.2. The failure of any one such contact shall not cause risk of electric shock.

6.3 Disconnection of the supply

6.3.1 Application

Automatic disconnection of supply or automatic limitation of fault current, e.g. by resistance insertion, shall be used in conjunction with protective bonding, where 6.2.3 would not be achieved.

Automatic disconnection of supply shall be provided where a risk of harmful physiological effects to a person could arise when a fault occurs, due to the value and duration of the touch voltage (for guidance, see IEC TS 60479-1).

For the evaluation of the relevant fault duration in order to assess the permissible touch voltage, the correct operation of the protection devices and switches shall be assumed. Multiple independent faults occurring simultaneously do not need to be considered.

6.3.2 Disconnection characteristic

~~A protective device shall automatically disconnect the supply to the circuit or equipment for which the device provides protection against *indirect contact* so that,~~ In the event of a fault between a live part and an exposed conductive part (or a protective conductor) in the circuit or equipment, an automatic protection device shall operate and disconnect the circuit or equipment for which the device provides protection against indirect contact. The protection shall prevent a prospective touch voltage exceeding the upper limit of band II voltages ~~does not~~ persisting for a time sufficient to cause a risk of harmful physiological effect to a person in contact with simultaneously accessible conductive parts. For further guidance, refer to ~~413.1~~ 411 of IEC 60364-4-41:2005.

6.4 ~~Vehicle~~ Main protective bonding

6.4.1 General

The following ~~shall apply~~ applies to all vehicles operating on systems employing a protective conductor ~~where this~~. This protective conductor may be separated from or combined with the running rails which form a part of the return circuit for the traction return current. For ~~other~~ insulated wheel or levitation systems without a protective conductor, refer to 6.5.5.

Vehicle bodies shall be bonded as set out in 6.4.2 and 6.4.3.

6.4.2 Bonding paths

There shall be at least two protective bonding paths between a vehicle body and the protective conductors of the fixed installation so that, if a failure occurs in one path, there shall be no risk of electric shock. Both paths shall be ~~visible~~ accessible for visual inspection.

Any protective bonding path of a vehicle body to the protective conductors of the fixed installation could be direct within the vehicle or via another vehicle.

NOTE 1 The protective conductors are normally the running rails. (See IEC 62128-1).

NOTE 2 The special national conditions for Great Britain are listed in Annex B, Clause B.3.

For the design of bonding path on vehicles it should be considered that the current values of IEC 62313 will be reduced by the vehicle impedance. Main protection can be assumed to operate normally. Even for the thermal design of earthing conductors on vehicles this main protection tripping time can be applied.

Additionally for DC systems main protection will further limit the maximum current to a value below the prospective current.

NOTE 3 Experience shows that in DC systems current peaks for faults to the vehicle typically do not exceed values of 50 kA for 20 ms.

The probability of a fault on the vehicle which is not seen by its circuit-breaker (e.g. current collector short-circuit) and an outage of the main protection in the traction power substation at the same time is low. For such cases the overheating of earthing conductors is acceptable if they remain in place until the fault is cleared. This includes cases where auto-reclosure in the traction power substation doubles the thermal stress. Maintenance rules should be in place to check their condition afterwards.

6.4.3 Impedance

The impedance between the ~~vehicle body~~ unit and the protective conductor of the fixed installation, e.g. the running rails, shall be low enough to prevent the existence of a hazardous voltage between them, ~~according to the criteria of IEC 60479-1~~ using the criteria set out in IEC 62128-1:2013, Clause 9.

The maximum impedance~~s~~ between the ~~vehicle body~~ unit and the protective conductor of the fixed installation are set out in Table 2. Lower figures shall be used if these values could cause the occurrence of a hazardous voltage. Consideration should also be given to the possible rail potentials ~~referred to in IEC 62128 (under consideration) which may add to the voltage between vehicle body and the rails~~ set out in IEC 62128-1:2013, Clause 9. This should be demonstrated both by calculation with an assumption of 1 mΩ per earth brush and verification by measurement (maximum values are set out in Table 2).

Table 2 – Maximum impedance between each vehicle body of a unit and protective conductor of the fixed installation

Type of vehicle	Maximum impedance Ω
Tractive stock Coaches	0,05
Wagons	0,15

These values shall be measured with a constant current of 50 A, where the ~~applied~~ open-circuit voltage shall not exceed 50 V. The measurement shall be carried out with a clean wheel to rail interface.

Resistance of protective bonding path can be calculated.

NOTE 1 The total impedance of units electrically connected is considered.

The calculated resistance should be smaller than 10 mΩ in DC and 15 kV AC systems and 20 mΩ in 25 kV AC systems.

Experience suggests that values in Table 2 are indicative of impedance at high current which is substantially lower.

NOTE 2 Example solutions for impedance management of electric multiple units can be found in Annex C.

6.4.4 Contact line fault

In the event of contact between an external electric traction power supply and a vehicle body (i.e. a broken contact wire), ~~the aim of~~ the system design shall ~~be to~~ reduce any excessive voltage at or within the vehicle body, to the levels required in 6.3 in the shortest ~~possible~~ practicable time.

Since the fault would normally be cleared by the fixed installations, in order to determine the voltage likely to occur at the vehicle, reference should be made to ~~IEC 62128 (under consideration)~~ IEC 62128-1.

The vehicle protective bonding shall take account of the above aim, and shall remain intact.

NOTE Special national conditions in Japan can be found in Annex B, Clause B.4.

6.5 Clarifications and exceptions with reference to indirect contact

6.5.1 Parts requiring protective provisions

Protective provisions shall be made for exposed conductive parts in the proximity of electrical equipment, for example: sinks, metal cupboards, aerial ground planes and other similar parts.

Where no electrical equipment is fixed to covers, doors and cover plates of the electronic equipment, the normal metal screws and locking devices as well as conducting corrosion-proof hinges are considered to be sufficient protective bonding. Where electrical equipment is attached to these movable parts of electronic equipment, the exposed conductive parts of the particular electrical equipment need a protective bonding. The protective bonding to these movable parts of electronic equipment should be made via a protective conductor.

6.5.2 Parts not requiring protective provisions

6.5.2.1 Exceptions of protective provisions

Protective provisions are not needed for exposed conductive parts separated from any source which may cause electric shock~~, for example small items of interior trim in an environment otherwise protected by bonding and/or insulation (e.g. grips, coat hooks, etc.)~~.

Furthermore, no protective provisions are required for equipment defined in 6.5.2.2, 6.5.2.3 and 6.5.2.4, tested and marked to the relevant standards.

6.5.2.2 Band II voltage

Protection against indirect contact may be dispensed with for the exposed conductive parts of equipment energized at voltages in band II, if the circuits meet the requirements of SELV or PELV (as defined in IEC 60364-4-41).

6.5.2.3 Double insulation

Electrical equipment having double or reinforced insulation shall comply with the requirements ~~of class II equipment of IEC 60536~~ set out in IEC 62497-1 or IEC 60364-4-41.

6.5.2.4 Total insulation (for voltages in band III only)

Assemblies of electrical equipment having total insulation shall meet the requirements ~~of IEC 60439~~ set out in IEC 61140.

6.5.3 Multi-stage insulation

When multi-stage insulation is ~~employed~~ used, for example in roof or underframe-mounted traction resistors which are air-insulated, exposed conductive parts located between the basic and supplementary insulation shall be regarded as live parts and the provisions of Clause 5 shall apply.

6.5.4 Floating supplies

Circuits at voltages in bands III or IV not bonded to the vehicle body (floating supplies) shall not be used to provide sole protection against indirect contact~~, unless they comply with IEC 60364 (refer also to clause 8). In all other cases~~. The provisions of either 6.2 or 6.3 shall also be applied. Account shall also be taken of the requirements of 7.1.

Equipment that is isolated and remains floating should be viewed as not protected with respect to indirect touch.

6.5.5 Insulated wheel or levitation systems without a protective conductor

~~**6.5.5.1** In this case 6.4 does not apply. The vehicle body including its *exposed conductive parts* shall be insulated from the power supply system.~~

~~For trolleybuses or other vehicles with no means of connection to the *protective conductor* of the fixed installation when stationary, all electrical equipment shall be double insulated. Any *failure* of either level of insulation shall be detectable either by procedure or by the use of monitoring devices.~~

~~**6.5.5.2** Such vehicles shall only be used on power supply systems that meet the requirements of IEC 62128 (under consideration).~~

The requirements of 6.4 do not apply to insulated wheel or levitation systems without a protective conductor. The vehicle body including its exposed conductive parts shall be insulated from the power supply system.

No supply circuit derived from within the unit or vehicle shall be capable of acquiring a voltage above the design range under normal or fault conditions either between poles or with respect to any exposed conductive parts.

Where a transport system is deemed touchable when not in earthed conditions, all electrical equipment shall be double insulated. Earthed conditions are where a connection is made, either automatically or manually, to the protective conductor of the fixed installation.

Any failure of either level of insulation shall be detectable either by procedure or by the use of monitoring devices.

Such transport systems shall only be used on power supply systems that meet the requirements set out in IEC 62128-1.

6.6 Additional requirements – Bearings

Bearings on vehicles other than wagons shall not be used to connect exposed conductive parts.

Bearings on wagons should not be used to connect exposed conductive parts, if there is a risk of damage to the bearings caused by electrical current.

7 Power circuit

7.1 General principles

Power circuit design shall ensure that all currents are returned to the source of supply without resulting in damage or risk of electric shock.

Where sliding or flexing connections between the body or bogie and the running rail are ~~employed~~ used, there shall be at least two separate paths per ~~vehicle~~ unit and a failure in one path shall not cause damage or risk of electric shock.

~~Where wheels are used as part of the return path, at least two wheels on different axles shall be used.~~

Paths shall be dimensioned to carry all currents which may flow through them. Due regard shall be paid to fault currents and currents flowing in the running rail.

Bearings in general shall not be used as part of the return path. Dedicated current limits of the bearing manufacture may be considered.

If any part of the return path is combined with the vehicle protective bonding at any point, the requirements set out in Clause 6 shall additionally apply.

To prevent damage or risk of electric shock from circuits directly fed from an external power supply, failures in the return current paths shall be detectable by an appropriate means, e.g. procedure or monitoring device.

~~No supply circuit derived from within a train or vehicle shall be capable of acquiring a voltage above the design range under normal or fault conditions either between poles or with respect to any *exposed conductive parts*.~~

Current return may conform to either of the methods below. The method chosen shall be the responsibility of the railway authorities and shall comply with requirements set out in either 7.2 or 7.3.

7.2 Power circuit insulated from the vehicle body or bogie

A path or paths insulated from the vehicle, or from any exposed conductive parts thereof, shall be provided to conduct current from the return of the power equipment to the return conductor of the supply system.

7.3 Power circuit using the vehicle body or bogie

Where returns are connected to the vehicle body, the connections shall be through members of sufficient cross-section to comply with the paragraphs below.

Current flowing in any paths through the body or bogie frame shall not cause damage or unacceptable deterioration to the structure or any mechanical parts.

Voltage differences between two different parts of the body or bogie sections shall not be sufficient to cause electric shock under any normal or failure condition.

In the event of contact between an external electric power supply and the vehicle body, additionally 6.4.4 shall apply.

8 Additional requirements

8.1 General

Means shall be provided for any live parts ~~to be made safe~~ which may be sufficiently energized to cause electric shock after disconnection from the supply to be secured against electric shock.

8.2 Current collectors

In addition to the requirements set out in Clause 5, means shall be provided to separate the overhead current collector from the contact wire and prevent accidental contact of the current collector with the wire.

For overhead current collectors and associated live parts normally energized in band III, see also 5.3.1.3.

For overhead current collectors and associated live parts normally energized in band IV, see also 5.3.2.1.

Shoe gear adjacent to the platform edge shall comply with the requirements set out in 5.3. ~~In exceptional circumstances where this condition cannot be met, protection shall be provided to prevent access in a straight line (see also IEC 62128 (under consideration)).~~

~~When vehicles with shoe gear are supplied with a traction supply from a shed or trolley supply connector, protection from the live shoe gear shall be provided by an appropriate means, e.g. by procedure or by *interlocking device*.~~

~~It shall not be allowed to separate collector shoes used exclusively for *protective bonding* from the *protective conductor* of the fixed installations before the vehicle is de-energized. This shall be achieved by procedure or by *interlocking device*.~~

8.3 Capacitors

For capacitors, which may retain charge when they become accessible to direct contact, means shall be provided to ensure that there is no risk of electric shock. This may be by means of integral design of discharge circuits, additional circuits or procedure.

An integral discharge circuit shall be a reliable and, if necessary, redundant discharge system connected directly across the capacitors, unless another suitable piece of electrical equipment is connected directly across the capacitors, thus constituting a discharge path. The discharge path shall only include devices which are operated as part of the means of gaining access to the capacitor or related circuits and shall exclude devices which could cause automatic disconnection of the discharge path.

The discharge system shall be capable, after the equipment has been switched off, of bringing the residual voltage down to 60 V, within a defined time period commensurate with the maintenance methods to be employed.

The requirement may also be met by means of additional discharge circuits which may be switched automatically by unlocking operations as set out in 5.3, or by separate connectable discharge devices. These methods may also be used to achieve a shorter discharge time.

Where separate connectable devices are used, the equipment shall be fitted with suitable connection points for checking the de-energized condition, and, if necessary, for discharging the equipment.

In addition to the above, a clearly visible warning label, identifying the hazard and the appropriate procedure shall be permanently attached to the equipment or its cover.

8.4 Plug and socket devices

8.4.1 Portable apparatus

The following paragraphs cover plug and socket devices for the supply of power to portable equipment from a power source up to band III on the train.

Sockets or couplers providing power supply to various devices used while running the train (ovens, cash registers, bottle heaters, etc.) and for maintenance (vacuum cleaners, etc.) shall be fitted with a protective-equipotential-bonding ~~conductor~~.

As additional protection, these sockets should be protected by a residual current device as recommended in IEC 60364-4-41:2005, ~~412.5~~ 415.1.

Sockets situated in passenger compartments and reserved for maintenance purposes shall be protected by an external flap or a shutter within the socket.

Sockets for electric shavers shall only be ~~protected by separation of the primary and secondary circuits by the use of an isolating transformer or by other suitable means~~ supplied from an isolating transformer with protective separation between the input winding(s) and output winding(s), or by other protective measure achieving an equivalent level of protection against electric shock originating from other circuits.

Sockets for the use of portable power tools which might be used outside the train shall be protected by the use of one of the following:

– SELV as set out in 5.4;
– automatic disconnection of the supply either by a residual current device or by an interlocking device upon removal of the plug;
– safe electrical separation of the circuit by an isolating transformer.

NOTE Special national conditions in Japan can be found in Annex B, Clause B.4.

8.4.2 Vehicle and intervehicle connectors

Plug and socket devices for shed or trolley traction and also for train auxiliary supplies which present the risk of electric shock or arcing if disconnected when energized, shall not be disconnected in this condition. This may be achieved by an interlocking device or procedure.

8.5 Special sources

8.5.1 General

For sources for which the rules set out in Clause 5 are not reasonably practicable or are inadequate, the following subclauses may be used to cover the requirements for protection against direct contact for live parts ~~energized by sources for which the rules of clause 5 are unreasonable or inadequate~~ instead. Examples are batteries, high voltage sources for electronic equipment, high current inductors, etc.

8.5.2 Live parts not requiring protective provisions

Protective provisions are not required for live parts energized with voltages above band I where the source satisfies the conditions for safe ~~isolation~~ insulation and the current and the stored energy are both limited to safe values ~~according to~~ using the criteria ~~contained~~ set out in IEC TS 60479-1.

8.5.3 Live parts requiring protective provisions

Protective provisions are required for live parts energized with voltages in band II or below which have ~~high~~ stored energy and may present a risk of electric shock.

Protective provisions are required for live parts energized with voltages in band II or below which are not protected by ~~a miniature circuit-breaker (MCB) or fuse~~ an over current protection device or for which the rating of the over current protection device may still present a hazard, for example battery circuits in which the hazard is mainly from burning by objects making contact.

Annex A
(normative)

List of items where contracting parties shall ~~choose either a procedure or a mechanical device~~ co-operate

~~**5.2.1.4 Protection against *hazards* from power supply bus lines (bands II and III)**~~

~~**5.2.2.1 Protection by the use of *closed electrical operating areas* (band IV)**~~

~~**5.2.2.3 Protection against *hazards* from power supply bus lines (band IV)**~~

~~**6.5.5.1 Insulated wheel or levitation systems without a protective conductor**~~

~~**7.1 *Power circuit* – General principles**~~

~~**8.1.2, 8.1.3 Current collectors**~~

~~**8.2 Capacitors**~~

~~**8.3.2 Vehicle and intervehicle connectors**~~

5.3.1.3 Protection by clearance
5.3.1.4 Protection against hazards from external power supply
5.3.2.1 Protection by the use of closed electrical operating areas
5.3.2.3 Protection against hazards from external power supply
6.5.5 Insulated wheel or levitation systems without a protective conductor
7.1 Power circuit – General principles
8.2 Current collectors
8.3 Capacitors
8.4.2 Vehicle and intervehicle connectors

Annex B
(informative)

Special national conditions

B.1 General

Special national condition: National characteristic or practice that cannot be changed even over a long period, e. g. climatic conditions, electrical earthing conditions.

For the countries in which the relevant special national conditions apply these provisions are normative, for other countries they are informative.

B.2 France

All French rolling stock have additional protection as set out in Table B.1 to protect people with a locking system (special keys to U > AC 500 V and U > DC 750 V, in particular to DC 1 500 V). Replace Table 1 by:

Table B.1 – Voltage bands

Band	Nominal voltage U_n	
	AC V	DC V
I	$U \leq 25$	$U \leq 60$
II	$25 < U \leq 50$	$60 < U \leq 120$
III	$50 < U \leq 500$	$120 < U \leq 750$
IV	$U > 500$	$U > 750$

B.3 Great Britain

B.3.1 Operate over 750 V DC third rail electrified lines

On vehicles that have to operate over the 750 V DC third rail electrified lines in Great Britain, it is permitted to have only a single protective bonding path between a vehicle body and the protective conductors of the fixed installation, as set out in B.3.2 and B.3.3.

B.3.2 Bonding between rail vehicle main body to bogie

Equipotential bonding of the rail vehicle main body should be provided by a single bonding path fitted between the vehicle main body and one bogie only.

The above equipotential bond should be provided by two bonding cables.

The frame of the other bogie should be electrically insulated from the vehicle main body structure.

There should be no low resistance conducting paths between the rail vehicle main body structure and the bogie frames, for example via suspension components.

Provisions of bonding at both bogies result in current flow between the bonded axles via the vehicle components.

B.3.3 Intervehicle bonding

Intervehicle frame bonding should not be used on multiple unit vehicles where power is derived from a trackside DC substation.

B.4 Japan

B.4.1 General

This clause specifies special national conditions only applicable to Japan.

In the title of the following subclauses the numbers in square brackets e.g. [1.2.3.4] indicate the corresponding subclause in this document.

B.4.2 [6.4.4] Contact line fault

In addition to 6.4.4, the following applies:

To prevent from catching fire in the event of contact between an external electric traction power supply and a vehicle roof, the roof top surface shall be covered with a flame retardant insulating material. This is limited to passenger trains that can be used for service on sections of track with electrified overhead contact lines except extremely high voltage contact lines.

In this case no fault current will flow due to the insulating materials and therefore the circuit breaker in the fixed installation will not trip. Since the vehicle body is connected to the running rail, the vehicle potential stays equal to that of the running rail.

NOTE Extremely high voltage contact line in Japan means 20 kV AC and 25 kV AC nominal voltages.

B.4.3 [8.4.1] Portable apparatus

To the second paragraph in 8.4.1, the following applies.

It is accepted that a protective-equipotential-bonding may be provided in proximity to the socket.

To the third paragraph in 8.4.1, the following may apply:

If a single phase nominal voltage of 100 V AC is insulated from the power supply by a transformer, etc., and one pole is connected to the vehicle body, a socket without a protective-equipotential-bonding may be used.

To the fifth paragraph in 8.4.1, the following applies:

For sockets of a single phase nominal voltage of 100 V AC, this subclause may apply.

Annex C
(informative)

Example solutions for impedance management in electric multiple units (EMUs)

C.1 Preventing absorption of return current in EMUs

Lower impedance of bonding between vehicle main bodies and protective conductors (usually rails) is necessary for preventing hazardous touch voltage on the vehicle main bodies. However, the lower impedance bonding also causes absorption of return current. The reason is that the impedance of vehicle main bodies is lower than that of rails. The absorption concentrates the return current on the end vehicle, and the current concentration may damage the bogie's earth brush or bearings (see Figure C.1).

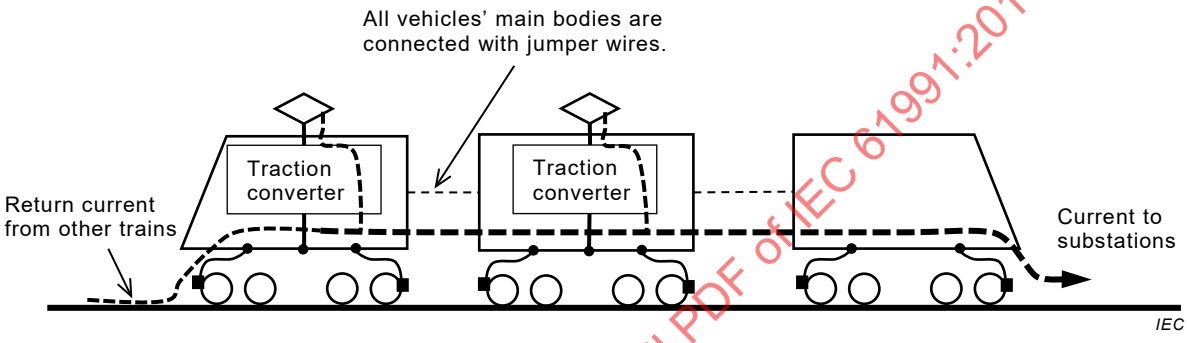


Figure C.1 – Concentration of return current

The fault is more likely to happen in long-length (above 200 m) EMU trains. Therefore, such trains' vehicles may have additional impedances intentionally; e.g. attach earth resistors between the main body and the earth brush (see Figure C.2) for preventing the absorption, if necessary.

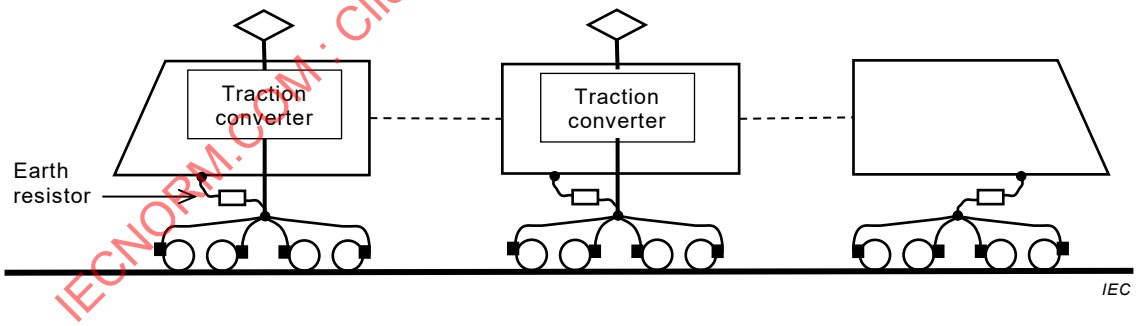


Figure C.2 – Attach earth resistors for long-length EMUs preventing current absorption

In the case of Figure C.2, the impedance between the main body of a vehicle and the protective conductor is larger than that defined in 6.4.3. However, the impedance between the main bodies of the train and the protective conductor is sufficiently low, since all the earth resistors are connected in parallel to the protective conductor. Hence the EMU train seldom causes hazardous voltage when the contact wire touches the EMU vehicle's body.

C.2 Examples of solutions

The vehicle body and its bogie frames may be connected either to the current return busbar or directly to the current return collectors or, where appropriate (i.e. for low current where no risk of bearing damage is proven), to the axle bearings.

In protective circuits, it may be necessary to connect the vehicle body structure via resistors or inductors to the current return collectors in order to:

– offer a circuit with a higher impedance than the current return paths;
– limit the return current flowing through axle bearings.

This may be particularly considered for axle bearings which have no axle brushes.

Bibliography

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

~~IEC 61133: 1992, *Electric traction – Rolling stock – Test methods for electric and thermal/ electric rolling stock on completion of construction and before entry into service*~~

IEC 61991

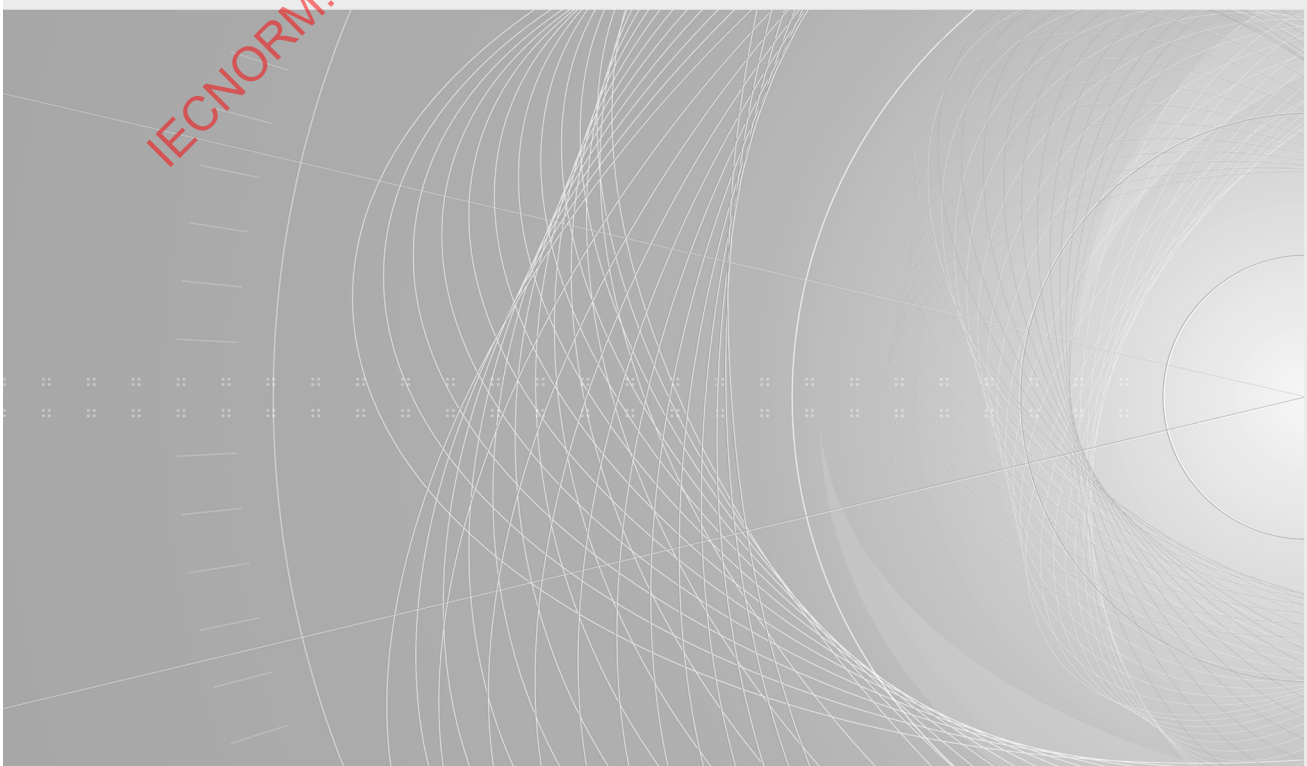
Edition 2.0 2019-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Railway applications – Rolling stock – Protective provisions against electrical hazards

Applications ferroviaires – Matériel roulant – Dispositions de protection contre les dangers électriques



IEC 61991:2019-05(en-fr)

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

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RAILWAY APPLICATIONS – ROLLING STOCK –

Protective provisions against electrical hazards

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61991 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This second edition cancels and replaces the first edition, published in 2000. This edition constitutes a technical revision. It is based on EN 50153:2014.

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

a) Replacement of several reference standards.
b) Several terms and abbreviated terms are introduced;
c) Table 2 – Voltage bands for France is moved to Annex B as Table B.1, Table 3 – Voltage bands for Italy is deleted;
d) Annex B and Annex C are introduced.
e) Annex B includes special national conditions.

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

FDIS	Report on voting
9/2467/FDIS	9/2487/RVD

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

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

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

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

INTRODUCTION

It is generally accepted that safety depends on human factors, based on the normal behaviour of the operators involved, as well as upon technical factors.

For these reasons, this document leaves a choice to the contracting parties between two alternatives in several instances. These alternatives consist of either the provision of operating rules, regulations and procedures, or the application of technical measures such as mechanical or electrical interlocking devices.

A list of the cases for which the contracting parties (e.g. user and manufacturer) shall reach agreement before signing the contract is included in Annex A.

RAILWAY APPLICATIONS – ROLLING STOCK –

Protective provisions against electrical hazards

1 Scope

This document defines requirements applied in the design and manufacture of electrical installations and equipment to be used on rolling stock to protect persons from electric shocks.

This document is applicable to rolling stock of rail transport systems, road transport systems if they are powered by an external supply (e.g. trolley buses), magnetically levitated transport systems, and to the electrical equipment installed in these systems.

This document does not apply to:

– mine railways in mines,
– crane installations, moving platforms and similar transport systems on rails,
– funicular railways,
– temporary constructions.

The requirements for the fixed installations about the protection against the vehicles' potential are not covered in this document.

2 Normative references

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

IEC 60364-4-41:2005, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC TS 60479-1, *Effects of current on human beings and livestock – Part 1: General aspects*

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

IEC 61140:2016, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61310-1, *Safety of machinery – Indication, marking and actuation – Part 1: Requirements for visual, acoustic and tactile signals*

IEC 62128-1:2013, *Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 1: Protective provisions against electric shock*

IEC 62313, *Railway applications – Power supply and rolling stock – Technical criteria for the coordination between power supply (substation) and rolling stock*

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

IEC 62995:2018, *Railway applications – Rolling Stock – Rules for installation of cabling*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

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

NOTE For more information relating to definitions of parts of the fixed installations, refer to IEC 62128-1 from which these definitions are derived.

3.1.1 Definitions concerning persons

3.1.1.1
<electrically> instructed person
person adequately advised or supervised by electrically skilled persons to enable him or her to perceive risks and to avoid hazards which electricity can create

[SOURCE: IEC 60050-195:1998, 195-04-02]

3.1.1.2
ordinary person
person who is neither a skilled person nor an instructed person

[SOURCE: IEC 60050-195:1998, 195-04-03]

3.1.1.3
<electrically> skilled person
person with relevant education and experience to enable him or her to perceive risks and to avoid hazards which electricity can create

[SOURCE: IEC 60050-195:1998, 195-04-01]

3.1.2 Other definitions

3.1.2.1
closed electrical operating area
room or location which serves exclusively for the operation of electrical equipment and is kept secure by a means appropriate to the voltage and location

Note 1 to entry: Access to such areas is permitted only to (electrically) skilled persons and (electrically) instructed persons.

Note 2 to entry: The definition of closed electrical operating area can be suitable for underfloor or upperroof cabinets. Generally speaking, it is any location (inside or outside the car body) which is kept secured because of the voltage that can be assumed to be present on the equipment inside it. Access to such areas is not allowed for ordinary persons.

3.1.2.2
contact line
conductor system for supplying electrical energy to rolling stock through current-collecting equipment

[SOURCE: IEC 60050-811:2017, 811-33-01, modified – The term “vehicle” has been replaced by “rolling stock” and Note 1 to entry has been omitted.]

3.1.2.3
contact wire
electric conductor of an overhead contact line with which the current collectors make contact

[SOURCE: IEC 60050-811:2017, 811-33-15]

3.1.2.4
direct contact
electric contact of persons or animals with live parts

[SOURCE: IEC 60050-195:1998, 195-06-03]

3.1.2.5
double insulation
insulation comprising both basic insulation and supplementary insulation

[SOURCE: IEC 60050-195:1998, 195-06-08]

3.1.2.6
earth
conductive mass of the earth, whose electrical potential at any point is conventionally taken as equal to zero

3.1.2.7
electrical operating area
room or location which serves primarily for the operation of electrical equipment and is normally entered only by skilled persons or (electrically) instructed persons

Note 1 to entry: Generally speaking, an electrical operating area is any location (mainly inside the car body) where electrical equipment operates. The above is the main function of this area but not the only one. In fact, normally the area is not kept secured and protection against direct contact is achieved by other means (e.g. (electrically) protective obstacles).

3.1.2.8
electric shock
physiological effect resulting from an electric current passing through a human or animal body

[SOURCE: IEC 60050-195:1998, 195-01-04]

3.1.2.9
extra-low voltage
voltage not exceeding the relevant voltage limit of band II specified in Table 1

[SOURCE: IEC 60050-826:2004, 826-12-30, modified – The term “band I” has been replaced by “band II” and “IEC 60449” has been replaced by “Table 1”.]

3.1.2.10
equipotential bond
electrical connection putting various exposed conductive parts at a substantially equal potential

Note 1 to entry: This can be abbreviated as ‘bond’ or ‘bonding’.

3.1.2.11
exposed conductive part <of electrical equipment>
conductive part of electrical equipment, which can be touched and which is not normally live, but can become live when basic insulation fails

Note 1 to entry: A conductive part of electrical equipment which can only become live through contact with an exposed conductive part which has become live is not considered to be an exposed conductive part itself.

3.1.2.12
indirect contact
electric contact of persons or animals with exposed conductive parts which have become live under fault conditions

[SOURCE: IEC 60050-195:1998, 195-06-04]

3.1.2.13
interlocking device
device which makes the operation of a switching device dependent upon the position or operation of one or more other pieces of equipment

[SOURCE: IEC 60050-441:2000, 441-16-49]

3.1.2.14
insulate, verb
prevent electric conduction between conductive elements by means of insulating materials

[SOURCE: IEC 60050-151:2001, 151-15-36]

3.1.2.15
insulation
all the materials and parts used to insulate conductive elements of a device

[SOURCE: IEC 60050-151:2001, 151-15-41]

3.1.2.16
live part <in electric traction>
conductor or conductive part intended to be energized in normal use

Note 1 to entry: This concept does not necessarily imply a risk of electric shock.

Note 2 to entry: By convention, this does not include the running rails and parts connected to them.

[SOURCE: IEC 60050-811:2017, 811-36-23]

3.1.2.17
locking system
system which comprises interlocking devices and physically prevents access to live parts unless the supply of electrical energy to the live parts has been isolated and made safe

3.1.2.18
mechanical locking
use of a lock or bolted /screwed fixings to prevent access panels or doors being opened and require the use of a key or tool to remove

3.1.2.19
multi-stage insulation
insulation system having more than one stage of insulation and an intermediate frame between consecutive stages

[SOURCE: IEC 60322:2001, 3.4, modified – Notes have been deleted.]

3.1.2.20
nominal voltage <of a system>
suitable approximate value of voltage used to designate or identify a system

Note 1 to entry: The voltages are expressed by the value between poles, ripple-free for DC and by the RMS value between phases for AC.

Note 2 to entry: The actual voltage can differ from the nominal voltage by a quantity within permitted tolerances. For further information about traction systems supply voltages, see IEC 60850.

[SOURCE: IEC 60050-601:1985, 601-01-21, modified – Notes to entry have been added.]

3.1.2.21
PELV system
electric system in which the voltage cannot exceed the value of extra-low voltage:

– under normal conditions and
– under single fault conditions, except earth faults in other electric circuits

[SOURCE: IEC 60050-826:2004, 826-12-32, modified – Note has been deleted.]

3.1.2.22
<electrically> protective obstacle
part preventing unintentional direct contact, but not preventing direct contact by deliberate action

[SOURCE: IEC 60050-195:1998, 195-06-16]

3.1.2.23
power circuit
circuit carrying the current of the machines and equipment, such as the converters and traction motors, which transmit the traction output

[SOURCE: IEC 60050-811:2017, 811-25-03]

3.1.2.24
protective conductor
conductor provided for purposes of safety, for example protection against electric shock

[SOURCE: IEC 60050-195:1998, 195-02-09]

3.1.2.25
protective-equipotential-bonding
equipotential bonding for the purposes of safety

[SOURCE: IEC 60050-195:1998, 195-01-15]

3.1.2.26
SELV system
electric system in which the voltage cannot exceed the value of extra-low voltage:

– under normal conditions and
– under single fault conditions, including earth faults in other electric circuits

[SOURCE: IEC 60050-826:2004, 826-12-31, modified – Note has been deleted.]

3.1.2.27

total insulation
insulation composed of basic insulation as provision for basic protection, and supplementary insulation as provision for fault protection, or providing basic and fault protection by reinforced insulation, in accordance with IEC 61140:2016, 7.4

[SOURCE: IEC 60050-851:2008/AMD1:2014, 851-15-11, modified – "equipment with" has been replaced with "insulation composed of" and "IEC 61140:2011,7.3" has been replaced with "IEC 61140:2016,7.4".]

3.1.2.28
Unit <electrically connected>
minimum operational formation comprising one or more vehicles coupled together

3.2 Abbreviated terms

AC	Alternating Current
DC	Direct Current
ELV	Extra Low Voltage
EMU	Electric Multiple Unit
PELV	Protective Extra Low Voltage
RMS	root-mean-square value (effective value)
SELV	Safety Extra Low Voltage

4 Classification of voltage bands

4.1 General principles

In this document, the applicable protective measures are based on the highest value of the nominal supply voltage which the equipment or the electrical circuits are subjected to.

The voltages are classified into bands according to the nominal value as shown in Table 1. Different rules apply to each of these bands.

The power supply of the various circuits installed in railway rolling stock can be from different sources such as:

– batteries,
– transformers,
– voltage dividers,
– rotating machines,
– static converters,
– capacitors,
– special sources.

Table 1 – Voltage bands

Band	Nominal voltage U_n	
	AC V	DC V
I	$U \leq 25$	$U \leq 60$
II	$25 < U \leq 50$	$60 < U \leq 120$
III	$50 < U \leq 1\,000$	$120 < U \leq 1\,500$
IV	$U > 1\,000$	$U > 1\,500$

NOTE The special national conditions for France are listed in Annex B, Clause B.2.

4.2 Connections between circuits

Circuits operating at different nominal voltages connected by power conversion equipment which provides a sufficient insulation between them are individually classified at the nominal voltage of each circuit.

If the conducting paths referred to in this subclause include capacitive or inductive connections, whose impedance is low enough to induce hazardous voltages into any circuit under either normal or fault conditions, then all the circuits so connected are classified at the nominal voltage of the highest voltage circuit.

NOTE This condition can apply to circuits connected, for example, by means of a chopper converter with impedance coupling.

Where circuits are linked conductively to a higher voltage source other than directly by circuit bonds connected to the vehicle body (for example by an auto-transformer or potential divider), all circuits in the group are treated as if energized at the nominal voltage of the source, unless the conditions of 4.3 have been met.

4.3 Exceptions

If voltage conversion from one band to another involves overvoltage detection resulting in disconnection of the primary or the secondary circuit, or having other means capable of preventing excessive voltage in the secondary circuit, then the secondary circuit is permitted to be classified according to the highest voltage at which the detection equipment will operate. Where overvoltage detection is used the integrity of the equipment should be evaluated as appropriate.

Circuits not connected to the vehicle body, for example floating supplies, are permitted to be classified in any voltage band. The band selected should be appropriate, taking due account of the various potentials possible in such circuits under normal or fault conditions so as to ensure that the requirements of this document are met.

The limit between bands III and IV is allowed to be lowered to take account of special national conditions.

5 Protective provisions against direct contact

5.1 General

Live parts capable of causing an electric shock shall be protected against direct contact. All types of equipment shall be capable of being operated without loss of protection against direct contact. Protection against direct contact shall be provided, where possible, by at least one of the means described in 5.2 to 5.3.

Where it is not possible to provide protective provisions in accordance with 5.2 or 5.3, then it is permitted to use protection by the use of band I voltage in accordance with the conditions of 5.4.

Additionally where required to ensure adequate protection against direct contact, warning labels as described in 5.5 shall be provided.

5.2 Protection by insulation

In addition to the requirements of IEC 62497-1, the insulating materials used to cover live parts shall be appropriate to the rated equipment operating voltage and the conditions of use. Further provisions should be considered in order to minimize the consequences of damage.

5.3 Protection by prevention of access

5.3.1 Voltages in bands I to III

5.3.1.1 Protection by the use of closed electrical operating areas

Live parts within the vehicle, energized with voltages in bands I to III shall be contained within closed electrical operating areas.

Access to closed electrical operating areas containing energized live parts is permitted as follows:

– band I and II: access is permitted to (electrically) instructed persons and skilled persons;

– band III: access is only permitted to (electrically) instructed persons and skilled persons provided that precautions against unintended direct contact are taken.

Prevention of access shall be achieved by mechanical locking supported with procedures and warning labels appropriate to the location and equipment enclosed.

Means of preventing access shall comply with the following:

- in areas within vehicles, accessible to ordinary persons, screens and covers shall conform to the degree of protection IP4X as set out in IEC 60529, or, where these are electrically connected to the vehicle body, to the degree of protection IP2XD as set out in IEC 60529; the requirements of this subclause do not apply to plug connectors, lamp holders without lamps and fuse sockets for screw-in type fuses without inserts;
- in other areas where grid or mesh screens are used, these shall be placed at a sufficient distance to prevent any direct contact, taking into account possible buckling or warping.

5.3.1.2 Protection by the use of electrical operating areas

For live parts contained within an electrical operating area the following shall apply:

– live parts energized within bands I and II need no protection against direct contact provided that the requirements of 8.5.2 are met.

– the use of (electrically) protective obstacles to afford a limited protection against direct contact with live parts at band III voltages may be acceptable in electrical operating areas

inaccessible to ordinary persons by their location (such as underframe cases, roofs, interiors of motor units, excluding driver's cabs), provided that the hazard is readily identifiable. For example, it is acceptable for fuses and isolating links of equipment at band III voltages, whose grips are protected with an insulating material, not to be protected. Such components shall only be situated in electrical operating areas.

5.3.1.3 Protection by clearance

For live parts on the outside of the vehicle (e.g. current collectors, roof conductors, resistors) which are potentially accessible to persons in a straight line from any standing surface in, on or by vehicles, protection against direct contact by means of clearance shall be provided if no other protective measures as defined in this document are used.

NOTE Accessible in a straight line implies that live parts can be touched from a standing surface without use of specially shaped objects.

Protection by clearance is considered to be provided, if at least the clearances from standing surfaces to live parts depicted in IEC 62128-1:2013, Figure 3, are maintained, excepting the condition of shoe gear adjacent to the platform edge.

This protection is considered to be present, if contact with live parts is possible but clearance is afforded in case of the movement of the vehicle (e.g. on road and foot-crossings). Where only (electrically) instructed persons and skilled persons have access and where operation of the system makes protection by clearance impossible (e.g. systems using third and/or third and fourth rail power supplies) protection shall be afforded by procedure.

5.3.1.4 Protection against hazards from external power supply

Access to live parts that may be energized with voltage band III when the supply system is likely to be energized from an external power supply (e.g. another vehicle, preheating equipment, shed supply, etc.) shall be prevented by an interlocking device or a procedure.

Connectors in the power supply bus line shall be fitted with warning labels as set out in 5.5.

5.3.2 Voltages in band IV

5.3.2.1 Protection by the use of closed electrical operating areas

Access to live parts energized with voltages in band IV shall be excluded to all persons including skilled persons.

Access to live parts normally energized with voltages in band IV shall only be possible to (electrically) instructed persons and skilled persons after the live parts have been de-energized and made safe by one or more of the following methods:

– procedure;
– interlocking devices;
– protective-equipotential-bonding;
– safety or monitoring devices.

Means of preventing access and making live parts safe shall comply with the following:

- covers in areas accessible to ordinary persons in vehicles shall conform to the degree of protection IP4X as set out in IEC 60529; areas accessible to instructed persons and skilled persons shall conform to the degree of protection IP2X as set out in IEC 60529;
- in cases where band III voltages are not eliminated after band IV live parts have been deenergized, the precautions of 5.3.1 shall be taken to prevent direct contact with live parts which remain energized with voltages in band III.

5.3.2.2 Protection by clearance

For live parts on the outside of the vehicle (e.g. current collectors, roof conductors, resistors), which are potentially accessible to persons in a straight line from any standing surface in, on or by vehicles, protection against direct contact by means of clearance shall be provided, except for the pantograph head, if no other protective measures as defined in this document are used.

NOTE Accessible in a straight line implies that live parts can be touched from a standing surface without use of specially shaped objects.

Protection by clearance is considered to be provided, if at least the clearances from standing surfaces to live parts depicted in IEC 62128-1:2013, Figure 4, are maintained, except for the condition of shoe gear adjacent to the platform edge.

5.3.2.3 Protection against hazards from external power supply

Access to live parts when the supply system is likely to be energized from an external power supply (e.g. another vehicle, preheating equipment, shed supply, etc.) shall be prevented by an interlocking device or procedure.

For equipment requiring frequent intervention, such as electric train supply jumpers, interlocking devices or procedures shall be provided to ensure that the live parts of the equipment become accessible only after their power supply has been switched off and the live parts have been made safe by protective bonding.

Connectors in the power supply bus line shall be fitted with warning labels as set out in 5.5.

5.4 Protection by the use of band I (ELV)

5.4.1 Requirements for systems of band I (SELV and PELV)

Systems of band I shall meet the following requirements:

- the power sources for SELV and PELV shall meet the requirements of 414.3, power sources for SELV and PELV, of IEC 60364-4-41:2005;
- the system shall meet the requirements of 414.4, requirements for SELV and PELV system, of IEC 60364-4-41:2005;
- the system shall meet the requirements of Clause 8 of this document.

5.4.2 Additional requirements for SELV

A SELV system shall not be connected to the protective bonding circuit (vehicle body). For SELV system at a voltage in band I no further protective provision is required provided that the circuit meets the requirements of 5.4.1.

5.4.3 Additional requirements for PELV

One pole of the PELV system or one pole of the source of the supply of that PELV system shall be connected to the protective bonding circuit. No further protective provision is required provided that the nominal voltage does not exceed 6 V AC or 15 V DC and the system meets the requirements of 5.4.1.

If the voltage exceeds 6 V AC or 15 V DC and ordinary persons have access, protection as set out in 411.7.2 of IEC 60364-4-41:2005 is required.

5.5 Warning labels

Warning labels for electrical hazards shall be as set out in IEC 61310-1.

If a hazard is considered to exist, after all interlocking devices or design features have been operated to gain access to equipment, then warning labels shall be fitted to identify the hazard and provide any supplementary information necessary to avoid danger to persons. The labels shall be fitted in positions that ensure that they are clearly visible and will remain so throughout the life of the equipment.

Access to elevated vehicle standing surfaces, from which live parts of a contact line system can be reached, shall be marked by means of warning labels.

A warning label shall be placed on the access points to any closed electrical operating areas containing voltages in bands III or IV. It is permitted not to provide warning labels where a locking system is used to ensure access is prohibited until the hazardous voltage is no longer present.

6 Protective provisions against indirect contact

6.1 General

Clause 6 defines the allowable methods permitted for use in order to ensure that the potential of the vehicles body is kept sufficiently close to the potential of the protective conductor of the fixed installation.

The methods described in 6.2 to 6.5 shall ensure that exposed conductive parts are incapable of causing electric shock through induction or contact with live parts in the vicinity under failure conditions.

The aim is to ensure that the exposed conductive parts which present such a risk are at the same potential. This aim may be achieved by protective bonding as set out in 6.2 alone or in conjunction with automatic disconnection of supply, or exceptions as described in 6.5.

Clarifications and exceptions are covered in 6.5.

Additional requirements are covered in 6.6.

6.2 Protective bonding

6.2.1 General

Bonding to the protective conductor shall be provided for any exposed conductive parts which are capable of causing electric shock through induction, capacitive coupling or contact with live parts under foreseeable failure conditions.

6.2.2 Equipotential bond

All parts of the protective equipotential bonding shall be capable of withstanding all internal and external influences (including mechanical, thermal and corrosive) which can be expected.

Conductors of a protective equipotential bonding system shall be as set out in IEC 62995:2018, 4.6.

6.2.3 Protective bonding rating

Protective bonding shall be dimensioned to provide adequate strength and current carrying capacity to ensure that the exposed conductive parts are incapable of causing electric shock under failure conditions. See also 6.3.

For characteristic values to support the dimensioning of cross-section for protective bonding, see IEC 62313.

Due regard shall be paid to all currents flowing in the running rail which may affect the rating of the bonding connections.

6.2.4 Sliding contacts

Sliding contacts, e.g. earth-return brushes, shall conform to the other requirements of 6.2. The failure of any one such contact shall not cause risk of electric shock.

6.3 Disconnection of the supply

6.3.1 Application

Automatic disconnection of supply or automatic limitation of fault current, e.g. by resistance insertion, shall be used in conjunction with protective bonding, where 6.2.3 would not be achieved.

Automatic disconnection of supply shall be provided where a risk of harmful physiological effects to a person could arise when a fault occurs, due to the value and duration of the touch voltage (for guidance, see IEC TS 60479-1).

For the evaluation of the relevant fault duration in order to assess the permissible touch voltage, the correct operation of the protection devices and switches shall be assumed. Multiple independent faults occurring simultaneously do not need to be considered.

6.3.2 Disconnection characteristic

In the event of a fault between a live part and an exposed conductive part (or a protective conductor) in the circuit or equipment, an automatic protection device shall operate and disconnect the circuit or equipment for which the device provides protection against indirect contact. The protection shall prevent a prospective touch voltage exceeding the upper limit of band II voltages persisting for a time sufficient to cause a risk of harmful physiological effect to a person in contact with simultaneously accessible conductive parts. For further guidance, refer to 411 of IEC 60364-4-41:2005.

6.4 Main protective bonding

6.4.1 General

The following applies to all vehicles operating on systems employing a protective conductor. This protective conductor may be separated from or combined with the running rails which form a part of the return circuit for the traction return current. For insulated wheel or levitation systems without a protective conductor, refer to 6.5.5.

Vehicle bodies shall be bonded as set out in 6.4.2 and 6.4.3.

6.4.2 Bonding paths

There shall be at least two protective bonding paths between a vehicle body and the protective conductors of the fixed installation so that, if a failure occurs in one path, there shall be no risk of electric shock. Both paths shall be accessible for visual inspection.

Any protective bonding path of a vehicle body to the protective conductors of the fixed installation could be direct within the vehicle or via another vehicle.

NOTE 1 The protective conductors are normally the running rails. (See IEC 62128-1).

NOTE 2 The special national conditions for Great Britain are listed in Annex B, Clause B.3.

For the design of bonding path on vehicles it should be considered that the current values of IEC 62313 will be reduced by the vehicle impedance. Main protection can be assumed to operate normally. Even for the thermal design of earthing conductors on vehicles this main protection tripping time can be applied.

Additionally for DC systems main protection will further limit the maximum current to a value below the prospective current.

NOTE 3 Experience shows that in DC systems current peaks for faults to the vehicle typically do not exceed values of 50 kA for 20 ms.

The probability of a fault on the vehicle which is not seen by its circuit-breaker (e.g. current collector short-circuit) and an outage of the main protection in the traction power substation at the same time is low. For such cases the overheating of earthing conductors is acceptable if they remain in place until the fault is cleared. This includes cases where auto-reclosure in the traction power substation doubles the thermal stress. Maintenance rules should be in place to check their condition afterwards.

6.4.3 Impedance

The impedance between the unit and the protective conductor of the fixed installation, e.g. the running rails, shall be low enough to prevent the existence of a hazardous voltage between them, using the criteria set out in IEC 62128-1:2013, Clause 9.

The maximum impedance between the unit and the protective conductor of the fixed installation are set out in Table 2. Lower figures shall be used if these values could cause the occurrence of a hazardous voltage. Consideration should also be given to the possible rail potentials set out in IEC 62128-1:2013, Clause 9. This should be demonstrated both by calculation with an assumption of 1 mΩ per earth brush and verification by measurement (maximum values are set out in Table 2).

Table 2 – Maximum impedance between each vehicle body of a unit and protective conductor of the fixed installation

Type of vehicle	Maximum impedance Ω
Tractive stock Coaches	0,05
Wagons	0,15

These values shall be measured with a constant current of 50 A, where the open-circuit voltage shall not exceed 50 V. The measurement shall be carried out with a clean wheel to rail interface.

Resistance of protective bonding path can be calculated.

NOTE 1 The total impedance of units electrically connected is considered.

The calculated resistance should be smaller than 10 mΩ in DC and 15 kV AC systems and 20 mΩ in 25 kV AC systems.

Experience suggests that values in Table 2 are indicative of impedance at high current which is substantially lower.

NOTE 2 Example solutions for impedance management of electric multiple units can be found in Annex C.

6.4.4 Contact line fault

In the event of contact between an external electric traction power supply and a vehicle body (i.e. a broken contact wire), the system design shall reduce any excessive voltage at or within the vehicle body, to the levels required in 6.3 in the shortest practicable time.

Since the fault would normally be cleared by the fixed installations, in order to determine the voltage likely to occur at the vehicle, reference should be made to IEC 62128-1.

The vehicle protective bonding shall take account of the above aim, and shall remain intact.

NOTE Special national conditions in Japan can be found in Annex B, Clause B.4.

6.5 Clarifications and exceptions with reference to indirect contact

6.5.1 Parts requiring protective provisions

Protective provisions shall be made for exposed conductive parts in the proximity of electrical equipment, for example: sinks, metal cupboards, aerial ground planes and other similar parts.

Where no electrical equipment is fixed to covers, doors and cover plates of the electronic equipment, the normal metal screws and locking devices as well as conducting corrosion-proof hinges are considered to be sufficient protective bonding. Where electrical equipment is attached to these movable parts of electronic equipment, the exposed conductive parts of the particular electrical equipment need a protective bonding. The protective bonding to these movable parts of electronic equipment should be made via a protective conductor.

6.5.2 Parts not requiring protective provisions

6.5.2.1 Exceptions of protective provisions

Protective provisions are not needed for exposed conductive parts separated from any source which may cause electric shock.

Furthermore, no protective provisions are required for equipment defined in 6.5.2.2, 6.5.2.3 and 6.5.2.4, tested and marked to the relevant standards.

6.5.2.2 Band II voltage

Protection against indirect contact may be dispensed with for the exposed conductive parts of equipment energized at voltages in band II, if the circuits meet the requirements of SELV or PELV (as defined in IEC 60364-4-41).

6.5.2.3 Double insulation

Electrical equipment having double or reinforced insulation shall comply with the requirements set out in IEC 62497-1 or IEC 60364-4-41.

6.5.2.4 Total insulation (for voltages in band III only)

Assemblies of electrical equipment having total insulation shall meet the requirements set out in IEC 61140.

6.5.3 Multi-stage insulation

When multi-stage insulation is used, for example in roof or underframe-mounted traction resistors which are air-insulated, exposed conductive parts located between the basic and supplementary insulation shall be regarded as live parts and the provisions of Clause 5 shall apply.

6.5.4 Floating supplies

Circuits at voltages in bands III or IV not bonded to the vehicle body (floating supplies) shall not be used to provide sole protection against indirect contact. The provisions of either 6.2 or 6.3 shall also be applied. Account shall also be taken of the requirements of 7.1.

Equipment that is isolated and remains floating should be viewed as not protected with respect to indirect touch.

6.5.5 Insulated wheel or levitation systems without a protective conductor

The requirements of 6.4 do not apply to insulated wheel or levitation systems without a protective conductor. The vehicle body including its exposed conductive parts shall be insulated from the power supply system.

No supply circuit derived from within the unit or vehicle shall be capable of acquiring a voltage above the design range under normal or fault conditions either between poles or with respect to any exposed conductive parts.

Where a transport system is deemed touchable when not in earthed conditions, all electrical equipment shall be double insulated. Earthed conditions are where a connection is made, either automatically or manually, to the protective conductor of the fixed installation.

Any failure of either level of insulation shall be detectable either by procedure or by the use of monitoring devices.

Such transport systems shall only be used on power supply systems that meet the requirements set out in IEC 62128-1.

6.6 Additional requirements – Bearings

Bearings on vehicles other than wagons shall not be used to connect exposed conductive parts.

Bearings on wagons should not be used to connect exposed conductive parts, if there is a risk of damage to the bearings caused by electrical current.

7 Power circuit

7.1 General principles

Power circuit design shall ensure that all currents are returned to the source of supply without resulting in damage or risk of electric shock.

Where sliding or flexing connections between the body or bogie and the running rail are used, there shall be at least two separate paths per unit and a failure in one path shall not cause damage or risk of electric shock.

Paths shall be dimensioned to carry all currents which may flow through them. Due regard shall be paid to fault currents and currents flowing in the running rail.

Bearings in general shall not be used as part of the return path. Dedicated current limits of the bearing manufacture may be considered.

If any part of the return path is combined with the vehicle protective bonding at any point, the requirements set out in Clause 6 shall additionally apply.

To prevent damage or risk of electric shock from circuits directly fed from an external power supply, failures in the return current paths shall be detectable by an appropriate means, e.g. procedure or monitoring device.

Current return may conform to either of the methods below. The method chosen shall be the responsibility of the railway authorities and shall comply with requirements set out in either 7.2 or 7.3.

7.2 Power circuit insulated from the vehicle body or bogie

A path or paths insulated from the vehicle, or from any exposed conductive parts thereof, shall be provided to conduct current from the return of the power equipment to the return conductor of the supply system.

7.3 Power circuit using the vehicle body or bogie

Where returns are connected to the vehicle body, the connections shall be through members of sufficient cross-section to comply with the paragraphs below.

Current flowing in any paths through the body or bogie frame shall not cause damage or unacceptable deterioration to the structure or any mechanical parts.

Voltage differences between two different parts of the body or bogie sections shall not be sufficient to cause electric shock under any normal or failure condition.

In the event of contact between an external electric power supply and the vehicle body, additionally 6.4.4 shall apply.

8 Additional requirements

8.1 General

Means shall be provided for any live parts which may be sufficiently energized to cause electric shock after disconnection from the supply to be secured against electric shock.

8.2 Current collectors

In addition to the requirements set out in Clause 5, means shall be provided to separate the overhead current collector from the contact wire and prevent accidental contact of the current collector with the wire.

For overhead current collectors and associated live parts normally energized in band III, see also 5.3.1.3.

For overhead current collectors and associated live parts normally energized in band IV, see also 5.3.2.1.

Shoe gear adjacent to the platform edge shall comply with the requirements set out in 5.3.

8.3 Capacitors

For capacitors, which may retain charge when they become accessible to direct contact, means shall be provided to ensure that there is no risk of electric shock. This may be by means of integral design of discharge circuits, additional circuits or procedure.

An integral discharge circuit shall be a reliable and, if necessary, redundant discharge system connected directly across the capacitors, unless another suitable piece of electrical equipment is connected directly across the capacitors, thus constituting a discharge path. The discharge path shall only include devices which are operated as part of the means of gaining access to the capacitor or related circuits and shall exclude devices which could cause automatic disconnection of the discharge path.

The discharge system shall be capable, after the equipment has been switched off, of bringing the residual voltage down to 60 V, within a defined time period commensurate with the maintenance methods to be employed.

The requirement may also be met by means of additional discharge circuits which may be switched automatically by unlocking operations as set out in 5.3, or by separate connectable discharge devices. These methods may also be used to achieve a shorter discharge time.

Where separate connectable devices are used, the equipment shall be fitted with suitable connection points for checking the de-energized condition, and, if necessary, for discharging the equipment.

In addition to the above, a clearly visible warning label, identifying the hazard and the appropriate procedure shall be permanently attached to the equipment or its cover.

8.4 Plug and socket devices

8.4.1 Portable apparatus

The following paragraphs cover plug and socket devices for the supply of power to portable equipment from a power source up to band III on the train.

Sockets or couplers providing power supply to various devices used while running the train (ovens, cash registers, bottle heaters, etc.) and for maintenance (vacuum cleaners, etc.) shall be fitted with a protective-equipotential-bonding.

As additional protection, these sockets should be protected by a residual current device as recommended in IEC 60364-4-41:2005, 415.1.

Sockets situated in passenger compartments and reserved for maintenance purposes shall be protected by an external flap or a shutter within the socket.

Sockets for electric shavers shall only be supplied from an isolating transformer with protective separation between the input winding(s) and output winding(s), or by other protective measure achieving an equivalent level of protection against electric shock originating from other circuits.

Sockets for the use of portable power tools which might be used outside the train shall be protected by the use of one of the following:

– SELV as set out in 5.4;
– automatic disconnection of the supply either by a residual current device or by an interlocking device upon removal of the plug;
– safe electrical separation of the circuit by an isolating transformer.

NOTE Special national conditions in Japan can be found in Annex B, Clause B.4.

8.4.2 Vehicle and intervehicle connectors

Plug and socket devices for shed or trolley traction and also for train auxiliary supplies which present the risk of electric shock or arcing if disconnected when energized, shall not be disconnected in this condition. This may be achieved by an interlocking device or procedure.

8.5 Special sources

8.5.1 General

For sources for which the rules set out in Clause 5 are not reasonably practicable or are inadequate, the following subclauses may be used to cover the requirements for protection against direct contact for live parts instead. Examples are batteries, high voltage sources for electronic equipment, high current inductors, etc.

8.5.2 Live parts not requiring protective provisions

Protective provisions are not required for live parts energized with voltages above band I where the source satisfies the conditions for safe insulation and the current and the stored energy are both limited to safe values using the criteria set out in IEC TS 60479-1.

8.5.3 Live parts requiring protective provisions

Protective provisions are required for live parts energized with voltages in band II or below which have high stored energy and may present a risk of electric shock.

Protective provisions are required for live parts energized with voltages in band II or below which are not protected by an over current protection device or for which the rating of the over current protection device may still present a hazard, for example battery circuits in which the hazard is mainly from burning by objects making contact.

Annex A
(normative)

List of items where contracting parties shall co-operate

5.3.1.3	Protection by clearance
5.3.1.4	Protection against hazards from external power supply
5.3.2.1	Protection by the use of closed electrical operating areas
5.3.2.3	Protection against hazards from external power supply
6.5.5	Insulated wheel or levitation systems without a protective conductor
7.1	Power circuit – General principles
8.2	Current collectors
8.3	Capacitors
8.4.2	Vehicle and intervehicle connectors

Annex B
(informative)

Special national conditions

B.1 General

Special national condition: National characteristic or practice that cannot be changed even over a long period, e. g. climatic conditions, electrical earthing conditions.

For the countries in which the relevant special national conditions apply these provisions are normative, for other countries they are informative.

B.2 France

All French rolling stock have additional protection as set out in Table B.1 to protect people with a locking system (special keys to U > AC 500 V and U > DC 750 V, in particular to DC 1 500 V). Replace Table 1 by:

Table B.1 – Voltage bands

Band	Nominal voltage U_n	
	AC V	DC V
I	$U \leq 25$	$U \leq 60$
II	$25 < U \leq 50$	$60 < U \leq 120$
III	$50 < U \leq 500$	$120 < U \leq 750$
IV	$U > 500$	$U > 750$

B.3 Great Britain

B.3.1 Operate over 750 V DC third rail electrified lines

On vehicles that have to operate over the 750 V DC third rail electrified lines in Great Britain, it is permitted to have only a single protective bonding path between a vehicle body and the protective conductors of the fixed installation, as set out in B.3.2 and B.3.3.

B.3.2 Bonding between rail vehicle main body to bogie

Equipotential bonding of the rail vehicle main body should be provided by a single bonding path fitted between the vehicle main body and one bogie only.

The above equipotential bond should be provided by two bonding cables.

The frame of the other bogie should be electrically insulated from the vehicle main body structure.

There should be no low resistance conducting paths between the rail vehicle main body structure and the bogie frames, for example via suspension components.

Provisions of bonding at both bogies result in current flow between the bonded axles via the vehicle components.

B.3.3 Intervehicle bonding

Intervehicle frame bonding should not be used on multiple unit vehicles where power is derived from a trackside DC substation.

B.4 Japan

B.4.1 General

This clause specifies special national conditions only applicable to Japan.

In the title of the following subclauses the numbers in square brackets e.g. [1.2.3.4] indicate the corresponding subclause in this document.

B.4.2 [6.4.4] Contact line fault

In addition to 6.4.4, the following applies:

To prevent from catching fire in the event of contact between an external electric traction power supply and a vehicle roof, the roof top surface shall be covered with a flame retardant insulating material. This is limited to passenger trains that can be used for service on sections of track with electrified overhead contact lines except extremely high voltage contact lines.

In this case no fault current will flow due to the insulating materials and therefore the circuit breaker in the fixed installation will not trip. Since the vehicle body is connected to the running rail, the vehicle potential stays equal to that of the running rail.

NOTE Extremely high voltage contact line in Japan means 20 kV AC and 25 kV AC nominal voltages.

B.4.3 [8.4.1] Portable apparatus

To the second paragraph in 8.4.1, the following applies.

It is accepted that a protective-equipotential-bonding may be provided in proximity to the socket.

To the third paragraph in 8.4.1, the following may apply:

If a single phase nominal voltage of 100 V AC is insulated from the power supply by a transformer, etc., and one pole is connected to the vehicle body, a socket without a protective-equipotential-bonding may be used.

To the fifth paragraph in 8.4.1, the following applies:

For sockets of a single phase nominal voltage of 100 V AC, this subclause may apply.

Annex C
(informative)

Example solutions for impedance management in electric multiple units (EMUs)

C.1 Preventing absorption of return current in EMUs

Lower impedance of bonding between vehicle main bodies and protective conductors (usually rails) is necessary for preventing hazardous touch voltage on the vehicle main bodies. However, the lower impedance bonding also causes absorption of return current. The reason is that the impedance of vehicle main bodies is lower than that of rails. The absorption concentrates the return current on the end vehicle, and the current concentration may damage the bogie's earth brush or bearings (see Figure C.1).

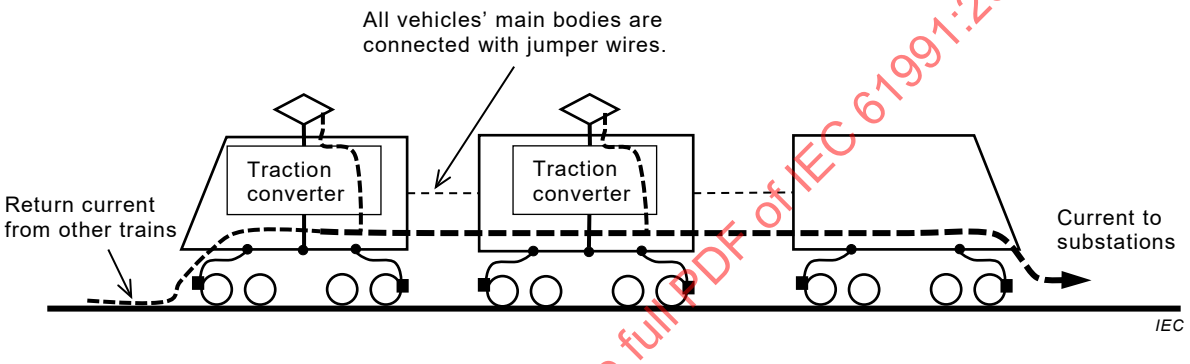

Figure C.1 – Concentration of return current

The fault is more likely to happen in long-length (above 200 m) EMU trains. Therefore, such trains' vehicles may have additional impedances intentionally; e.g. attach earth resistors between the main body and the earth brush (see Figure C.2) for preventing the absorption, if necessary.

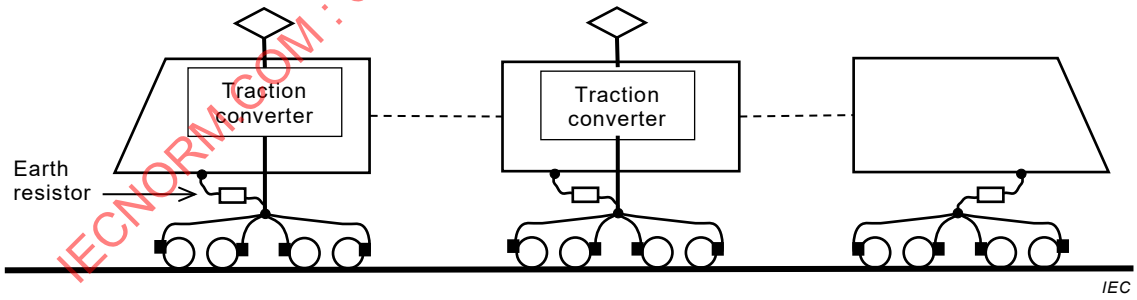

Figure C.2 – Attach earth resistors for long-length EMUs preventing current absorption

In the case of Figure C.2, the impedance between the main body of a vehicle and the protective conductor is larger than that defined in 6.4.3. However, the impedance between the main bodies of the train and the protective conductor is sufficiently low, since all the earth resistors are connected in parallel to the protective conductor. Hence the EMU train seldom causes hazardous voltage when the contact wire touches the EMU vehicle's body.

C.2 Examples of solutions

The vehicle body and its bogie frames may be connected either to the current return busbar or directly to the current return collectors or, where appropriate (i.e. for low current where no risk of bearing damage is proven), to the axle bearings.

In protective circuits, it may be necessary to connect the vehicle body structure via resistors or inductors to the current return collectors in order to:

– offer a circuit with a higher impedance than the current return paths;
– limit the return current flowing through axle bearings.

This may be particularly considered for axle bearings which have no axle brushes.

Bibliography

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

SOMMAIRE

COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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APPLICATIONS FERROVIAIRES – MATÉRIEL ROULANT –

Dispositions de protection contre les dangers électriques

AVANT-PROPOS

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La Norme internationale IEC 61991 a été établie par le comité d'études 9 de l'IEC: Matériels et systèmes électriques ferroviaires.

Cette deuxième édition annule et remplace la première édition, publiée en 2000. Cette édition constitue une révision technique. Elle est basée sur l'EN 50153:2014.

Cette édition inclut les changements techniques significatifs suivants par rapport à l'édition précédente:

a) Remplacement de plusieurs références de normes.
b) Ajout de plusieurs termes et termes abrégés.
c) Le Tableau 2 – Classes de tension pour la France est déplacé dans l'Annex B comme Tableau B.1, le Tableau 3 – Classes de tension pour l'Italie est supprimé.

d) L'Annexe B et l'Annexe C sont introduites.

e) L'Annexe B inclut des conditions nationales particulières.

Le texte de cette Norme internationale est issu des documents suivants:

FDIS	Rapport de vote
9/2467/FDIS	9/2487/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

Ce document a été rédigé selon les Directives ISO/IEC, Partie 2.

Le comité a décidé que le contenu de ce document ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "http://webstore.iec.ch" dans les données relatives au document recherché. A cette date, le document sera

- reconduit,
- supprimé,
- remplacé par une édition révisée, ou
- amendé.

INTRODUCTION

Il est généralement admis que la sécurité dépend de facteurs humains, reposant sur le comportement normal des opérateurs impliqués, ainsi que de facteurs techniques.

C’est pour cette raison que, dans certains cas, le présent document laisse aux parties contractantes le choix entre deux possibilités. Ces possibilités correspondent, d'une part à la mise en place de modes opératoires, règlementations ou procédures, et d'autre part à la prise de mesures techniques comme des dispositifs de verrouillage mécaniques ou électriques.

Une liste des cas pour lesquels les parties contractantes (c'est-à-dire l'utilisateur et le fabricant) doivent conclure un accord préalable au contrat est donnée en Annexe A.

APPLICATIONS FERROVIAIRES – MATÉRIEL ROULANT –

Dispositions de protection contre les dangers électriques

1 Domaine d'application

Le présent document définit les exigences appliquées, dans la conception et la fabrication des installations et équipements électriques à utiliser sur le matériel roulant, pour la protection des personnes contre les chocs électriques.

Le présent document est applicable aux matériels roulants des systèmes de transport sur rails, aux systèmes de transport routier, s'ils sont alimentés par une source extérieure (trolleybus), aux systèmes de transport à sustentation magnétique et aux équipements électriques installés dans ces systèmes.

Le présent document ne s'applique pas aux:

– chemins de fer miniers,
– installations de grues, plates-formes mobiles et systèmes de transport similaires sur rails,
– funiculaires,
– constructions provisoires.

Les exigences pour les installations fixes sur la protection contre le potentiel des véhicules ne sont pas couvertes dans le présent document.

2 Références normatives

Les documents suivants cités dans le texte constituent, pour tout ou partie de leur contenu, des exigences du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 60364-4-41:2005, *Installations électriques à basse tension – Partie 4-41: Protection pour assurer la sécurité – Protection contre les chocs électriques*

IEC TS 60479-1, *Effets du courant sur l'homme et les animaux domestiques – Partie 1: Aspects généraux*

IEC 60529, *Degrés de protection procurés par les enveloppes (Code IP)*

IEC 61140:2016, *Protection contre les chocs électriques – Aspects communs aux installations et aux matériels*

IEC 61310-1, *Sécurité des machines – Indication, marquage et manœuvre – Partie 1: Exigences pour les signaux visuels, acoustiques et tactiles*

IEC 62128-1:2013, *Applications ferroviaires – Installations fixes – Sécurité électrique, mise à la terre et circuit de retour – Partie 1: Mesures de protection contre les chocs électriques*

IEC 62313, *Applications ferroviaires – Alimentation électrique et matériel roulant – Critères techniques pour la coordination entre le système d'alimentation (sous-station) et le matériel roulant*

IEC 62497-1, *Applications ferroviaires – Coordination de l'isolement – Partie 1: Exigences fondamentales – Distances d'isolement dans l'air et lignes de fuite pour tout matériel électrique et électronique*

IEC 62995:2018, *Applications ferroviaires – Matériel roulant – Règles d'installation du câblage*

3 Termes, définitions et termes abrégés

3.1 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

L'ISO et l'IEC tiennent à jour des bases de données terminologiques destinées à être utilisées en normalisation, consultables aux adresses suivantes:

- IEC Electropedia: disponible à l'adresse http://www.electropedia.org/
- ISO Online browsing platform: disponible à l'adresse http://www.iso.org/obphttp://www.iso.org/obp

NOTE Pour de plus amples informations relatives aux définitions de parties d'installations fixes, se référer à l'IEC 62128-1 d'où ces définitions ont été extraites.

3.1.1 Définitions concernant les personnes

3.1.1.1
personne avertie <en électricité>
personne suffisamment informée ou surveillée par des personnes qualifiées en électricité pour lui permettre de percevoir les risques et d'éviter les dangers que peut présenter l'électricité

[SOURCE: IEC 60050-195:1998, 195-04-02]

3.1.1.2
personne ordinaire
personne qui n'est ni une personne qualifiée ni une personne avertie

[SOURCE: IEC 60050-195:1998, 195-04-03]

3.1.1.3
personne qualifiée <en électricité>
personne ayant la formation et l'expérience appropriées pour lui permettre de percevoir les risques et d'éviter les dangers que peut présenter l'électricité

[SOURCE: IEC 60050-195:1998, 195-04-01]

3.1.2 Autres définitions

3.1.2.1
zone de service électrique fermée
local ou emplacement renfermant exclusivement des équipements électriques en fonctionnement et protégé d'une manière sûre en fonction de la tension et de l'environnement

Note 1 à l'article: L'accès à ce type de zone n'est autorisé qu'aux personnes qualifiées et aux personnes averties (dans le domaine de l'électricité).

Note 2 à l'article: La définition de zone de service électrique fermée peut s'appliquer à des armoires sous caisse ou en toiture. D'une manière générale, il s'agit d'un emplacement (à l'intérieur ou à l'extérieur de la caisse du véhicule) qui reste sécurisé en fonction de la tension qui peut être supposée présente sur les équipements qui se trouvent à l'intérieur. L'accès à ce type de zone n'est pas autorisé aux personnes ordinaires.

3.1.2.2
ligne de contact
ligne électrique destinée à alimenter le matériel roulant en énergie électrique, par l'intermédiaire d'organes de prise de courant

[SOURCE: IEC 60050-811:2017, 811-33-01, modifié – Le terme "véhicule" a été remplacé par "matériel roulant" et la Note 1 à l'article a été omise.]

3.1.2.3
fil de contact
conducteur électrique d'une ligne aérienne de contact sur lequel appuie l'appareil de prise de courant

[SOURCE: IEC 60050-811:2017, 811-33-15]

3.1.2.4
contact direct
contact électrique de personnes ou d'animaux avec des parties sous tension

[SOURCE: IEC 60050-195:1998, 195-06-03]

3.1.2.5
double isolation
isolation comprenant à la fois une isolation principale et une isolation supplémentaire

[SOURCE: IEC 60050-195:1998, 195-06-08]

3.1.2.6
terre
masse conductrice de la terre, dont le potentiel électrique en chaque point est pris, par convention, égal à zéro

3.1.2.7
zone de service électrique
local ou emplacement qui sert principalement au fonctionnement d'un équipement électrique et n'est normalement accessible qu'aux personnes qualifiées ou aux personnes averties (dans le domaine de l'électricité)

Note 1 à l'article: En général, zone de service électrique désigne tout emplacement (principalement à l'intérieur de la caisse) où fonctionne un équipement électrique. Même s'il s'agit de l'utilité principale de cette zone, elle n'en est pas la seule. En fait, la zone n'est généralement pas verrouillée et la protection contre les contacts directs est assurée par d'autres moyens (par exemple des obstacles de protection (électriques)).

3.1.2.8
choc électrique
effet physiologique résultant du passage d'un courant électrique à travers le corps humain ou celui d'un animal

[SOURCE: IEC 60050-195:1998, 195-01-04]

3.1.2.9
très basse tension
tension ne dépassant pas les limites spécifiées dans le domaine II du Tableau 1

[SOURCE: IEC 60050-826:2004, 826-12-30, modifié – Le terme "bande I" a été remplacé par "bande II" et "l'IEC 60449" a été remplacé par le "Tableau 1".]

3.1.2.10
liaison équipotentielle
connexion électrique qui fixe le potentiel de plusieurs parties conductrices accessibles à un niveau similaire

Note 1 à l'article: Peut être désigné de manière abrégée par le terme "liaison".

3.1.2.11
partie conductrice accessible <d'un équipement électrique>
partie conductrice d'un équipement électrique, susceptible d'être touchée et qui n'est pas normalement sous tension, mais qui peut le devenir en cas de défaillance de l'isolation principale

Note 1 à l'article: Une partie conductrice d'un équipement électrique qui peut uniquement être mise sous tension par le contact avec une partie conductrice accessible n'est pas elle-même considérée comme étant une partie conductrice accessible.

3.1.2.12
contact indirect
contact électrique de personnes ou d'animaux avec des parties conductrices accessibles mises sous tension à la suite d'un défaut

[SOURCE: IEC 60050-195:1998, 195-06-04]

3.1.2.13
dispositif de verrouillage
dispositif qui subordonne la possibilité de fonctionnement d'un appareil de connexion à la position ou au fonctionnement d'un ou de plusieurs autres éléments de l'équipement

[SOURCE: IEC 60050-441:2000, 441-16-49]

3.1.2.14
isoler, verbe
empêcher la conduction électrique entre des éléments conducteurs au moyen d'isolants

[SOURCE: IEC 60050-151:2001, 151-15-36]

3.1.2.15
isolation
ensemble des matériaux et parties utilisés pour isoler des éléments conducteurs d'un dispositif

[SOURCE: IEC 60050-151:2001, 151-15-41]

3.1.2.16
partie sous tension <en traction électrique>
conducteur ou partie conductrice destiné à être sous tension en service normal

Note 1 à l'article: La notion n'implique pas nécessairement un risque de choc électrique.

Note 2 à l'article: Par convention, ceci n'inclut pas les rails de roulement et les parties qui leur sont connectées.

[SOURCE: IEC 60050-811:2017, 811-36-23]

3.1.2.17
système de blocage
système qui comprend des dispositifs de verrouillage et empêche physiquement l'accès aux parties sous tension à moins que l'alimentation en énergie électrique des parties sous tension n'ait été coupée et sécurisée

3.1.2.18
blocage mécanique
utilisation d'une serrure ou de fixations boulonnées/vissées pour empêcher l'ouverture de panneaux ou de portes d'accès et nécessitant l'utilisation d'une clé ou d'un outil

3.1.2.19
isolation multi-niveaux
système d'isolation ayant plus d'un niveau d'isolation et une masse intermédiaire entre deux niveaux consécutifs

[SOURCE: IEC 60322:2001, 3.4, modifié – Les Notes ont été supprimées.]

3.1.2.20
tension nominale <d'un système>
valeur approchée appropriée d'une tension utilisée pour identifier ou désigner un réseau

Note 1 à l'article: Les tensions sont exprimées par la valeur de la tension entre pôles pour le courant continu lisse et la valeur efficace de la tension entre phases pour le courant alternatif.

Note 2 à l'article: La tension réelle peut différer de la tension nominale dans la limite des tolérances admissibles. Pour de plus amples informations concernant les tensions d'alimentation des systèmes de traction, se reporter à l'IEC 60850.

[SOURCE: IEC 60050-601:1985, 601-01-21, modifié – Les Notes à l'article ont été ajoutées.]

3.1.2.21
schéma TBTP
schéma électrique dont la tension ne peut pas dépasser la valeur de la très basse tension:

– dans des conditions normales et
– dans des conditions de premier défaut, à l'exception des défauts à la terre dans les autres circuits électriques

[SOURCE: IEC 60050-826:2004, 826-12-32, modifié – La Note a été supprimée]

3.1.2.22
obstacle de protection <électrique>
élément empêchant un contact direct fortuit mais ne s'opposant pas à un contact direct par une action délibérée

[SOURCE: IEC 60050-195:1998, 195-06-16]

3.1.2.23
circuit de puissance
circuit parcouru par le courant des machines et appareils, tels que les convertisseurs et les moteurs de traction, qui transmet la puissance de traction

[SOURCE: IEC 60050-811:2017, 811-25-03]

3.1.2.24
conducteur de protection
conducteur prévu à des fins de sécurité, par exemple protection contre les chocs électriques

[SOURCE: IEC 60050-195:1998, 195-02-09]

3.1.2.25
liaison équipotentielle de protection
liaison équipotentielle réalisée à des fins de sécurité

[SOURCE: IEC 60050-195:1998, 195-01-15]

3.1.2.26
schéma TBTS
schéma électrique dont la tension ne peut pas dépasser la valeur de la très basse tension:

– dans des conditions normales et

– dans des conditions de premier défaut, y compris les défauts à la terre dans les autres circuits électriques

[SOURCE: IEC 60050-826:2004, 826-12-31, modifié – La Note a été supprimée]

3.1.2.27
isolation totale
isolation comprenant l'isolation principale comme mesure de protection principale, et l'isolation supplémentaire comme mesure de protection en cas de défaut, ou dont les protections principales et protections en cas de défaut sont assurées par une isolation renforcée conformément à la IEC 61140:2016, 7.4

[SOURCE: IEC 60050-851:2008/AMD1:2014, 851-15-11, modifié – "matériel dont" a été remplacé par "isolation comprenant" et "l'IEC 61140:2011 7.3" a été remplacé par "l'IEC 61140:2016,7.4".]

3.1.2.28
rame <connectée électriquement>
plus petit ensemble fonctionnel formé du couplage d'un ou de plusieurs véhicules

3.2 Termes abrégés

CA	Courant Alternatif
CC	Courant Continu
EMU	Rames électriques multiple
TBT	Très Basse Tension
TBTP	Très Basse Tension de Protection
r.m.s.	root-mean-square value (valeur efficace)
TBTS	Très Basse Tension de Sécurité

4 Classification des classes de tension

4.1 Principes généraux

Dans le présent document, les mesures de protection applicables sont basées sur la valeur la plus élevée de la tension nominale à laquelle les équipements ou les circuits électriques sont soumis.

Les tensions sont rangées dans des classes en fonction de leur valeur nominale comme indiqué dans le Tableau 1. Différentes règles d'installation s'appliquent à chacune de ces classes.

Les sources d'énergie alimentant les divers circuits installés dans le matériel roulant peuvent être de différentes sources telles que:

– des batteries,

– des transformateurs,

– des diviseurs de tension,

– des machines tournantes,

– des convertisseurs statiques,
– des condensateurs,
– des sources spéciales.

Tableau 1 – Classes de tension

Classe	Tension nominale U_n	
	CA V	CC V
I	$U \leq 25$	$U \leq 60$
II	$25 < U \leq 50$	$60 < U \leq 120$
III	$50 < U \leq 1\,000$	$120 < U \leq 1\,500$
IV	$U > 1\,000$	$U > 1\,500$

NOTE Les conditions nationales particulières pour la France sont listées dans l'Annexe B, Article B.2.

4.2 Connexions entre circuits

Les circuits fonctionnant à différentes tensions nominales reliés par un équipement de conversion de puissance qui fournit une isolation suffisante entre eux sont classés individuellement à la tension nominale de chaque circuit.

Si les chemins conducteurs référencés dans ce paragraphe comprennent des connexions capacitives ou inductives dont l'impédance est suffisamment faible pour induire des potentiels dangereux dans un circuit dans des conditions normales ou de défaut, tous les circuits connectés de la sorte sont classés à la tension nominale du circuit présentant la tension la plus élevée.

NOTE Cette condition peut s'appliquer à des circuits connectés, par exemple, au moyen d'un convertisseur à découpage avec une impédance de couplage.

Lorsque des circuits sont reliés électriquement à une source à une tension supérieure autrement que par des connexions directes à la caisse du véhicule (par exemple, par un autotransformateur ou un diviseur de tension), tous les circuits connectés sont traités comme s'ils étaient alimentés à la tension nominale de la source, sauf si les conditions en 4.3 sont respectées.

4.3 Exceptions

Si la conversion de tension d'une classe à une autre comprend une détection de surtension provoquant la coupure du circuit primaire ou secondaire, ou disposant d'autres moyens capables d'éviter une tension excessive dans le circuit secondaire, il est permis de classifier le circuit secondaire en fonction de la plus haute tension à laquelle l'équipement de détection fonctionnera. Lorsque la détection de surtension est utilisée, il convient d'évaluer l'intégrité de l'équipement de manière appropriée.

Les circuits qui ne sont pas reliés à la caisse du véhicule, par exemple des alimentations flottantes, peuvent être classés dans toutes les classes de tension. Il convient de choisir convenablement la classe en tenant compte des différents potentiels possibles auxquels les circuits peuvent être portés dans les conditions normales ou de défaut, de façon à s'assurer que les exigences du présent document sont respectées.

La frontière entre la classe III et la classe IV peut être abaissée pour tenir compte des conditions nationales particulières.

5 Mesures de protection contre les contacts directs

5.1 Généralités

Les parties sous tension susceptibles de causer un choc électrique doivent être protégées contre les contacts directs. Tous les types d'équipements doivent pouvoir être utilisés sans perte de la protection contre les contacts directs. La protection contre les contacts directs doit être assurée par l'un au moins des moyens décrits en 5.2 et 5.3.

Lorsque les mesures de protection selon 5.2 ou 5.3 ne sont pas applicables, la protection peut être assurée par l'emploi de tensions de la classe I, en respectant les conditions de 5.4.

En complément, des avertissements de sécurité en 5.5 doivent être fournis pour assurer une protection adéquate contre les contacts directs.

5.2 Protection par isolation

Outre les exigences de l'IEC 62497-1, les matériaux utilisés pour l'isolation des parties sous tension doivent être adaptés à la tension assignée de fonctionnement de l'équipement et aux conditions d'emploi. Il convient d'envisager d'autres dispositions pour minimiser les conséquences de détérioration.

5.3 Protection par prévention d'accès

5.3.1 Tensions des classes I à III

5.3.1.1 Protection par l'emploi de zones de service électrique fermées

Les parties sous tension à l'intérieur d'un véhicule, à un potentiel des classes I à III, doivent être contenues dans des zones de service électrique fermées.

L'accès aux zones de service électrique fermées contenant des parties sous tension sous tension est autorisé comme suit:

– classes I et II: l'accès est autorisé aux personnes averties (dans le domaine de l'électricité) et aux personnes qualifiées;

– classe III: l'accès est uniquement autorisé aux personnes averties (dans le domaine de l'électricité) et aux personnes qualifiées à condition que des précautions soient prises contre les contacts directs accidentels.

La prévention d'accès doit être réalisée par blocage mécanique avec en appui des procédures et des avertissements de sécurité adaptés à l'emplacement et à l'équipement enfermé.

Les moyens utilisés pour empêcher l'accès doivent se conformer aux principes suivants:

- dans les zones accessibles aux personnes ordinaires à l'intérieur des véhicules, les écrans et les panneaux doivent être conformes au degré de protection IP4X comme indiqué dans l'IEC 60529 ou, lorsqu'ils sont électriquement reliés à la caisse du véhicule, au degré de protection IP2XD comme indiqué dans l'IEC 60529; les exigences de ce paragraphe ne s'appliquent pas aux connecteurs enfichables, douilles sans lampes, porte-fusibles pour fusibles à visser sans la cartouche;
- dans les autres zones, lorsque des écrans grillagés ou maillés sont utilisés, ils doivent être placés à une distance suffisante pour empêcher tout contact direct, compte tenu de leur déformation possible.

5.3.1.2 Protection par l'emploi de zones de service électrique

Pour les parties sous tension contenues dans une zone de service électrique, les dispositions suivantes doivent s'appliquer: