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Electrically propelled road vehicles — Safety specifications —

Part 3: Electrical safety

Véhicules routiers électriques — Spécifications de sécurité —

Partie 3: Sécurité électrique

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 22 *Road vehicles*, Subcommittee SC 37, *Electrically propelled vehicles*.

This fourth edition cancels and replaces the third edition (ISO 6469-3:2018), which has been technically revised. It also incorporates the Amendment ISO 6469-3:2018/Amd.1:2020.

The main changes are as follows:

— changes from ISO 6469-3:2018/Amd.1:2020 were implemented,

— requirements for equipotential bonding were revised.

A list of all parts in the ISO 6469 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Electrically propelled road vehicles — Safety specifications —

Part 3: Electrical safety

1 Scope

This document specifies electrical safety requirements for voltage class B electric circuits of electric propulsion systems and conductively connected auxiliary electric systems of electrically propelled road vehicles.

It specifies electrical safety requirements for protection of persons against electric shock and thermal incidents.

It does not provide comprehensive safety information for manufacturing, maintenance and repair personnel.

NOTE 1 Electrical safety requirements for post-crash are described in ISO 6469-4.

NOTE 2 Electrical safety requirements for conductive connections of electrically propelled road vehicles to an external electric power supply are described in ISO 17409.

NOTE 3 Specific electrical safety requirements for magnetic field wireless power transfer between an external electric power supply and an electrically propelled vehicle are described in ISO 19363.

NOTE 4 Electrical safety requirements for motorcycles and mopeds are described in the ISO 13063 series.

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.

ISO 17409, *Electrically propelled road vehicles — Conductive power transfer — Safety requirements*

ISO 20653, *Road vehicles — Degrees of protection (IP code) — Protection of electrical equipment against foreign objects, water and access*

IEC 60664 (all parts), *Insulation coordination for equipment within low-voltage systems*

IEC 60990:2016, *Methods of measurement of touch current and protective conductor current*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
auxiliary electric system
vehicle system, other than the propulsion system, that operates on electric energy

3.2
balance of electric circuit
remaining section of an electric circuit when all *electric power sources* (3.37) that are *energized* (3.16) [e.g. *RESS* (3.31) and *fuel cell stacks* (3.20)] are disconnected

3.3
basic insulation
insulation of *hazardous live parts* (3.22) which provides *basic protection* (3.4)

Note 1 to entry: This concept does not apply to insulation used exclusively for functional purposes.

Note 2 to entry: Where insulation is not provided by solid insulation only, it is complemented with *protective barriers* (3.29) or *protective enclosures* (3.30) to prevent access to live parts in order to achieve basic protection.

[SOURCE: IEC 60050-195:2021, 195-06-06, modified — The phrase "hazardous live parts" and Note 2 to entry were added.]

3.4
basic protection
protection against *electric shock* (3.14) under fault-free conditions

[SOURCE: IEC 60050-195:2021, 195-06-01, modified — The phrase "fault-free conditions" replaces "normal conditions".]

3.5
clearance
shortest distance in air between two *conductive parts* (3.6)

[SOURCE: IEC 60050-581:2008, 581-27-76]

3.6
conductive part
part which can carry electric current

[SOURCE: IEC 60050-195:2021, 195-01-06]

3.7
conductively connected
not separated by at least a provision for *basic protection* (3.4)

3.8
creepage distance
shortest distance along the surface of a solid insulating material between two *conductive parts* (3.6)

[SOURCE: IEC 60050-151:2001/Amd.1:2013, 151-15-50]

3.9
degree of protection
IP
protection provided by an enclosure or barriers against access, foreign objects and/or water and verified by standardized test methods in accordance with ISO 20653

[SOURCE: ISO 20653:2013, 3.2, modified — The phrases "or barriers" and "in accordance with ISO 20653", and the term IP were added.]

3.10
direct contact
electric contact of persons or animals with *live parts* (3.25)

[SOURCE: IEC 60050-195:2021, 195-06-03, modified — "persons" replaces "human beings" and "animals" replaces "livestock".]

3.11
double insulation
insulation comprising both *basic insulation* (3.3) and *supplementary insulation* (3.33)

[SOURCE: IEC 60050-195:2021, 195-06-08]

3.12
electric chassis
conductive parts (3.6) of a vehicle that are electrically connected and whose potential is taken as reference

3.13
electric drive
combination of traction motor, power electronics and their associated controls for the conversion of electric to mechanical power and vice versa

3.14
electric shock
physiological effect resulting from an electric current through a human body or animal body

[SOURCE: IEC 60050-195:2021, 195-01-04, modified — "animal body" replaces "livestock".]

3.15
electrically propelled vehicle
vehicle with one or more *electric drive(s)* (3.13) for vehicle propulsion

3.16
energized
live
at an electric potential different from that of *electric chassis* (3.12) at the worksite and which presents an electrical hazard

Note 1 to entry: A part is energized when it is electrically connected to a source of electric energy. It can also be energized when it is electrically charged and/or under the influence of an electric or magnetic field.

[SOURCE: IEC 60050-651:2014, 651-21-08, modified — "electric chassis" replaces "earth" and the Note 2 to entry was deleted.]

3.17
equipotential bonding
provision of electric connections between *conductive parts* (3.6), intended to achieve equipotentiality

[SOURCE: IEC 60050-195:2021, 195-01-10, modified — "provision" replaces "set".]

3.18
exposed conductive part
conductive part (3.6) of equipment which can be touched and which is not normally live, but which can become live when *basic insulation* (3.3) fails

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

[SOURCE: IEC 60050-442:1998, 442-01-21, modified — "equipment" replaces "electric equipment".]

3.19
fault protection
protection against *electric shock* (3.14) under single-fault conditions

[SOURCE: IEC 60050-195:2021, 195-06-02]

3.20
fuel cell stack
assembly of two or more fuel cells that are electrically connected

3.21
fuel cell system
system, typically containing the following subsystems: *fuel cell stack* (3.20), air processing, fuel processing, thermal management, water management, and their control

3.22
hazardous live part
live part (3.25) which, under certain conditions, can give a harmful *electric shock* (3.14)

Note 1 to entry: For guidance on harmful physiological effects see IEC 61140.

[SOURCE: IEC 60050-195:2021, 195-06-05, modified — Term changed from "hazardous-live-part" to "hazardous live part" and Note 1 to entry was added.]

3.23
isolation resistance
insulation resistance
resistance between *live parts* (3.25) of an electric circuit and the *electric chassis* (3.12) as well as other electric circuits which are insulated from this electric circuit

3.24
isolation resistance monitoring system
system that periodically or continuously monitors the *isolation resistance* (3.23) between *live parts* (3.25) and the *electric chassis* (3.12)

3.25
live part
conductor or *conductive part* (3.6) intended to be *energized* (3.16) in normal use, but by convention not the *electric chassis* (3.12)

3.26
maximum working voltage
highest value of AC voltage (rms) or of DC voltage that can occur under any normal operating conditions according to the manufacturer's specifications, disregarding transients and ripple

3.27
overload protection
protection intended to operate in the event of overload on the protected section

[SOURCE: IEC 60050-448:1995, 448-14-31]

3.28
overcurrent protection
protection intended to operate when the current is in excess of a predetermined value

[SOURCE: IEC 60050-448:1995, 448-14-26]

3.29
protective barrier
part providing protection against *direct contact* (3.10) from any usual direction of access

[SOURCE: IEC 60050-195:2021, 195-06-15, modified — "against direct contact" replaces "against contact by a human being or livestock with hazardous-live-parts" .]

3.30
protective enclosure
electrical enclosure surrounding internal parts of equipment to prevent access to *hazardous live parts* (3.22) from any direction

[SOURCE: IEC 60050-195:2021, 195-06-14]

3.31
RESS
rechargeable energy storage system
rechargeable system that stores energy for delivery of electric energy for the *electric drive* (3.13)

EXAMPLE Battery, capacitor, flywheel.

3.32
reinforced insulation
insulation of *hazardous live parts* (3.22) which provides protection against *electric shock* (3.14) equivalent to *double insulation* (3.11)

Note 1 to entry: Reinforced insulation may comprise several layers that cannot be tested singly as *basic insulation* (3.3) or *supplementary insulation* (3.33).

[SOURCE: IEC 60050-581:2008, 581-21-27]

3.33
supplementary insulation
independent insulation applied in addition to *basic insulation* (3.3), for *fault protection* (3.19)

[SOURCE: IEC 60050-195:2021, 195-06-07]

3.34
touch current
electric current passing through a human body or through livestock when it touches one or more accessible parts of cables or equipment

[SOURCE: ISO 17409:2020, 3.57, modified — "cables" replaces "an installation".]

3.35
vehicle power supply circuit
voltage class (3.36) B electric circuit which includes all parts that are *conductively connected* (3.7) to the vehicle inlet (case B, case C) or the plug (case A) or part of an autoconnect charging device that is mounted on the *electrically propelled vehicle* (3.15) (case D, case E) and that is operational when connected to an external electric power supply

Note 1 to entry: Case A, case B, case C are defined in IEC 61851-1.

Note 2 to entry: Case D, case E and autoconnect charging device are defined in IEC 61851-23–1 [1)].

[SOURCE: ISO 17409:2020, 3.61, modified — Note 1 to entry replaced and Note 2 to entry added.]

3.36
voltage class
classification of an electric component or circuit according to its *maximum working voltage* (3.26)

1) Under preparation. Stage at the time of publication: IEC/PRVC 61851-23-1:2021.

3.37
electric power source
system that provides electric energy

EXAMPLE *RESS* (3.31), *fuel cell system* (3.21), photovoltaic system.

4 Voltage classes

Depending on its maximum working voltage U, an electric circuit, a section of a circuit or an electric component belongs to the voltage classes specified in Table 1.

Table 1 — Voltage classes

Voltage class	Maximum working voltage	
	DC in V	AC in V (rms value)
A	$0 < U \le 60$	$0 < U \le 30$
B	$60 < U \le 1\,500$	$30 < U \le 1\,000$
B1	$60 < U \le 75$	$30 < U \le 50$
B2	$75 < U \le 1\,500$	$50 < U \le 1\,000$

The voltage classes B1 and B2 are subclasses of voltage class B. Due to the different voltage levels, different requirements are specified for voltage class B1 and voltage class B2, whereas the requirements for voltage class B2 are more stringent. The requirements for voltage class B2 may be applied for the complete range of voltage class B, including the voltage range of voltage class B1. It is allowed to use voltage class B instead of voltage class B1 and voltage class B2.

In cases where voltage class B is referenced by another standard, the requirements for voltage class B2 apply.

NOTE 1 Dividing voltage class B into two voltage classes B1 and B2 allows chassis-connected voltage class B1 drivetrain and connected electrical systems in electric vehicles according to the given scope. Otherwise, all circuits which contain AC sections with a maximum working voltage between 30 V AC and 50 V AC, and DC sections with a maximum working voltage up to 60 V DC, would have to be insulated from the chassis, only because the AC part of the circuit falls into voltage class B range, whereas it would be possible for the DC part to still fall under the regulations for a voltage class A circuit.

NOTE 2 If the requirements of voltage class B1 are fulfilled, the maximum working voltage of an electric circuit, a section of a circuit or an electric component can be up to 75 V DC and up to 50 V AC.

NOTE 3 The requirements for voltage class B1 are based on IEC 61140, IEC 60479-1, IEC 60479-2, IEC 60479-5, and IEC 60364-4–41.

NOTE 4 The voltage limits of voltage class B1 are harmonized with the European Low Voltage Directive and IEC 61140 (the AC limit). Electric vehicles are not in the scope of the European Low Voltage Directive.

5 General requirements

5.1 Environmental and operational requirements

The requirements given in this document shall be met across the range of environmental and operational conditions for which the electrically propelled vehicle is designed to operate, as specified by the vehicle manufacturer.

NOTE See the ISO 16750 series, ISO 21498-1 and the ISO 19453 series for guidance.

5.2 Marking

5.2.1 Marking of voltage class B electric components

The symbol ISO 7010–W012 in Figure 1 shall be visible on protective barriers and protective enclosures, which, when removed, expose hazardous live parts of voltage class B electric circuits. Accessibility and removability of protective barriers and protective enclosures should be considered when evaluating the requirement for the symbol.

The symbol may be embossed or engraved in accordance with Figure 1. In this case colour is not required.

For a protective enclosure consisting of several parts, one symbol is sufficient when visibility of the symbol is given.

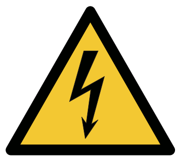


Figure 1 — ISO 7010-W012 - Warning; Electricity

5.2.2 Marking of voltage class B wiring

The outer covering of cables and harness for voltage class B2 electric circuits not within protective enclosures or behind protective barriers shall be marked with orange colour. Voltage class B1 cables and harness shall be marked with a two-colour combination of orange and purple or with orange colour. In case of the two-colour combination, each colour shall cover at least 30 % of the surface. The marking shall be visible over the whole cable length and from all usual directions of access.

Voltage class B connectors may be identified by the harnesses to which the connector is attached.

NOTE Specifications of the orange colour are given, for example, in standards in the US (8.75R5.75/12.5) and in Japan (8.8R5.8/12.5) according to the Munsell colour system.

6 Requirements for protection of persons against electric shock

6.1 General requirements

6.1.1 General requirements for connected sections of a circuit

If not specified otherwise, an electric circuit consisting of conductively connected sections with different maximum working voltages shall be classified according to the highest maximum working voltage.

6.1.2 General requirements for voltage class B1

Protection against electric shock for voltage class B1 shall be comprising:

— limitation of voltage in accordance with Table 1 under normal conditions;

— provisions for basic protection according to 6.2; and

— additional measures according to 6.3.1 and 6.3.3.

The electric chassis may be used as a conductor for the DC sections of a voltage class B1 electric circuit. The electric chassis shall not be used as a conductor for the AC sections of a voltage class B1 electric circuit.

An electric circuit may consist of sections with voltage class B1 and sections with voltage class A. In this case the following conditions shall apply.

— At a single fault in this circuit the voltage of the voltage class A sections shall not exceed the limits specified for voltage class A.

— The voltage class A sections shall be classified as voltage class A.

NOTE A failure of an electronic switch is an example for a single fault.

6.1.3 General requirements for voltage class B2

Protection against electric shock for voltage class B2 shall be comprising:

— provisions for basic protection according to 6.2; and

— provisions for fault protection according to 6.3.

The provisions for protection shall meet the requirements as described in 6.2. and 6.3.

Provisions for fault protection shall include 6.3.1, 6.3.2 and 6.3.3.

6.2 Basic protection

For basic protection, the requirement of basic insulation shall be fulfilled.

The protective provisions in 6.4 shall apply.

Different measures to provide basic protection may be used for different sections of a circuit.

6.3 Fault protection and additional measures

6.3.1 Equipotential bonding

Exposed conductive parts of voltage class B electric equipment that can be touched by a test finger according to IPXXB (see ISO 20653) after removing all other parts that can be removed without using tools, shall be bonded to the electric chassis to achieve equipotentiality.

All components forming the equipotential bonding current path shall withstand the maximum current it will be exposed to in the event of a single insulation fault between a voltage class B live part and an exposed conductive part or between a voltage class B live part and the equipotential bonding current path.

If de-energization in case of such a single insulation fault is not implemented, provisions shall be taken to avoid risk of harmful electric shock in the event of two insulation faults, each between a voltage class B live part and an exposed conductive part or between a voltage class B live part and the equipotential bonding current path, existing simultaneously.

NOTE 1 The fault current originated from an insulated voltage class B electric circuit (i.e. a voltage class B2 electric circuit or a voltage class B1 electric circuit which is not conductively connected to the electrical chassis) is low in the event of such a fault and de-energization is not imperative.

EXAMPLE 1 The equipotential bonding current path is designed to withstand a short-circuit current until de-energization is achieved.

EXAMPLE 2 The isolation monitoring according to 6.3.2.2 is used to deactivate and de-energize (see 6.3.4) the voltage class B2 system depending on the operational state of the vehicle and the ability to activate the voltage class B2 system is limited if the minimum isolation resistance requirement is violated.

NOTE 2 Currents caused by electromagnetic interference (EMI) and currents from voltage class A and voltage class B1 systems using the equipotential bonding path as a conductor contribute to the maximum current through the equipotential bonding current path.

The resistance of the equipotential bonding path between any two of these exposed conductive parts of the voltage class B electric circuit that can be touched simultaneously by a person shall not exceed 0,1 Ω.

Conformance shall be tested in accordance with 10.2.

NOTE 3 Parts that are separated by a distance of more than 2,5 m are normally considered not to be simultaneously accessible.

NOTE 4 A physical barriers is a means that can prevent simultaneous access to exposed conductive parts.

6.3.2 Isolation resistance

6.3.2.1 General

The voltage class B2 electric circuits shall have sufficient isolation resistance.

The isolation resistance, divided by the maximum working voltage, shall have a minimum value of 100 Ω/V for DC circuits and a minimum value of 500 Ω/V for AC circuits.

NOTE According to IEC 60479-1, body currents within zone DC-2 or zone AC-2 are not harmful. The currents calculated from 100 Ω/V for DC and 500 Ω/V for AC are 10 mA and 2 mA respectively, and within these zones.

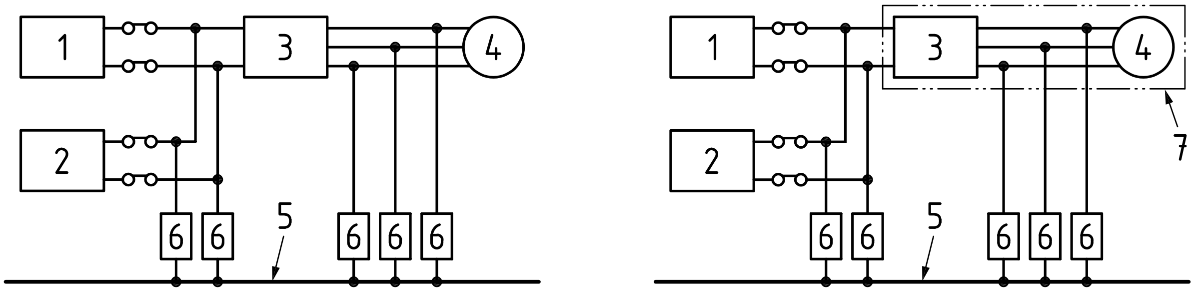
To meet the above requirement for the entire circuit, it is necessary to provide a higher isolation resistance for each component, depending on the number of the components and the structure of the circuit to which they belong.

If DC and AC voltage class B2 electric circuits are conductively connected (see Figure 2), one of the following two requirements shall be fulfilled for the conductively connected circuit:

— option 1: isolation resistance, divided by the maximum working voltage, shall have a minimum value of 500 Ω/V for the combined circuit;

— option 2: isolation resistance, divided by the maximum working voltage, shall have a minimum value of 100 Ω/V, if at least one of the alternative protection measures as specified in 6.3.5 is applied to the AC circuit.

Conformance shall be tested in accordance with 10.3.



a) Option 1

b) Option 2

Key

1 fuel cell system
2 RESS
3 inverter
4 motor
5 vehicle electric chassis
6 partial isolation resistances
7 additional protection measures for AC circuit

NOTE The isolation resistance results from all partial isolation resistances "6" of the relevant electric circuits.

Figure 2 — Isolation resistance - examples for conductively connected AC and DC circuits

6.3.2.2 Additional measures at a non-maintained isolation resistance

If the minimum isolation resistance requirement of a voltage class B2 circuit cannot be maintained under all operational conditions and over the entire service life, one of the following measures shall be applied.

— The isolation resistance shall be monitored periodically or continuously. An appropriate warning shall be provided if the minimum isolation resistance requirement is violated. The voltage class B2 circuit may be deactivated and de-energized (see 6.3.4) depending on the operational state of the vehicle or the ability to activate the voltage class B2 circuit may be limited. The insulation resistance monitoring system shall be tested in accordance with 10.4.

— Alternative protection measure according to 6.3.5.

NOTE 1 Isolation resistances below the required minimum values can occur due to deterioration of fuel cell systems' cooling liquids or of certain battery types.

NOTE 2 If multiple isolation monitoring systems are applied for an electric circuit, their coordination is considered.

NOTE 3 De-energization is not applicable for the RESS.

6.3.3 Provisions for capacitive coupling and capacitive discharge

Capacitive coupling between the electric chassis and live parts of an electric circuit usually results from Y capacitors, used for electromagnetic compatibility reasons, or from parasitic capacitive coupling.

The following requirements apply to:

— any section of a voltage class B2 electric circuit individually, if the touch current depends on different operating conditions, e.g. working voltage, AC circuit, DC circuit; and

— an AC section of a voltage class B1 electric circuit which is not conductively connected to the electric chassis.

NOTE 1 It is possible that an AC section of a voltage class B1 electric circuit has a conductive connection to the electric chassis through a different section of the same circuit.

If a touch current between a live part of a voltage class B electric circuit and electric chassis can occur in case of a single-failure, one of the following requirements shall apply.

— The stored electric energy between any energized voltage class B live part and the electric chassis shall be < 0,2 J and, after discharge of this stored energy, the touch current shall not exceed 5 mA for an AC circuit and 25 mA for an DC circuit.

— Alternative protection measure according to 6.3.5.

NOTE 2 5 mA represents the threshold between AC-2 and AC-3 in IEC 60479-1 and 25 mA represents the threshold between DC-2 and DC-3.

The relevant capacitance is the total capacitance resulting from all parallel capacitances between a live part of a voltage class B electric circuit and the electric chassis. For the energy requirement, the maximum working voltage of a section of a circuit shall apply.

The requirement on the energy limit is deemed to be fulfilled, if the energy limit is confirmed by calculation based on the designed capacitances of all related parts and components.

The touch current shall be measured according to 10.5.

6.3.4 De-energization

The voltage class B2 electric circuit in question may be de-energized as a protection measure. The monitoring of faults within the circuit or the detection of events may be used to trigger the de-energization. One of the following conditions shall be met for the de-energized circuit:

— the voltage shall be reduced to a value below 50 V AC and 75 V DC;

— the total stored energy of the circuit shall be < 0,2 J and

the touch current flowing between simultaneously accessible conductive parts shall not exceed 5 mA AC or 25 mA DC.

NOTE 5 mA represents the threshold between AC-2 and AC-3 in IEC 60479-1 and 25 mA represents the threshold between DC-2 and DC-3.

The transition time and conditions to reach the de-energized state shall be specified by the manufacturer in accordance with expected failures and vehicle operating conditions including driving.

6.3.5 Alternative protection measures

The following measures shall provide both basic protection and fault protection:

— double insulation;

— reinforced insulation;

— protective barriers in addition to the basic protection;

— protective enclosures in addition to the basic protection;

— conductive protective barrier with equipotential bonding in addition to basic insulation;

— conductive protective enclosure with equipotential bonding in addition to basic insulation;

— rigid protective barriers with sufficient mechanical robustness and durability over the vehicle service life; and

— rigid protective enclosures with sufficient mechanical robustness and durability, over the vehicle service life.

The selected measure or combination of measures shall address the single fault for which it is intended.

Different measures may be used for different sections of a circuit.

The requirements for protective provisions in 6.4 shall apply.

6.4 General requirements for protective provisions

6.4.1 General

All protective provisions shall be designed and constructed to be effective during the anticipated lifetime of the vehicle when used as intended and properly maintained according to the vehicle manufacturer's specification.

6.4.2 Requirements for insulation

The following requirements apply to basic insulation, double insulation and reinforced insulation.

Insulation shall fulfil the specific requirements related to basic insulation, double insulation or reinforced insulation in accordance with 6.4.5.

Insulation can be a solid, a liquid or a gas (e.g. air), or any combination.

Where insulation is not provided by solid insulation only, access to live parts shall be prevented by protective barriers or protective enclosures according to 6.4.3.

Live parts of cables not within protective enclosures or behind protective barriers shall be totally encapsulated by solid insulation that can be removed only by destruction.

6.4.3 Requirements for protective barriers and protective enclosures

6.4.3.1 General

Protective barriers and protective enclosures shall have sufficient mechanical strength, stability and durability to maintain the specified provisions of protection, taking into account all relevant environmental conditions.

It shall not be possible to open or remove protective barriers and protective enclosures without the use of tools or they shall have means to de-energize voltage class B live parts according to 6.4.4 c).

The protective barriers and protective enclosures may be electrically conductive or provided by solid insulation.

6.4.3.2 Degree of protection for protective barriers and protective enclosures

Protective barriers and protective enclosures shall comply with the degree of protection IPXXB at a minimum.

Protective barriers and protective enclosures in passenger and load compartments shall comply with the degree of protection IPXXD at a minimum.

Conformance shall be tested in accordance with ISO 20653.

6.4.4 Requirements for connectors

Connectors for voltage class B electric circuits shall comply with 6.4.3.2 in the mated condition.

Connectors for voltage class B electric circuits including vehicle inlet (in case B or C according to IEC 61851-1) or the plug (in case A according to IEC 61851-1) and including the contacts of an autoconnect charging device (case D and E according to IEC 61851-23-1) shall comply with at least one of the following requirements.

a) A connector shall comply with 6.4.3.2 in the unmated condition.

b) It shall not be possible to unmate a connector without the use of tools. This requirement is deemed to be fulfilled by placing a connector behind a protective barrier or inside a protective enclosure.

c) Voltage class B live parts of a connector shall be de-energized when it is unmated. One of the following conditions shall be met for the de-energized live parts:

   — the voltage shall be reduced to a value below 30 V AC and 60 V DC;

   — the total stored energy of the circuit shall be ≤ 0,2 J and the touch current flowing

   between simultaneously accessible conductive parts shall not exceed 2 mA AC or 10 mA DC Conformance shall be tested according to 10.5 or demonstrated by calculation.

NOTE 2 mA AC touch current aligns with an isolation resistance of 500 Ohm/V. 10 mA DC touch current aligns with an isolation resistance of 100 Ohm/V.

6.4.5 Insulation coordination

Clearance, creepage distance and solid insulation of voltage class B components and wiring shall be designed according to the applicable sections of the IEC 60664 series.

A different approach may be used if it provides equivalent safety.

Voltage class B circuits not conductively connected to the electric chassis shall be tested according to 10.6.

6.5 Alternative approach for protection against electric shock

As an alternative to 6.3, the vehicle manufacturer shall conduct an appropriate hazard analysis and establish a set of measures which give sufficient protection against electric shock under single fault conditions.

7 Protection against thermal incidents

7.1 Overload protection

Overload protection shall be provided for live conductors of a voltage class B electric circuit according to their cross-sectional area.

Conformance shall be checked by inspection of the design.

7.2 Short-circuit protection

The requirements in a) or b) shall be fulfilled for short-circuit protection.

a) The cross-sectional area of the live conductors of the voltage class B electric circuit shall have a short-circuit current withstand rating (I^2t) according to the maximum short-circuit current of an electric power source.

b) Overcurrent protection shall be provided for live conductors of a voltage class B electric circuit according to their cross-sectional area.

Conformance shall be checked by inspection of the design.

8 Requirements for vehicle power supply circuit

The vehicle power supply circuit, when not conductively connected to an external electric power supply, shall fulfil the requirements of this document.

Requirements for the vehicle power supply circuit for the purpose of conductive connection to an external electric power supply shall be followed as are described in ISO 17409.

9 Owner's manual

Special attention to electric safety shall be given in the owner's manual.

10 Test procedures

10.1 General

The tests for the selected protection measures according to Clause 6 shall be performed on each voltage class B electric circuit or section of a circuit and in principle on the vehicle level, when the vehicle is disconnected from the external electric power supply.

If the safety requirements for the whole vehicle are not affected, the tests may be performed on the components or sections of a circuits individually instead.

10.2 Continuity test for equipotential bonding

The equipotential bonding resistances shall be tested with a test current of at minimum 0,2 A and a voltage ≤ 60 V DC, which shall be passed through the equipotential bonding path between any two exposed conductive parts of voltage class B equipment for at least 5 s. This path shall be isolated from other unintended potential paths for measurement. These equipotential bonding paths shall include voltage class B component housings, connections to electric chassis and the vehicle electric chassis or protective barriers and protective enclosures.

A lower test current and/or a shorter test time may be used, provided the accuracy of the equipotential bonding resistance test results remain on a sufficient accuracy level.

The voltage drop between any two exposed conductive parts in a distance of 2,5 m which can be simultaneously touched by a person shall be measured. The resistance shall be calculated based on the applied current and this voltage drop.

10.3 Isolation resistance measurements for voltage class B2 electric circuits

10.3.1 Preconditioning and conditioning

Prior to the measurement, the device under test shall be subjected to a preconditioning period of at least 8 h at (5 ± 2) °C, followed by a conditioning period of 8 h at a temperature of (23 ± 5) °C, a humidity of (90 + 10/-5) %, and an atmospheric pressure of between 86 kPa and 106 kPa.

Alternative preconditioning and conditioning parameters may be selected provided transition across the dew point occurs shortly after the beginning of the conditioning period.

The isolation resistance shall be measured during the conditioning period at a rate from which the lowest value can be determined.

10.3.2 Isolation resistance measurements of the balance of electric circuits

The test voltage shall be a DC voltage of at least the maximum working voltage of the voltage class B2 electric circuit or 500 V whichever is higher and be applied for a time long enough to obtain stable reading.

If the voltage class B2 electric circuit has several voltage ranges (e.g. because of boost converter) in conductively connected sections of the circuit and some of the components cannot withstand the maximum working voltage of the entire circuit, the isolation resistances of sections of the circuit can be measured separately by applying their own maximum working voltages after those sections of the circuit are disconnected.

The following test procedure combines the measurement of the isolation resistance of the live parts of the voltage class B2 balance of electric circuits against the vehicle electric chassis and against the live parts of the voltage class A balance of auxiliary electric circuits and against the live parts of the voltage class B1 balance of auxiliary electric circuits.

— RESS shall be disconnected at their terminals from the electric circuit.

— Fuel cell stacks and other electric power sources that are energized may be disconnected at their terminals from the electric circuit; if they remain connected, they shall not be energized.

— Protective barriers and protective enclosures shall be included unless evaluations prove otherwise.

— All live parts of the balance of electric circuits (voltage class B2) shall be connected to each other.

— All exposed conductive parts of the balance of electric circuits shall be connected to the electric chassis, see 6.3.1.

— Batteries of the auxiliary electric systems (voltage class A and B1) shall be disconnected at their terminals from the auxiliary circuits.

— All live parts of the balance of auxiliary electric systems (voltage class A and B1) shall be connected to the electric chassis.

Then the test voltage shall be applied between the connected live parts of the voltage class B2 balance of electric circuits and the electric chassis.

The measurements shall be performed using suitable instruments that can apply DC voltage (e.g. megohmmeter), provided they deliver the required test voltage.

Alternatively, the isolation resistance may be measured using the test procedure for the measurement of the voltage class B2 electric power sources as given in 10.3.3 with the balance of electric circuits connected to an external power source.

10.3.3 Isolation resistance measurement of the voltage class B2 electric power sources

10.3.3.1 General

The following test requirements shall apply to voltage class B2 electric power sources that are energized, for example RESS and fuel cell stack.

10.3.3.2 Preparation

10.3.3.2.1 General

For the measurement of the isolation resistance of the electric power sources installed as for normal operation within the vehicle, the terminals of a voltage class B2 electric circuit of the electric power sources shall be disconnected from any electric circuit not galvanically coupled to the said voltage class B2 power source.

Terminals of the internal auxiliary systems of the electric power sources that are operated by power sources outside the electric power sources (e.g. the auxiliary 12 V battery) shall be disconnected from the outside power source and connected to the electric chassis of the vehicle, except for terminals that are required to enable the measurement.

For the isolation resistance measurement of an electric power source when not installed in the vehicle (as a stand-alone system), the electric chassis shall be simulated by a conductive part, e.g. a metal plate, to which the electric power source shall be attached with its standard mounting devices to include the resistances between the electric power source housing and the electric chassis of the vehicle. In the case that the electric power source has a conductive housing, its housing may be regarded as the electric chassis of the vehicle.

The voltmeter or the measuring device used in this test shall have an internal resistance above 10 MΩ.

10.3.3.2.2 Preparation for RESS

If possible, the RESS should be charged to the maximum state of charge in normal operation recommended by the manufacturer.

For measurements within the vehicle, if the RESS is rechargeable only from on-board energy sources, the RESS should be charged at a state of charge within the normal operation level that is appropriate for measurement, as defined by the vehicle manufacturer.

10.3.3.2.3 Preparation for fuel cell stack

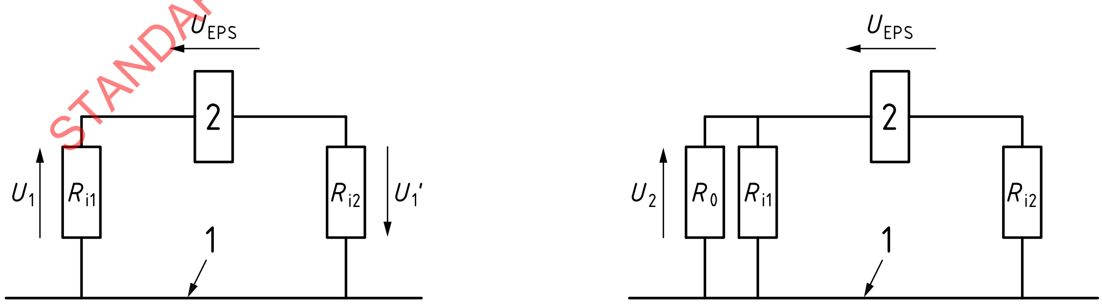
For the measurement of the isolation resistance of a fuel cell stack, the entire mechanical structure of the fuel cell system (including the cooling system with its cooling medium) shall be considered. Prior to the measurement, stop power generation after operation at maximum output according to the manufacturer's specification. All cables shall be disconnected from the fuel-cell stack power terminals, and all other cables from other electric terminals of the fuel-cell stack. All cooling pipes, fuel pipes, and air pipes shall remain connected.

10.3.3.3 Procedure

10.3.3.3.1 General

If switches for the electric power source current are integrated in the electric power source, they shall be closed during the measurement, unless they do not affect the test result.

The procedure for each measurement is the following [see Figure 3 and Formula (1)].



a) **Measurement of U_1 and U_1'**

b) **Addition of R_0 and measurement of U_2**

Key

1 electric chassis

2 electric power source

NOTE 1 R_{i1} and R_{i2} represent the fictitious isolation resistances between the two terminals of an electric power source and the electric chassis.

NOTE 2 R_0 is the measuring resistance.

Figure 3 — Example for the measurement of the isolation resistance

Measure the voltage U_{EPS} between the negative and the positive terminal of the electric power source.

Measure the voltages between each terminal of the electric power source and the vehicle electric chassis, and name the higher one U_1, the lower one U'_1 and the two corresponding isolation resistances R_{i1} and $R_{i2} = R_i$.

R_{i2} is the lower isolation resistance and is, therefore, the isolation resistance R_i to be determined.

— Add a known measuring resistance R_0 parallel to R_{i1} and measure the voltage U_2.

— During the measurements, the test voltage shall be stable.

Theoretically, the value of R_0 has no influence on the calculated isolation resistance. However, R_0 could be selected so that sufficient accuracy is achieved for the measured voltages on the calculated isolation resistances. R_0 (Ω) can be the value of the minimum required isolation resistance (in Ω/V) multiplied by the maximum working voltage of the electric power source or voltage class B2 electric circuit which includes the electric power source ± 20 %. R_0 is not required to be precisely this value since the equations are valid for any R_0; however, a R_0 value in this range provides an appropriate voltage range for the voltage measurements.

— Calculate the isolation resistance R_i, using R_0 and the three voltages U_1, U'_1, and U_2 with Formula (1):

$$R_i = R_0 \times U_{EPS} \times (1/ U_2 - 1/U_1) \quad (1)$$

where

R_i is the isolation resistance;

R_0 is the measuring resistance;

U_{EPS} is the voltage of the electric power source;

U_2 is the voltage measured, when R_0 has been added to the circuit;

U_1 is the bigger of the two voltage values measured from each HV potentials to ground.

NOTE Formula (1) is also used in ISO 6469-4, but partly with different indexes.

Alternatively, the isolation resistance may be determined by adequate procedures and measurement equipment if the results will be equivalent to, or have a clear correlation with, the one measured as specified above, e.g. by using an internal isolation-resistance monitoring system.

10.3.3.3.2 Procedure for fuel cell stack

The measurement of the isolation resistance of a fuel cell stack shall be in accordance with 10.3.3.3.1 with the fuel cell stack in operation.

Alternatively, after discharging the electricity across the fuel cell stack power terminals, the procedure shall be performed as given in 10.3.2. The applied test voltage shall be at least the maximum open circuit voltage of the fuel cell stack.

10.3.4 Isolation resistance measurement of entire electric circuits

The isolation resistance of entire conductively connected voltage class B2 electric circuits may be calculated using the measured isolation resistances of the electric power sources and the balance of electric circuit.

Alternatively, the isolation resistance of entire conductively connected voltage class B2 electric circuits may be measured using one of the following procedures.

— The test procedure for the measurement of the electric power sources given in 10.3.3 with the balance of electric circuit connected to the electric power sources. In case electric or electronic switches exist in the circuit (e.g. transistors in power electronics), these switches shall be activated. If these switches cannot be activated, the relevant part of the circuit may be measured separately in accordance with 10.3.2.

— An isolation resistance monitoring system that is part of the vehicle may be used, provided that its accuracy is sufficiently high.

10.4 Test for isolation resistance monitoring system

A resistor as specified by the vehicle manufacturer shall be inserted between the terminal of a circuit being monitored and the electric chassis.

This resistor shall not cause the isolation resistance to drop below the minimum required isolation resistance specified in 6.3.2.1.

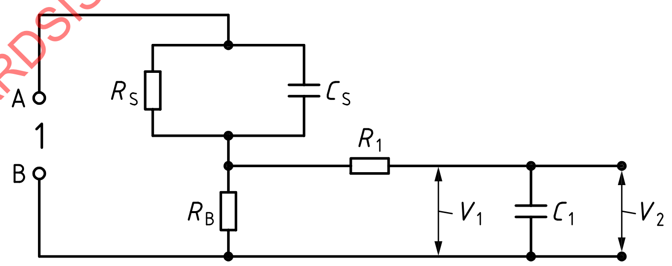
The warning shall be triggered.

NOTE This test is intended to trigger the warning above, or, at the minimum, required isolation resistance.

10.5 Touch current

The voltage class B electric circuit or section of a circuit shall be operated under normal operating conditions as specified by the vehicle manufacturer.

The steady-state touch current shall then be measured using the measurement network according to Figure 4 (see also IEC 60990). The terminal A of the measurement circuit shall be connected to the live part of the circuit under test. The terminal B of the measurement circuit shall be connected to the electric chassis.



Key

1 terminals of measurement circuit

R_S = 1,5 kΩ ± 5 %

R_B = 500 Ω ± 5 %

R_1 = 10 kΩ ± 5 %

C_S = 0,22 µF ± 10 %

C_1 = 0,022 µF ± 10 %

Figure 4 — Measurement circuit

The rms value of the voltage V_2 shall be measured, see Figure 4. For voltage measurement, an instrument according to IEC 60990:2016, Annex G shall be used.

The touch current shall be calculated by Formula (2):

$$I_{\mathrm{rms}}\ V_{2\mathrm{rms}}/500 \tag{2}$$

where

I_{rms} is the touch current, expressed in A;

$V_{2\mathrm{rms}}$is the rms value of voltage V_2.

10.6 Withstand voltage test

10.6.1 General

This test is intended to demonstrate the adequacy of the protection measures to isolate live parts of voltage class B electric circuits.

This test shall be performed on the balance of electric circuit.

Electric power sources, which can be de-energized, shall be de-energized and included into the balance of the electric circuit.

Electric power sources, which are not part of the balance of the electric circuit shall be tested according to 10.7.

The test may be performed at the component level at the discretion of the vehicle manufacturer.

Surge protective devices (SPDs) that can affect the test result shall be disconnected before testing. Components such as RFI filters shall be included in the impulse test but may be disconnected during AC tests.

10.6.2 Preconditioning and conditioning

Unless the vehicle manufacturer specifies alternative conditions according to the environment during vehicle operation, the following procedure shall apply.

— Preconditioning at the temperature selected for conditioning within tolerance of $^{+4}_{-0}$ K and a duration that ensures a constant temperature.

— Conditioning: for 48 h within ± 2 K at a temperature between 20 °C and 40 °C, a humidity of 93 % ± 3 %, and an atmospheric pressure of 86 kPa to 106 kPa.

10.6.3 Test procedure

10.6.3.1 General

The test shall include protective barriers and protective enclosures.

The test shall apply to the following electric circuits of the device under test:

— voltage class B2 electric circuits; and

— voltage class B1 electric circuits that are not conductively connected to a voltage class A electric circuit or electric chassis.

