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Electrically propelled mopeds and motorcycles — Safety specifications —

Part 3: Electrical safety

Cyclomoteurs et motocycles à propulsion électrique — Spécifications de sécurité —

Partie 3: Sécurité électrique

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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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 38, *Motorcycles and mopeds*.

This first edition of ISO 13063-3, together with ISO 13063-1 and ISO 13063-2, cancels and replaces ISO 13063:2012, which has been technically revised.

The main changes are as follows:

— extension of protection against electric shock to all electric safety requirements;

— alignment of structure and requirements as possible with ISO 6469-3:2018;

— splitting the document into three documents which consist of the following parts, under the general title *Electrically propelled mopeds and motorcycles — Safety specifications:*

  — *Part 1: On-board rechargeable energy storage system (RESS)*;

  — *Part 2: Vehicle operational safety*;

  — *Part 3: Electrical safety*;

— addition of specific requirements for capacitive discharge;

— new test specification for the isolation resistance monitoring system;

— new requirements and test for touch current; and

— the requirements for conductive connection to an external electric power supply can be covered by ISO 18246.

A list of all parts in the ISO 13063 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 mopeds and motorcycles — Safety specifications —

Part 3: Electrical safety

1 Scope

This document specifies electric safety requirements for protection against electric shock and thermal incidents of electric propulsion systems and conductively connected auxiliary electric systems of electrically propelled mopeds and motorcycles when used in normal conditions. It is applicable to a maximum working voltage of the on-board electrical circuit up to 1 000 V alternating current (a.c.) or 1 500 V direct current (d.c.). This document does not provide comprehensive safety information for manufacturing, maintenance and repair personnel.

NOTE Requirements for conductive connections of electrically propelled mopeds and motorcycles to an external electric power supply are described in ISO 18246.

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

IEC 60227-1, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V — Part 1: General requirements*

IEC 60245-1, *Rubber insulated cables — Rated voltages up to and including 450/750 V — Part 1: General requirements*

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* (3.46), that operates on electric energy

[SOURCE: ISO 6469-3:2021, 3.1]

3.2
balance of electric circuit
remaining section of an electric circuit when all electric power sources that are energized (e.g. *RESS* (3.23) and fuel cell stacks) are disconnected

[SOURCE: ISO 6469-3:2021, 3.2]

3.3
protective barrier
part providing protection against *direct contact* (3.9) from any usual direction of access

[SOURCE: IEC 60050-826:2004, 826-12-23, modified — Domain "<electrically>" was removed.]

3.4
basic insulation
insulation of *hazardous live parts* (3.35) which provides *basic protection* (3.5)

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* (3.3) or *protective enclosures* (3.15) to prevent access to *live parts* (3.19) in order to achieve basic protection.

[SOURCE: IEC 60050-581:2008, 581-21-24, modified — "Note 2 to entry" was added.]

3.5
basic protection
protection against *electric shock* (3.13) under fault-free conditions.

[SOURCE: IEC 60050-195:2021, 195-06-01, modified — "normal" was replaced by "fault-free".]

3.6
conductive part
part which can carry electric current

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

3.7
conductor
conductive part (3.6) intended to carry a specified electric current

[SOURCE: IEC 60050-195:2021, 195-01-07]

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, 151-15-50]

3.9
direct contact
electric contact of persons or animals with *live parts* (3.19)

[SOURCE: IEC 60050-826:2004, 826-12-03]

3.10
double insulation
insulation comprising both *basic insulation* (3.4) and *supplementary insulation* (3.25)

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

3.11
electric chassis
conductive parts (3.6) of a vehicle that are electrically connected and whose potential is taken as reference

3.12
electric drive
combination of traction motor, power electronics and their associated controls for the conversion of electric to mechanical power and vice versa

[SOURCE: ISO 6469-3:2021, 3.13]

3.13
electric shock
physiological effect resulting from an electric current passing through a human body or animal body

[SOURCE: IEC 60050-826:2004, 826-12-01]

3.14
electrically propelled vehicle
vehicle with one or more *electric drive(s)* (3.12) for vehicle propulsion

[SOURCE: ISO 6469-3:2021, 3.15]

3.15
protective enclosure
electrical enclosure surrounding internal parts of equipment to prevent access to *hazardous live parts* (3.35) from any direction

[SOURCE: IEC 60050-195:2021, 195-06-14, modified — Domain "<electrically>" was removed.]

3.16
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* (3.4) 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]

3.17
isolation resistance monitoring system
system that periodically or continuously monitors the *isolation resistance* (3.18) between *live parts* (3.19) and the *electric chassis* (3.11)

[SOURCE: ISO 6469-3:2021, 3.24]

3.18
isolation resistance
insulation resistance
resistance between *live parts* (3.19) of an electric circuit and the *electric chassis* (3.11) as well as other electric circuits which are insulated from this electric circuit

[SOURCE: ISO 6469-3:2021, 3.23]

3.19
live part
conductor (3.7) or *conductive part* (3.6) intended to be energized in normal use, but by convention not the *electric chassis* (3.11)

[SOURCE: IEC 60050-442:1998, 442-01-40, modified — "including a neutral conductor" and Note were removed, and "combined protective and neutral conductor (PEN)" was replaced by "electric chassis".]

3.20
maximum working voltage
highest value of AC voltage (rms) or of DC voltage that can occur under any normal operating conditions according to the manufacturers' specifications, disregarding transients and ripple

[SOURCE: ISO 6469-3:2021, 3.26]

3.21
equipotential bonding
provision of electric connections between *conductive parts* (3.6), intended to achieve equipotentiality

[SOURCE: IEC 60050-826:2004, 826-13-19]

3.22
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 term "IP" and the phrase "in accordance with ISO 20653" were added.]

3.23
rechargeable energy storage system
RESS
rechargeable system that stores energy for delivery of electric energy for the *electric drive* (3.12)

EXAMPLE Battery, capacitor, flywheel.

[SOURCE: ISO 6469-3:2021, 3.31]

3.24
reinforced insulation
insulation of *hazardous live parts* (3.35) which provides protection against *electric shock* (3.13) equivalent to *double insulation* (3.10)

Note 1 to entry: Reinforced insulation may comprise several layers that cannot be tested singly as *basic insulation* (3.4) or *supplementary insulation* (3.25).

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

3.25
supplementary insulation
independent insulation applied in addition to *basic insulation* (3.4) for *fault protection* (3.29)

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

3.26
voltage class
classification of an electric component or circuit according to its *maximum working voltage* (3.20)

[SOURCE: ISO 6469-3:2021, 3.36]

3.27
wiring
system of wires providing electric circuits and including cables and connectors

3.28
service disconnect
device for deactivation of the electrical circuit when conducting checks and services of the vehicle, *RESS* (3.23), etc.

3.29
fault protection
protection against *electric shock* (3.13) under single-fault conditions

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

3.30
functional insulation
insulation between *conductive parts* (3.6), necessary for the proper functioning of the component

[SOURCE: IEC 60050-195:2021, 195-02-41, modified — "equipment" replaces "component".]

3.31
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”.]

3.32
vehicle power supply circuit
voltage class (3.26) B electric circuit which includes all parts that are conductively connected to the *vehicle inlet* (3.33) [*case B* (3.40), *case C* (3.41)] or the *plug* (3.45) [*case A* (3.39)]

[SOURCE: ISO 6469-2:2022, 3.18, modified — “conductively” replaces “galvanically” and "and that is operational when connected to an external electric power supply" was deleted.]

3.33
vehicle inlet
part of a vehicle coupler incorporated in, or fixed to, the electric vehicle

[SOURCE: IEC 62196-1:2014, 3.3.2, modified — "electric vehicle inlet" was deleted.]

3.34
removable RESS
RESS (3.23) that by design can be taken out from the vehicle by the vehicle user for off-board charging and/or other operation

3.35
hazardous live part
live part (3.19) which, under certain conditions, can give a harmful *electric shock* (3.13)

Note 1 to entry: For guidance on harmful physiological effects see IEC 61140:2016.

[SOURCE: IEC 60050-195:2021, 195-06-05, modified —Note 1 to entry was replaced.]

3.36
specific voltage condition
condition that the maximum voltage of a conductively connected electric circuit between a DC *live part* (3.19) and any other live part (DC or AC) is ≤ 30 V a.c. (rms) and ≤ 60 V d.c.

Note 1 to entry: When a DC live part of such an electric circuit is connected to chassis and the specific voltage condition applies, the maximum voltage between any live part and the *electric chassis* (3.11) is ≤ 30 V a.c. (rms) and ≤ 60 V d.c.

Note 2 to entry: For pulsating DC voltages (alternating voltages without change of polarity) the DC threshold is applied.

3.37
chassis-connected electric circuit
electric circuit that is conductively connected to each other, where the DC part of this circuit is connected to the *electric chassis* (3.11) and the *specific voltage condition* (3.36) is fulfilled

3.38
clearance
shortest distance in air between two *conductive parts* (3.6)

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

3.39
case A
connection of an EV to the supply network with a *plug* (3.45) and cable permanently attached to the EV

[SOURCE: IEC 61851-1:2017, 3.1.10]

3.40
case B
connection of an EV to the AC supply network with a cable assembly detachable at both ends

[SOURCE: IEC 61851-1:2017, 3.1.11]

3.41
case C
connection of an EV to the AC supply network utilizing a cable and vehicle connector permanently attached to the EV charging station

[SOURCE: IEC 61851-1:2017, 3.1.12]

3.42
conductively connected circuit
two electric circuits are considered conductively connected unless they are separated by at least *basic insulation* (3.4)

[SOURCE: ISO/TR 8713:2019, 3.26]

3.43
overload protection
protection intended to operate in the event of overload on the protected section

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

3.44
overcurrent protection
protection intended to operate when the current is in excess of a predetermined value

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

3.45
plug
accessory having contacts designed to engage with the contacts of a socket-outlet, also incorporating means for the electrical connection and mechanical retention of flexible cables or cords

[SOURCE: IEC 61851-1:2017, 3.5.9]

3.46
propulsion system
combination of power source and powertrain for vehicle propulsion

[SOURCE: ISO 6469-2:2022, 3.12]

4 Abbreviated terms

AC	alternating current (adjective)
a.c.	alternating current (noun)
DC	direct current (adjective)
d.c.	direct current (noun)
rms	root mean square
RESS	rechargeable energy storage system
EV	electrically propelled vehicle
DUT	device under test
SPD	surge protective device
RFI	radio frequency interference
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization

5 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. Voltage class A is specified with maximum working voltage of ≤30 V a.c. (rms) or ≤60 V d.c., respectively.

Voltage class B is specified with maximum working voltage between (> 30 and ≤ 1 000) V a.c. (rms) or (> 60 and ≤ 1 500) V d.c., respectively.

Table 1 — Voltage classes

Voltage class	Maximum working voltage	
	V (DC)	V (AC) (rms value)
A	$0 < U \leq 60$	$0 < U \leq 30$
B	$60 < U \leq 1\,500$	$30 < U \leq 1\,000$
NOTE The values 60 V d.c. and 30 V a.c. are selected taking into account humid weather conditions.		

6 General requirements

6.1 Environmental and operational conditions

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.

6.2 Marking

6.2.1 Marking of voltage class B electric components

The symbol ISO 7010–W012 shown 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 — Symbol ISO 7010–W012

6.2.2 Marking of voltage class B wiring

The outer covering of cables and harness for voltage class B electric circuits not within protective enclosures or behind protective barriers shall be marked with orange colour.

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.

7 Requirements for protection against electric shock

7.1 General requirements

7.1.1 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.

In case of electric circuits, that are conductively connected to each other, and fulfilling the specific voltage condition, only the parts of the electric circuit that operate on voltage class B shall be classified as a voltage class B circuit.

NOTE In the case above, parts of the electric circuit that operate on only voltage that is ≤ 30 V a.c. (rms) and ≤ 60 V DC are classified as a voltage class A circuit.

The electric chassis may be used as a conductor for the DC sections of a voltage class A electric circuit, if the specific voltage condition is fulfilled.

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

7.1.2 General requirements for voltage class B

Protection against electric shock for voltage class B shall be comprised of:

— provisions for basic protection; and

— provisions for fault protection.

The provisions for protection shall meet the requirements of 7.2 and 7.3. Provisions for fault protection shall include combination of 7.3.1, 7.3.2, 7.3.3, and 7.3.6.

Compliance shall be tested according to test methods specified in Clause 11.

The provisions for electric cables and connectors, specified as a), b) and c) in 7.1.3.3, shall be applied.

7.1.3 Requirements for voltage class A

7.1.3.1 General requirements for voltage class A

Protection against electric shock for voltage class A shall be comprised of:

— limitation of voltage in accordance with Table 1.

At least functional insulation shall apply to live parts of voltage class A components or circuits to prevent direct contact to live parts other than portion which are connected to electric chassis.

The protective measures required for voltage class B component and circuit may apply also to voltage class A component or circuit.

7.1.3.2 General requirements of barrier and enclosures of voltage class A components

If a measure to prevent direct contact is provided by barriers and enclosures, live parts shall be placed inside enclosures or behind barriers from any usual direction of access.

The barriers and enclosures shall provide sufficient mechanical strength under normal operating conditions, as specified by the manufacturer.

7.1.3.3 Requirements for electric cables and connectors

The following provisions apply to voltage class A wirings.

a) Wire ways shall be smooth and free from sharp edges.

b) Wires shall be protected so that they do not come into contact with burrs, cooling fins or similar sharp edges that may cause damage to their insulation. Holes in metal through which insulated wires pass shall have smooth well-rounded surfaces or be provided with bushings.

c) Wiring shall be effectively prevented from coming into contact with moving parts.

Compliance with a), b), c) shall be checked by inspection.

d) If an open coil spring is used, it shall be correctly installed and insulated. Flexible metallic tubes shall not cause damage to the insulation of the conductors contained within them.

Compliance with d) shall be checked by inspection.

e) The movable part is moved backwards and forwards, so that the conductor is flexed through the largest angle permitted by its construction.

Compliance with e) shall be checked by the test described in 11.7.

f) The insulation of internal wiring shall withstand the electrical stress likely to occur in normal use. Alternatively, the wiring shall not reduce the basic insulation adopted by the manufacturer or the basic insulation shall be electrically equivalent to the basic insulation of cords complying with IEC 60227-1 or IEC 60245-1.

Compliance with f) shall be checked by the test described in 11.7 or appropriate test for basic insulation.

7.1.4 Requirements of voltage class A power cables and conduits

Conduit entries, cable entries and knockouts shall be constructed or located so that the introduction of the conduit or cable does not reduce the protective measures adopted by the manufacturer.

Compliance is checked by inspection.

7.2 Basic protection

The protective measures against direct contact shall be provided by either one or both of the following:

— basic insulation of the live parts;

— barriers and enclosures, preventing access to the live parts.

The protective measures of chassis-connected voltage class B electric circuit against direct contact, shall be barriers and enclosures, preventing access to the live parts.

The protective provision in 7.4 shall apply.

7.3 Fault protection and additional measures

7.3.1 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 (conductors, connections) shall withstand the maximum current in a single fault condition.

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.

Compliance shall be tested in accordance with 11.2.

NOTE 1 Parts that are separated by a distance of more than 2,5 m are normally considered not to be simultaneously accessible.

NOTE 2 Physical barriers are means to prevent simultaneous access to exposed conductive parts.

7.3.2 Isolation resistance

7.3.2.1 General

The isolation resistance requirement shall not apply to chassis-connected electric circuits.

The voltage class B 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/TS 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 a.c. are 10 mA and 2 mA respectively, and within these zones.

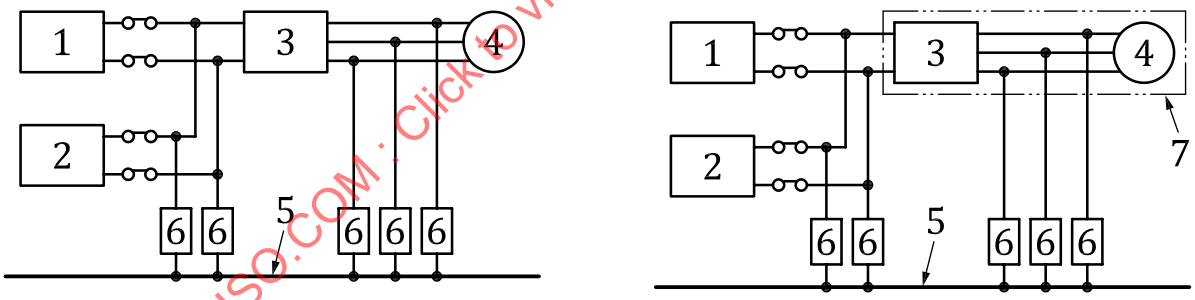
To meet the above requirements for the entire circuit, it is necessary to provide a higher isolation resistance for each component, depending on the number of the components and the structure of the circuit to which they belong.

If DC and AC voltage class B 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 protective measures as specified in 7.3.4 is applied to the AC circuit.

Compliance shall be tested in accordance with 11.3.



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

7.3.2.2 Additional measures at a non-maintained isolation resistance

If the minimum isolation resistance requirement of a voltage class B 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 B circuit may be deactivated and de-energized (see 7.3.5) depending on the operational state of the vehicle or the ability to activate the voltage class B circuit may be limited. The insulation resistance monitoring system shall be tested in accordance with 11.4.

— Alternative protective measure according to 7.3.4.

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 It is possible that de-energization is not applicable for the RESS.

7.3.3 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 applicable requirement shall apply to any individual voltage class B section of an electric circuit which is not conductively connected to the electric chassis, if the touch current depends on different operating conditions, e.g. working voltage, AC circuit, DC circuit.

NOTE 1 An AC section of a voltage class B electric circuit can possibly have 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, the touch current shall not exceed 5 mA for an AC circuit;

— alternative protective measures shall be followed according to 7.3.4.

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

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 11.5.

7.3.4 Alternative electrical or mechanical measures

The following protective 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;

— 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 failure for which it is intended.

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

As the alternative protective measures, the following measure shall not be used for the chassis-connected voltage class B electric circuits:

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

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

The requirements for protective provisions in 7.4 shall apply.

7.3.5 De-energization

The voltage class B electric circuit in question may be de-energized as a protective 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 30 V a.c. (rms) and 60 V d.c.;

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

— the touch current flowing between simultaneously accessible conductive parts shall not exceed 2 mA a.c. or 10 mA d.c.

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.

7.3.6 Provision for chassis-connected voltage class B circuit

In case of a single-failure on the measure of basic protection, chassis-connected voltage class B electric circuits shall meet alternative protective measures according to 7.3.4.

7.4 General requirements for protective provisions

7.4.1 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.

7.4.2 Requirements for insulation of voltage class B

If protection is provided by insulation, the live parts of the electric system, electric circuit and component shall be totally encapsulated by insulation which can be removed only by destruction.

The insulating material shall be suitable to the maximum working voltage and temperature ratings of the vehicle and its systems.

Insulating varnish, dope, enamel, and other similar materials are not acceptable as basic insulation of the voltage class B.

The insulation shall have sufficient withstand voltage capability. Compliance shall be tested according to 11.6.

7.4.3 Requirements of protective barrier and protective enclosures of voltage class B electric components

7.4.3.1 General

If protection is provided by protective barriers and protective enclosures, live parts shall be placed inside protective enclosures or behind protective barriers, preventing access to the live parts from any usual direction of access.

The protective barriers and protective enclosures shall provide sufficient mechanical resistance under normal operating conditions, as specified by the manufacturer.

If protective barriers and protective enclosures are accessible directly, they shall be opened or removed only by the use of tools or maintenance keys or they shall have means to deactivate and de-energize live parts with class B voltage, for example interlock.

NOTE See 6.2 for marking of protective barriers and protective enclosures.

7.4.3.2 Degree of protection for protective barriers and protective enclosures

Protective barriers and protective enclosures shall comply with the protection degree IPXXD at minimum (see 3.22), where all protective barriers and protective enclosures are installed to a whole motorcycle.

However, if the vehicle fulfils the specific voltage condition (3.36), IPXXB may be applied to the voltage class B live parts of the chassis-connected electric circuits (3.37).

Compliance shall be tested in accordance with ISO 20653.

7.5 Requirements for connectors

Connectors for voltage class B electric circuits shall comply with 7.4.3.2 in the mated condition.

Connectors for voltage class B electric circuits including vehicle inlet, connectors for power transfer between the propulsion circuit of the vehicle and removable RESS, connector for service disconnect and 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), shall comply with at least one of the following requirements.

a) A connector shall comply with 7.4.3.2 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 a.c. and 60 V d.c. within less than one second after the connector is separated;

   — the total stored energy of the circuit shall be ≤ 0,2 J;

— the touch current flowing between simultaneously accessible conductive parts shall not exceed 0,2 mA a.c. or 10 mA d.c.

Compliance shall be tested according to 11.5 or demonstrated by calculation.

For connectors containing contacts providing equipotential bonding the contact sequencing shall be: power contacts mate after equipotential bonding contact and unmate before equipotential bonding contact.

7.6 Insulation coordination

Clearance, creepage distance and solid insulation of voltage class B components and wiring shall be designed according to the applicable sections of IEC 60664-1.

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

Voltage class B circuits not conductively connected to the chassis shall be tested according to 11.6.

7.7 Alternative approach for protection against electric shock

As an alternative to 7.2 and 7.3, the vehicle manufacturer shall conduct an appropriate hazard analysis and establish a set of measures which give sufficient protection against electric shock.

8 Protection against thermal incidents

8.1 Overload protection

Overload protection shall be provided for live conductors of an electric circuit according to their cross-sectional area.

Compliance shall be checked by inspection of the design.

8.2 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 electric circuit shall have a short-circuit current withstand rating (I2t) according to the maximum short-circuit current of an electric power source.

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

Compliance shall be checked by inspection of the design.

9 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 are described in ISO 18246.

10 Owner's guide manual

Special attention shall be given in the owner's manual to aspects specific to the vehicle.

11 Test procedures

11.1 General

The tests for the selected protective measures according to Clause 7 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.

11.2 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 d.c., 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 remains on a sufficiently accurate level.

The voltage drops 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.

11.3 Isolation resistance measurements for voltage class B electric circuits

11.3.1 Preconditioning and conditioning

Prior to the measurement, the device under test (DUT) 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.

11.3.2 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 B electric circuit or 500 V whichever is higher and be applied for a time long enough to obtain stable reading.

If the voltage class B 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 B balance of electric circuits against the vehicle electric chassis and against the live parts of the voltage class A balance of auxiliary electric circuits, if they are conductively connected to the electric chassis.

— 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 B) shall be connected to each other.

— All exposed conductive parts of the balance of electric circuits shall be connected to the electric chassis, see 7.3.1.

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

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

Then the test voltage shall be applied between the connected live parts of the voltage class B 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 B electric power sources as given in 11.3.3 with the balance of electric circuits connected to an external power source.

11.3.3 Isolation resistance measurement of the voltage class B electric power sources

11.3.3.1 General

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

11.3.3.2 Preparation

11.3.3.2.1 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 B electric circuit of the electric power sources shall be disconnected from any electric circuit not galvanically coupled to the said voltage class B 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, for example, 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.

11.3.3.2.2 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.

11.3.3.2.3 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.

11.3.3.3 Procedure

11.3.3.3.1 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 Formula (1) and Figure 3 a)]:

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

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 $R_{i2} = R_i$.

NOTE 1 R_{i2} is the lower isolation resistance and is therefore, the isolation resistance R_i to be determined.

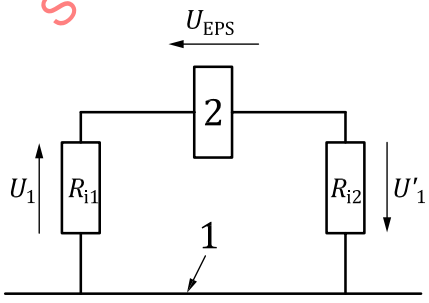
— Add a known measuring resistance R_0 parallel to R_{i1} and measure the voltage U_2.

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

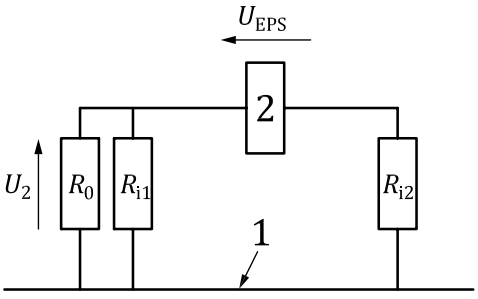
NOTE 2 Theoretically, the value of R_0 has no influence on the calculated isolation resistance. However, R_0 it is possible to be selected such that sufficient accuracy is achieved for the measured voltages on the calculated isolation resistances. R_0 (Ω) can be the value of the minimum required isolation resistance (in Ω/V) multiplied by the maximum working voltage of the electric power source or voltage class B electric circuit which includes the electric power source ± 20 %. R_0 is not required to be precisely this value since the formulae 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):

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



a) Measurement of U_1 and U'_1



b) Addition of R_0 and measurement of U_2